Scope and Applications of Geoinformatics
<table>
<thead>
<tr>
<th>Block 4</th>
<th>SCOPE AND APPLICATIONS OF GEOINFORMATICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIT 11</td>
<td>Natural Resources Studies and Management 5</td>
</tr>
<tr>
<td>UNIT 12</td>
<td>Land Use Planning, Infrastructure and E-governance 29</td>
</tr>
<tr>
<td>UNIT 13</td>
<td>Climate, Environment and Disaster Management 53</td>
</tr>
<tr>
<td>UNIT 14</td>
<td>Other Applications 75</td>
</tr>
<tr>
<td></td>
<td>Glossary 103</td>
</tr>
</tbody>
</table>
In Block 3, you have studied about map projections and coordinate systems as well as basics of maps and mapping along with topographical maps and their interpretation. After studying the basics of geoinformatics, its components and various types of geospatial data, maps and topographical maps, you would be interested to know the application aspects of the geoinformatics. This block, comprising of four units, would introduce the scope and application potential of geoinformatics.

There are numerous applications of geoinformatics. For our convenience, the application areas are divided into four major divisions, which form the theme of the four units.

**Unit 11** deals with the role of geoinformatics in ecosystem management and natural resources management. Here you will get to know how the technology can be used for terrestrial and aquatic ecosystem studies, such as habitat mapping, vegetation mapping, mapping of waterbodies and water quality monitoring along with land, water, soil and mineral resources studies and management.

In **Unit 12**, you will study about how the geoinformatics can be utilised for land use and land cover mapping, rural and urban planning, urban infrastructure monitoring and e-governance.

**Unit 13** deals with the application of geoinformatics for climate and environment related studies, such as global warming, climate change, air pollution mapping and monitoring. It would also give you an idea about the significance of geoinformatics in studying the natural disasters and their management.

There are many other areas where geoinformatics has found its use, such as agriculture, health, archaeology, humanities, social sciences, business and forensic sciences. The **Unit 14** deals with some of the applications in these fields.

**Objectives**

After studying this block, you should be able to:

- discuss the scope and applications of geoinformatics in terrestrial and aquatic ecosystem studies;
- explain the role of geoinformatics in natural resources studies and management;
- elaborate upon the scope of geoinformatics in land use and land cover mapping, planning, infrastructure monitoring and e-governance; and
- analyse the application potential of geoinformatics in many other fields, such as agriculture, health, archaeology, humanities, social sciences, business and forensic sciences, etc.

We hope that after studying this block, you will acquire basic understanding of the application potential of geoinformatics in different fields.
11.1 INTRODUCTION

In the first three blocks, you have studied about geoinformatics, the concept of geospatial data analysis tools and the basics of mapping. The applications of geoinformatics have great potential as the technology can be utilised for resource inventory, baseline data creation, planning and management purposes.

This unit, which has two major parts, comprises of introduction about the application aspects of geoinformatics with special reference to studies of natural resources and their management. The first and second parts discuss a broad spectrum of conceptual ideas pertaining to the capability of geoinformatics for different kinds of ecosystems, and natural resources management, respectively with some case studies and examples.

Objectives

After reading this unit, you should be able to:

- discuss the scope of geoinformatics for terrestrial ecosystem studies and management;
- explain applications of geoinformatics for aquatic ecosystem studies and management;
- describe the role of geoinformatics in land and water resources studies, mapping and management; and
- elucidate the role of geoinformatics in minerals and soil resources studies.
Before studying the role of geoinformatics in ecosystem management, let us have a brief overview of ecology, ecosystem and environment.

Ecology is concerned with the study of the structure and function of organisms and their environment. It is also described as the science of living things in relation to their environment that provides linkages to problems related to environmental planning. It helps to understand the importance and its contribution to the environmental management. It includes relationships between organisms and their physical environments (physiological ecology); between organisms of the same species (population ecology); between organisms of different species (community ecology); and between organisms and the fluxes of matter and energy through biological systems (ecosystem ecology). Possibly, the most important role of ecology is the concept of an ecosystem.

Ecosystem is the basic functional unit that incorporates organisms, populations and communities together with the causal mechanisms that define the relationships, interdependencies and pathways that direct energy flow and control the properties of the system (Balasubramanian, 1995). Ecosystem is a complex network of both biotic and abiotic components dependent either directly or indirectly upon the input of solar energy as shown in Fig. 11.1. Flow of energy and matter in a typical ecosystem is shown in Fig. 11.2. The flow establishes critical cycles of matter and energy that sustain ecosystem structure, function and complexity in a dynamic balance over time and space.

Environment is the combination of various Terrestrial and Aquatic ecosystems that includes Hill ecosystem, fluvial ecosystem, Coastal ecosystem, Desert ecosystem and many more.
11.2.1 Advantages and Role of Geoinformatics in Ecosystem Studies

You should note that the condition of terrain/landscape, in which all the types of ecosystem are present is not uniform throughout the world. Some of them are situated in the rugged mountain while others in deep valley. Further, some of the ecosystems are not completely accessible by people due to their large aerial extents. In addition to this, there are number of different kinds of features and organisms bearing unique and varied characteristics in an environment.

Geoinformatics has the following advantages for ecosystem related studies:

- it is possible to map all types of terrains ranging from rugged mountains to deeper valleys due to capture of satellite images from higher altitude
- by virtue of use of high-resolution sensor and high-end computer technology, it is possible to discriminate more features, which are not distinguishable by our naked eye
- due to temporal resolution, it is possible to visualise the past and present changes that have taken place in an ecosystem, especially for forest cover changes, land degradation and so on
- handling of voluminous data, both raster and vector, is possible under an umbrella of geoinformatics
- it is time and cost-effective, particularly for large areas.

Following kinds of studies are possible using geoinformatics technology for terrestrial and aquatic ecosystems:

- estimation of terrestrial and aquatic vegetation cover and historical changes
- shoreline mapping
- identification of different kinds of plant communities
- biodiversity estimation, species richness and distribution
- migration of wildlife
- desertification
- identification and mapping of habitats and habitat suitability, etc.
- identification and mapping of water bodies
- monitoring water quality
- mapping bathymetry
- primary productivity
- identification of potential fishing zones
- mapping and monitoring of water surface temperature, etc.

Let us now discuss about the applications of geoinformatics in mapping, monitoring and managing the ecosystem and natural resources with some examples and case studies. You should note that the application of geoinformatics is vast hence we would be briefly discussing selected applications.
For our convenience, let us categorise ecosystems into two categories i.e., Terrestrial and Aquatic ecosystems and discuss them one by one.

### 11.2.2 Terrestrial Ecosystems

Geosciences have a profound impact on ecosystems because global circulation patterns and climate zones set basic physical conditions for the organisms that inhabit a given area. The most important factors are:

- temperature ranges
- moisture availability
- light,
- nutrient availability

These factors together determine what types of life forms are most likely to flourish in specific regions and what environmental challenges they will face. Earth is divided into distinct climate zones that are created by global circulation patterns. The tropics are the warmest and wettest regions of the globe while subtropical high-pressure zones create dry zones at about 30° latitude north and south. Temperatures and precipitation are lowest at the poles. These conditions create different types of biomes as shown in Fig. 11.3. **Biomes** are defined as broad geographic zones whose plants and animals are adapted to different climate patterns. Since temperature and precipitation vary by latitude, Earth’s major terrestrial biomes are broad zones that stretch around the globe. Land biomes are typically named for their characteristic types of vegetation, which in turn influence what kinds of animals will live there. Soil characteristics also vary from one biome to another, depending on local climate and geology. It includes forest ecosystem, grassland ecosystem, desert ecosystem, manmade or artificial ecosystem (such as crop fields and gardens).

![Fig. 11.3: The main biomes in the world (source: http://en.wikipedia.org)](image)

In the following paragraphs, we will discuss about some of the examples of applications of geoinformatics.

In a recent study by Padalia and Roy, (2010), tropical forests (spread over 1,294 km² area) of South Andaman Islands were mapped using remote sensing data. They mapped vegetation types, structure and composition of the 17
vegetation classes spreading over 89.92% forested area of the islands as shown in the Fig. 11.4. They reported that evergreen, semi-evergreen and mangrove forests were reasonably well distributed forests, while moist deciduous and littoral evergreen were narrowly restricted. They also studied the forest cover density with the help of remote sensing data and field sample plots (Fig. 11.5), and reported that the stocking was quite variable across the forest types. About 60% of forested area is under medium to high canopy density. Information on floristic composition, structure and diversity of various forest types were obtained from field sample plots. Evergreen forests were found to have highest diversity followed almost equally by semi-evergreen and moist deciduous forests.

Fig. 11.4: Vegetation type map of South Andaman Islands prepared using Landsat TM remote sensing data. (source: www.springerlink.com/content/cg23876q1024p85p/fulltext.pdf)

Geoinformatics also helps in biodiversity characterisation. In a study, vegetation diversity of the Western Ghats was assessed to find biodiversity hot-spots using principles of landscape ecology and geoinformatics techniques (http://pune.cdac.in/html/geomat/projcomp.aspx). Biodiversity maps were generated and areas for conservation were prioritised using information on
biodiversity, disturbance and ecosystem uniqueness. Spatial and non-spatial databases were modelled using GIS to prepare various spatial indices, such as interspersion, juxtaposition, porosity, patchiness, disturbance index. Finally, outputs were integrated to prepare biodiversity map of the area as shown in Fig. 11.6.

Fig. 11.5: Forest canopy density map of South Andaman Islands derived using IRS ID LISSII and Pan merged data. (source: www.springerlink.com/content/cg23876q1024p85p/fulltext.pdf)

Fig. 11.6: Biodiversity characterisation at Landscape Level using Satellite Remote Sensing in the Western Ghats of Maharashtra (source: http://pune.cdac.in/html/geomat/projcomp.aspx)
Let us now understand the potential of geoinformatics for terrestrial ecosystem through a case study in which forest cover was monitored through remote sensing data for a period of about 70 years.

**Case Study: Geoinformatics in Forest Cover Change Detection in a part of Eastern Ghat.**

One of the main advantages of remote sensing technique is temporal resolution that helps in generating data sets. The case study focuses on the role of remote sensing and GIS in assessment of changes in forest cover, between 1931 and 2001, in the Kalrayan hills, Tamil Nadu (Fig. 11.7). The trend of forest cover changes over the time span of 70 years was precisely analysed using high resolution Satellite data. In this case study, the Indian Remote Sensing Satellites (IRS) LISS III geocoded False Colour Composite (FCC) of year 2001 at 1:50,000 scale was used for assessing the temporal changes in the forest cover (Fig. 11.7).

Map of the study area, the Kalrayan hills, was prepared from SOI topographical maps at 1:50,000 scale. The forest cover in the study area was derived from the SOI topographical maps of 1931 and 1971 at 1:50,000 (after georegistration), respectively. The classes were then visually interpreted from the 2001 IRS 1C LISS III geocoded satellite data by using the elements of image interpretation. The forest areas were delineated from their red tone and contiguous pattern. The scrubs were identified from their brownish yellow tone, coarse texture and scattered pattern. The agriculture and human habitations were identified from the light reddish-brown tone and regular pattern. The rocky outcrops were identified from their brighter tone, absence of vegetation cover and their association to the steeper slopes. Necessary ground truthing were carried out and corrections were made at required places and the various classes viz. forests, scrubs, agriculture and human habitations, and rocky outcrops were identified. Thus, a thematic layer depicting various forests and other land use classes was generated. The primary forest type and landuse maps were prepared based on field observation and image interpretation.

The ArcGIS software was used to prepare the classified (final) forest cover and land use maps. Finally, the status of changes (either increase or decrease) during 1931-1971, 1931-2001 and 1971-2001 and land covers were assessed by overlaying of various period (1931, 1971 and 2001) maps (Fig. 11.8). The final maps which represent the forest cover and its changes during 1931, 1971 & 2001 (both in area and percentage) were also generated. The changes observed are given in Table 11.1. It was noticed that forest cover has increased between 1931 and 1971 because of the implementation of various afforestation schemes by the forest department and sacred grooves. It also revealed that the forest cover loss between 1971 and 2001 could be due to shifting cultivation and illegal encroachments by villagers; and the forest cover drastically decreased on plateau areas due to human population pressure (Sakthivel et al, 2010). The study analysed forest cover change in the tropical deciduous forest region of the Eastern Ghats of India. This study shows the utility of geoinformatics in forest cover change detection and restoration planning.
Table 11.1: Forest cover and its changes during the period 1931-2001

<table>
<thead>
<tr>
<th>Year</th>
<th>Forest Cover (in km²)</th>
<th>Changes observed in Forest Cover (in km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1931</td>
<td>275.6</td>
<td>-</td>
</tr>
<tr>
<td>1971</td>
<td>481.7</td>
<td>206.1 (1971-1931)</td>
</tr>
<tr>
<td>2001</td>
<td>266.5</td>
<td>9.1 (2001-1931)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>215.2 (2001-1971)</td>
</tr>
</tbody>
</table>

Fig. 11.7: a) A panoramic view of the Kalrayan Hills, a part of Eastern Ghats; b) IRS-1C LISS-III satellite image of a part of Kalrayan hills, Eastern Ghats (source: Sakthivel et al, 2010)

Fig. 11.8: Forest cover (a) in 1971, (b) in 2001 and (c) forest cover changes observed (1971-2001), Kalrayan hills, Eastern Ghats (source: Sakthivel et al, 2010)
Check Your Progress I

1) List out the components of an ecosystem.

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................

2) What were the major findings in the forest cover change detection case study?

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................

11.2.3 Aquatic Ecosystems

Aquatic biomes (marine and freshwater) cover three-quarters of the Earth’s surface, and include rivers, lakes, coral reefs, estuaries, and open ocean. Of these, the oceans account for the maximum area. Large bodies of water (oceans and lakes) are stratified into different layers based on temperature. Surface waters are warmest and contain most of the available light but depend on mixing to bring up nutrients from deeper levels. The distribution of temperature, light, and nutrients set broad conditions for life in aquatic biomes in much the same way that climate and soils do for land biomes. Daily or seasonal changes occur in marine and freshwater biomes. For example, in the intertidal zone where the oceans and land meet, areas are submerged and exposed as the tide moves in and out. During the winter months, lakes and ponds can freeze over, and wetlands that are covered with water in late winter and spring can dry out during the summer months.

Saltwater and freshwater ecosystems contain several types of organisms. One type of aquatic life is weakly swimming, free-floating plankton (consisting mostly of phyto plankton and zoo plankton), and another type is nekton (strongly swimming consumers), such as fish, turtles and whales. A third type, bottom dwellers (benthos), include barnacles and oysters that anchor themselves at one spot, worms that burrow into the sand or mud, and lobsters and crabs that walk about on the bottom. Finally, decomposers break down the organic compounds in the dead bodies and wastes of aquatic organisms into simple nutrient compound for use by producers.

Aquatic ecosystems are further classified into the following two types on the basis of salt content in water.

- Fresh Water Ecosystem (Pond, Lake, River and Spring Ecosystem)

Fresh water life zones occur where water with a dissolved salt concentration of less than 1% by volume accumulates on or flows through the surfaces of
terrestrial biomes. Examples are standing (also called as *lentic*) bodies of water, such as lakes, pond and inland wetlands and flowing (known as *lotic*) systems, such as streams and rivers (Fig. 11.9). Although, freshwater systems cover less than 1% of Earth’s surface, they contain a variety of species and provide a number of ecological and economic services.

Small streams, which originate from high altitude areas, join to form rivers which flow downhill and ultimately to the ocean as part of the hydrologic cycle. As streams flow downhill, they become powerful shapers of land. Over millions of years, the friction of moving water levels the mountains and cuts deep canyons. The rock and soil, transported by water are deposited as sediment in low-lying areas. Streams are fairly open ecosystems that receive many of their nutrients from bordering land ecosystems. Such nutrient inputs come from falling leaves, animal faeces, insects, and other forms of biomass washed into streams during heavy rainstorms or by melting snow. To protect a stream or river ecosystem from excessive inputs of nutrients and pollutants, we must protect its watershed and the land around it. As discussed above, a river starts its journey from mountains or hill and it creates different kinds of landforms during its three stages (i.e. youth, mature and old). Rivers can easily be mapped through remote sensing. Following kinds of study are commonly carried out using geoinformatics:

- identification of paleochannels as shown in Fig. 11.10
- mapping of water bodies and their monitoring as shown in Fig. 11.11
- river migration
- identification of flood prone areas and flood inundated areas, etc.

Water quality can also be accessed through remote sensing. Lakes are the large natural bodies of standing fresh water formed when precipitation, runoff or groundwater seepages fills depressions in the Earth’s surface.
Fig. 11.10: IRS P3 WiFS image showing palaeo drainage in Sarasvati River Basin. Thick channels represent the course of river Sarasvati. The synoptic coverage of remote sensing data and indirect evidence such as presence of vegetation in a linear fashion helps in identifying a palaeo channel (source: www.springerlink.com/content/6816423032wt48k8/fulltext.pdf)

Fig. 11.11: Mapping and monitoring of Lake Chhad in Africa. The lake falls in the territory of four countries namely Chad, Cameroon, Nigeria and Niger. The images of different time period show how the lake has almost disappeared with time. The first image of 1973 shows large extent of the lake which has gradually reduced. The 2001 image shows that the lake has almost disappeared and is occupied by vegetation (source: http://en.wikipedia.org/wiki/Lake_Chad)
Scope and Applications of Geoinformatics

- **Marine or Oceanic Ecosystem (Estuaries and Ocean Ecosystem)**

Oceans have two major categories: the coastal zones and open sea. The coastal zone is warm, nutrient-rich, shallow water that extends from the high-tide mark on land to the gently sloping, shallow edge of the continental shelf. This zone has numerous interactions with the land, and thus easily affected by human activities. The coastal zone contains 90% of all marine species and most ecosystems found in the coastal zone have a high net primary productivity per unit area because of the ample supplies of sunlight and nutrients.

One highly productive area in the coastal zone is the estuary. Estuary is a partially enclosed area of coastal water where sea mixes with fresh water nutrients coming from rivers, streams and run off from land. Estuaries (Fig. 11.12) and their associated coastal wetlands (i.e. land areas covered with water throughout the year) include river mouths, inlets, bays, mangrove forest swamps in tropical waters and salt marshes in temperate zones. In the context of marine or oceanic ecosystems, geoinformatics is generally used for the following:

- shoreline mapping and change detection
- coastal habitat mapping and monitoring
- mapping bathymetry
- monitoring water quality
- sediment discharge
- marine pollution
- oil spill
- potential fishing zone demarcation, etc.

Mapping of shorelines (i.e. the boundary between land and sea) is one of the most common applications of remote sensing data in coastal applications. It is easy to demarcate the shoreline from remote sensing images, and with the comparison of historical shorelines one can estimate the erosion and accretion and also understand the nature of shoreline as shown in Fig. 11.13.

About 7500 km long coastal zone of India has been mapped using remote sensing data at different scales. It also included mapping and monitoring of...
vital/critical coastal habitats, such as coral reefs and mangroves, marine protected areas, shore line changes, coastal landforms, land use/land cover, impact of sea level rise to be used for the integrated coastal zone management (Nayak, 2002 & 2004; Nayak and Bahuguna, 2001). Coastal Zone Information System (CZIS) have also been developed for different parts of the Indian coast (Dwarakish et. al., 2006). Further, models have been developed for preparing integrated coastal zone management plans and identifying suitable sites for mangrove plantation.

Fig. 11.13: Shoreline changes in Mahanadi deltaic coast as observed from field survey and remote sensing data. (A) Comparison of field survey data of 1929-30 with IRS 1D LISS-III image of 2001. (B) Comparison of field survey data of 1972-74 with the LISS-III image of 2001. Note the different zones of accretion and erosion (source: ISRO Scientific Report, 2003)

In one of the studies, mangroves of the Marine National Park of the Gulf of Kachchh, which constitute the second largest patch of mangroves in Gujarat was mapped using remote sensing data with the help of ground data (Fig. 11.14a). The mangroves, comprising of six species, cover about 11,000 ha. The study identified distribution of different mangrove communities with respect to shoreline (Fig. 11.14b). The zoning of the mangroves also helped in assessing the diversity of the region. Based on the richness of species, some areas were identified as highly diverse and most suitable area for preservation.

Fig. 11.14: a) Mangrove habitat map and b) Mangrove zonation map of Jindra and surroundings in the southern part of the Gulf of Kachchh prepared using IRS LISS III data of 1998 (source: www.springerlink.com/content/36507w5142116056/fulltext.pdf)
It is difficult to physically survey large areas of waterbody and sea. Capability of remote sensing data to provide synoptic view and repeatability at definite time interval helps in water quality mapping and monitoring over a large area. Fig. 11.15 shows a river bringing pollutants in a bay in Andhra Pradesh.

Fig. 11.15: Discharge of pollutants from a river in the bay and breach of Kakinada spit in Andhra Pradesh as observed in IRS-1C LISS-III image (source: ISRO Scientific Report, 2003)

Similarly, the total suspended matter in water can also be estimated and movements of sediment plumes can be monitored as shown in the Fig. 11.16.

Fig. 11.16: Suspended sediment concentration as derived from IRS-P4 Ocean Colour Monitor (OCM) data showing sediment dispersal pattern in the Gulf of Kachchh and Arabian Sea. Colour bar indicates concentration levels. (source: www.mapindia.org/2005/papers/pdf/310.pdf)
Geoinformatics is being actively used by Fisheries Survey of India (FSI) for fishery forecast by synergistic application of chlorophyll and SST data derived. The technique developed for the potential fishing zone (PFZ) forecast (up to 2-3 days in advance), which combines chlorophyll information from OCM and SST from NOAA-AVHRR has been validated with a number of ship campaigns in the Indian water (Fig. 11.17). Results have shown 70-90% success in PFZ identification.

![Fig. 11.17: Potential fishing zones are forecast by using chlorophyll and sea surface temperature estimates derived from remote sensing data (source: www.ias.ac.in/currsci/dec252007/1747.pdf)](image)

Check Your Progress II

1) List out the aquatic ecosystems related studies which can be carried out using geoinformatics.

..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................

11.3 GEOINFORMATICS IN NATURAL RESOURCES MANAGEMENT

In this section, we will discuss about the applications of geoinformatics in natural resources management. Literal meaning for resource is wealth. Conservation and proper management of natural resources is essential for the betterment of future generation. Because of greater areal extent, voluminous data and uneven topography under changing climatic condition, monitoring and managing the available resources by people is not an easy task.

Let us see, how geoinformatics is being used for natural resources management. As you know satellite sensors collects data from space without...
having any physical contact with the feature. The data are available both in the form of hard copy print and digital format. By using various interpretation keys and elements and applying proper interpretations techniques, such as visual interpretation (for hard copy/printed data) and digital image processing (for digital data) techniques, the data can be converted into an information or a map to represent a theme, which is called as **thematic map**. A thematic map may have only point/line/polygon features or combination of these features. The various thematic maps can be viewed/over-laid in a GIS environment to visualise any on-going natural process, which determines the existence or extinction of natural resources in an area.

Following kinds of information and studies are possible using geoinformatics technology in natural resources management.

- identification of degraded land
- identification of mineral resources
- identification of potential mineral zones
- mapping of different rock types
- water resources mapping
- water quality mapping and monitoring
- identification of potential groundwater zones
- soil resources mapping, etc.

In the following subsections, we will discuss some of the case studies for different kinds of natural resources from which you can better understand the use of geoinformatics with special reference to natural resources management.

**11.3.1 Land Resources**

Land is an important resource which man puts in to diverse uses. Land is used for construction of buildings, roads, railways, etc. It is also used for cultivation, grazing of animals, mining, industries, etc. The type of land use varies from one region to another. The proportions of land put to different major uses, such as cultivation, forests, grazing and human settlements in any region change in course of time. The land use pattern shows variation not only from one region to another but also from time to time in same region. These valuable land resources are subjected to various kinds of degradation. When degradation level continues to rise, it directly affects the living resources of an area. Already considerable areas of the world are highly degraded due to natural as well as anthropogenic activities. Some of the important natural causes that result in land degradation are soil erosion, landslides, volcanoes, earthquakes, floods, droughts and desertification. Anthropogenic causes include deforestation, construction of large dams, mining, over-irrigation, persistent usage of fertilisers and pesticides, etc.

Some of the commonly observed applications of geoinformatics for land resources are following:

- land use/land cover mapping
- geomorphology
- land degradation, etc.
Utility of remote sensing data has long been established for geomorphological applications because of its capability of providing synoptic view and repetitive coverage. Studies related to movements of sand dunes, shifting of rivers, beach migration and changes are the most common examples. The geomorphological maps are useful in monitoring, planning and management of several other resources aspects.

11.3.2 Mineral Resources

Let us first see, what is meant by a mineral. Mineral is a naturally occurring inorganic substance having definite chemical composition and atomic structure. Minerals are compounds of their constituent elements, whereas rocks are mixtures of their component minerals. Thus, the mineral quartz, \( \text{SiO}_2 \) is a compound of the elements silicon (Si) and oxygen (O), whereas the rock granite is a mixture of several minerals, and one of them is the quartz.

Mineral resource is a mineral deposit that is of great economic value and which can be mined profitably. Demarcation of mineral resource is carried out by using some clues, such as soil tonal variations, dense or stunted vegetation growth and different anomalies.

Geoinformatics has several applications in mineral resources and geomorphology related studies. Some of the application areas are given below:

- preparing reconnaissance maps of inaccessible areas
- updating existing geological maps
- identifying potential mineral zones

![Fig. 11.18: Illustrating the concept of mineral potential zone mapping. (a) favourable parameter x (such as geochemical anomalies); (b) favourable parameter y (such as faults); (c) mineral potential zone map prepared based on the occurrence of the favourable parameters x and y showing the prospective areas where the mineral of our interest may be found](image)

As listed above and shown in Fig. 11.18, geoinformatics is useful for identifying potential zones for a specific mineral. The potential zones are identified based on the analysis and mapping of different parameters which are favourable for occurrence of a particular mineral as shown in the figure.

11.3.3 Water Resources Management

Water is an elixir of life and is available as an extremely finite but replenishable natural resource. Water is the most widely occurring substance
Scope and Applications of Geoinformatics

Hydrological cycle/water cycle describes the storage and continuous movement of water from oceans to land, and back to oceans.

Energy Cycle: Energy enters the ecosystem from the Sun and exits after the organisms have taken as much as they need. Organisms release energy back into the biosphere as heat. Energy also enters the ecosystem from the interior of the Earth and is usually in the form of heat, not the electromagnetic radiation from the Sun.

The hydrological cycle/water cycle describes the storage and continuous movement of water from oceans to land, and back to oceans. Globally distributed by the hydrological cycle and driven by the energy cycle, the circulation of water powers most of the other natural cycles and conditions the weather and climate. Water has shaped the Earth’s evolution and continues to fashion its progress. Some proportion of the water resurface later to aid/sustain river flow.

The definition of water resource is the total range of natural waters present on the Earth and that are of potential use to human beings. These water resources may occur in form of liquid, vapour or solid. These resources include rivers, lakes, ground water, oceans, snow fields, glaciers, etc. Water covers about 71% of Earth’s surface and is vital for all forms of life on it. About 1.6% of water is below the ground in aquifer and about 0.001% is present in air as vapour, perspiration and clouds. About 0.6% of water is present on land’s surface in form of rivers, lakes and ponds. Glaciers and polar ice caps cover about 2.4%. The largest part of surface water is in form of oceans as approximately 97% (Fig. 11.19).

The strength of remote sensing techniques lies in their ability to provide both spatial and temporal views of surface water quality parameters that are typically not possible from in situ measurements. Remote sensing makes it possible to monitor the landscape effectively and efficiently, identifying water bodies with significant water quality problems. Water quality parameters can often be quantified using remote sensing techniques, which allow management plans to be formulated to reduce movement of substances from watersheds to water bodies, thus reducing the effects of the pollutant on water quality.

The various pollutants of water bodies are sedimentation, industrial effluents, municipal sewage, agricultural runoff and air pollution. Remote sensing for determining water quality of larger water bodies makes use of the properties of light and its interaction with water, its constituents and the adjacent terrain.

To demarcate the groundwater potential zones, different thematic maps, such as geology, geological structure, hydrogeomorphology, landuse, drainage and topography, etc., are prepared and analysed along with the ground survey data.

To demarcate the different groundwater potential zones, all the thematic layers are integrated together according to their importance through the GIS union concept (Fig. 11.20). Favourable conditions for the occurrence of ground water

Fig. 11.19: Distribution of Earth’s water (source: http://en.wikipedia.org/wiki/File:Earth%27s_water_distribution.svg)
are studied and the areas where the favourable conditions (based on the above mentioned parameters) occur are identified. The ground water potential zones can be classified into (i) very good, (ii) good, (iii) moderate and (iv) poor, based on these parameters and the favourable conditions.

With increasing awareness towards climate change and global warming, a number of studies have been taken up for inventory, monitoring and retreat of Himalayan glaciers. Majority of the studies are concentrating on glacier inventory of Himalayas (Indus, Ganga and Brahmaputra basins), snow cover monitoring and estimation of retreat of Himalayan glaciers. Glacial inventory has already been carried out for many parts of the glacial regions of Indus, Ganga and Brahmaputra basins at 1:50,000 scale. Fig. 11.21 shows an example of snow cover and glacier monitoring.

![Fig. 11.20: Satellite image and the various maps derived from the image and used as input in generation of ground water prospect map (source: www.ias.ac.in/currsci/dec252007/1747.pdf)](image1)

![Fig. 11.21: a) Monitoring of snow using AWiFS data for the period 2004-2008, b) Retreat of Himalayan glaciers showing about 16% loss in glacial area during 1962-2004 (source: www.isro.org/scripts/rsa_sgs.aspx)](image2)

11.3.4 Soil Resources

The soil is at the interface between the atmosphere and lithosphere. It also has an interface with the biosphere and hydrosphere, i.e. the sphere describing surface water, ground water and oceans. A combination of physical, chemical
and biotic forces acts on organic and weathered rock fragments to produce soils with a porous fabric that contain water and air. The unconsolidated mineral or organic material on the immediate surface of the Earth serves as a natural medium for the growth of land plants.

Because soil is important for cultivation and agricultural production, soil fertility and productivity are important issues to address. Detailed pedological knowledge is useful for land evaluation purposes. Soils are an integral part of landscapes and the knowledge of the distribution of different soils helps to preserve a high standard in environmental quality. For example, site specific management cannot be developed without detailed knowledge of soils. Remote sensing is useful for identification and mapping of different kinds of soil. You should note that remote sensing is particularly useful for soil mapping when surface soils are not covered with dense vegetation. Another important parameter where remote sensing is useful is the soil moisture content. Optical remote sensing techniques are useful for soil type mapping and delineation of their boundaries whereas microwave remote sensing is useful for soil moisture content mapping.

11.4 ACTIVITY

1) See your surroundings and find out where you can use geoinformatics.
2) Prepare a list of the areas where you think you can apply geoinformatics.

11.5 SUMMARY

In this unit, we have discussed about applications and scope of geoinformatics for studying terrestrial and aquatic ecosystem and natural resources. Let us now summarise what we have studied in this unit.

- Geoinformatics is useful for identifying suitable habitats for different kinds of animals and plants, different land and aquatic plant communities and their cover, biodiversity estimation, species richness and historical changes.
- Geoinformatics is also useful for identification of degraded land, potential mineral resources and zones, mapping of different rock types and soil resources.
- The technology is also used for identification of potential groundwater zones, mapping and monitoring of water resource and water quality.

11.6 UNIT END QUESTIONS

1) What is meant by ecosystem and how do you classify it?
2) How do you use geoinformatics for forest cover change detection studies?
3) How will you apply remote sensing tool to demarcate ground water potential zones?
4) Describe how geoinformatics is useful in natural resources management?
11.7 REFERENCES

- www.ias.ac.in/currsci/dec252007/1747.pdf.
- www.ias.ac.in/currsci/dec252007/1747.pdf.
- www.physicalgeography.net.
Scope and Applications of Geoinformatics

- www.springerlink.com/content/36507w5142116056/fulltext.pdf.
- www.springerlink.com/content/6816423032wt48k8/fulltext.pdf.
- www.springerlink.com/content/cg23876q1024p85p/fulltext.pdf.
- www.springerlink.com/content/cg23876q1024p85p/fulltext.pdf.

All websites were retrieved between 10 June 2011 and 03 August 2011.

11.8 FURTHER/SUGGESTED READING


11.9 ANSWERS

Check Your Progress I

1) Abiotic and biotic components.

2) The major findings in the forest cover change detection case study:
   - Forest cover has increased between 1931-1971 because of the implementation of various afforestation schemes by the forest department and sacred grooves.
   - Forest cover has decreased between 1971-2001 due to shifting cultivation and illegal encroachments by villagers.

Check Your Progress II

The studies that can be carried out using geoinformatics for aquatic ecosystem are: identification of paleochannels, river migration, mapping and monitoring of water bodies and identification of flood prone areas and flood inundated areas, etc.

Unit End Questions

1) Ecosystem is the basic functional unit that incorporates organisms, populations and communities together with the causal mechanisms that define the relationships, interdependencies and pathways that direct energy flow and control the properties of the system. Ecosystem is categorised into terrestrial and aquatic ecosystems.

2) Forest cover change detection can be done using geoinformatics techniques by adopting systematic procedures such as preparation of forest cover maps of different seasons/years. The forest areas can be delineated from their red tone and contiguous pattern. The scrubs can be identified from their brownish yellow tone, coarse texture and scattered pattern. The agriculture and human habitations can be identified from the light reddish-brown tone and regular pattern. The rocky outcrops/slopes are identified from their brighter tone, absence of vegetal cover and their association to the steeper slopes.

3) For the purpose of ground water potential zone demarcation the following maps, such as area of interest, geology, drainage, drainage density,
lineament, lineament density, geomorphology, land use land cover, slope, rainfall, etc., are prepared with due care during interpretation. After preparing the above mentioned thematic maps, all the features are ranked as per their favourability towards the presence of ground water. Finally, all the thematic layers are integrated in GIS and a map showing distribution of ground water potential zones comes as an output of the integration depending upon the ranking of favourable conditions.

4. The various thematic maps can be viewed in a GIS environment to visualise any ongoing natural processes, which determine the existence or extinction of natural resources in an area. Apart from this various information and studies are possible such as identification of degraded land, potential mineral resources and zones, groundwater potential zones, mapping of different rock types, mapping and monitoring of water resources and quality, etc.
Scope and Applications of Geoinformatics
UNIT 12 LAND USE PLANNING, INFRASTRUCTURE AND E-GOVERNANCE

Structure

12.1 Introduction
   Objectives

12.2 Land Use and Land Cover Studies
   Land Use and Land Cover Classification System
   Identification of Land Use / Land Cover Features
   Data Consideration for Land Use and Land Cover Studies

12.3 Geoinformatics in Rural and Urban Planning and Infrastructure Monitoring
   What is Planning?
   Spatial Planning
   Data Consideration for Urban and Rural Environment
   Monitoring Urban Sprawl
   Urban Infrastructure/Facilities Mapping and Monitoring
   National Urban Information System (NUIS) Scheme
   Land Use Planning
   Planning Support System (PSS)

12.4 E-Governance Applications
   Geoinformatics in E-Governance
   The National E-Governance Plan (NeGP)
   E-Governance Infrastructure

12.5 Summary

12.6 Unit End Questions

12.7 References

12.8 Further/Suggested Reading

12.9 Answers

12.1 INTRODUCTION

In the previous unit, you have studied about the application of geoinformatics for different kinds of ecosystems and natural resources management. Today, we live in time characterised by technological developments so dynamic that it goes beyond many peoples’ imagination. In the rapidly changing world, our policy makers have to deal with a highly chaotic information environment. In particular, urban areas are highly dynamic and face serious challenges of growth and its management. So, an increasing need for structured information enabling governments to make the right policy decisions is anticipated.

In this unit, we will study about the use of geoinformatics in land use and land cover studies and planning. We will also study about its use in infrastructure and e-governance.
Objectives

After reading this unit, you should be able to:

• define land use and land cover;
• describe use of geoinformatics for land use and land cover studies;
• explain the scope of geoinformatics in rural and urban planning; and
• discuss application potential of geoinformatics in infrastructure and e-governance.

12.2 LAND USE AND LAND COVER STUDIES

Although the terms land use and land cover are often used interchangeably, their actual meanings are quite distinct. The term land use refers to the usage of land by human beings, such as houses, roads, manufacturing plants, etc. Land cover refers to the natural landscape as surface component of a portion of the Earth’s surface, such as forests, lakes, beaches, rivers, etc. The concept of land cover is best understood when applied to natural surfaces where no activity has occurred for, e.g. unharvested forest land. Land use designates economic activity and hence it is abstract. Land cover designates the surface features, and is therefore directly observable.

The analysis of land use change depends on the chosen system of land use and land cover classification. The magnitude and quality of land use change is expressed in terms of specific land use or land use and land cover types. The assessment of the environmental and socio-economic impact of land use change is possible only when the particular environmental and socio-economic features of the chosen land use and land cover types are specified.

Remote sensing data has an advantage over the data collected using conventional survey. Collection of data through conventional surveys is a time and resource consuming task. By the time the plan is made using these data, the data may become old, hence, the plan may not be appropriate for implementation. Remote sensing data providing finer details of urban and rural features are useful to generate different thematic layers. GIS is useful to analyse those layers and generate different scenarios and display the results as maps. This makes the visualisation of real world problems simple and assists in land use and land cover studies and planning.

12.2.1 Land Use and Land Cover Classification System

Land use and land cover pattern in an area reflects how society is interacting with its physical environment. Any developing nation must have adequate information on many complex interrelated aspects of its activities in order to make decisions. Land use is only one such aspect but knowledge about land use and land cover has become increasingly important as the nation plans to overcome the problems of population growth, loss of prime agricultural lands and rapid urbanisation. Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels. In this dynamic situation, accurate, meaningful and up to date data on land use are essential.
While mapping land use/land cover from remote sensing data, we need to follow a classification system. There is no ideal classification of land use/land cover but there are different perspectives in the classification process. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet their needs. In attempting to develop a classification system for use with remote sensing data that should provide a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established. A land use/land cover classification system, which can effectively employ remote sensing data, should meet at least the following criteria (Anderson, 1971):

- the minimum level of interpretation accuracy
- repeatable or repetitive results should be obtainable from one interpreter to another and also from one time of remote sensing data acquisition to another
- the classification system should be applicable over extensive areas
- effective use of sub-categories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensing data should be possible
- aggregation of categories must be possible
- multiple uses of land should be recognised when possible.

For India, a land use/land cover classification system was prepared by National Remote Sensing Agency (NRSA) after discussion with many user departments/institutions in the country as shown in Table 12.1.

**Table 12.1: Land use and land cover classification scheme (NRSA, 1983)**

<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
<th>Level III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Built Up:</strong> other than agriculture, covers residential units, other buildings, transport, communication utilities with water, vegetation and vacant lands.</td>
<td>1.1. Towns/Cities/Villages</td>
<td>2.1.1 Kharif (June–Sep.)</td>
</tr>
<tr>
<td><strong>Agricultural land:</strong> used for farming, production of food, fiber, commercial, horticultural crops.</td>
<td>2.1 Crop land</td>
<td>2.1.2 Rabi (Oct–Feb.)</td>
</tr>
<tr>
<td></td>
<td>2.2 Fallow land</td>
<td>2.1.3 Kharif+Rabi</td>
</tr>
<tr>
<td></td>
<td>2.3 Plantation</td>
<td></td>
</tr>
<tr>
<td><strong>Forest:</strong> notified boundary; trees and other vegetation; timber and other forest produce</td>
<td>3.1 Evergreen/Semi evergreen</td>
<td>3.1.1 Dense</td>
</tr>
<tr>
<td></td>
<td>3.2 Deciduous (Moist and Dry)</td>
<td>3.1.2 Open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.1 Dense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.2 Open</td>
</tr>
<tr>
<td><strong>Wastelands:</strong> degraded land, brought under vegetative cover with reasonable water and soil management or on account of natural causes</td>
<td>4.1 Salt Affected Land</td>
<td>4.1.1 Dense</td>
</tr>
<tr>
<td></td>
<td>4.2 Waterlogged Land</td>
<td>4.1.2 Open</td>
</tr>
<tr>
<td></td>
<td>4.3 Marshy/Swampy Land</td>
<td>4.1.3 Wetland</td>
</tr>
<tr>
<td></td>
<td>4.4 Gullied/Ravenous Land</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5 Land with Scrub</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.6 Land without Scrub</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7 Sandy area (Coastal and desertic)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.8 Mining/Industrial Wasteland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.9 Barren Rocky/Stony Waste/Sheet Rock Area</td>
<td></td>
</tr>
</tbody>
</table>
**Scope and Applications of Geoinformatics**

**Water bodies:** an area of impounded water, areal in extent and often with a regulated flow of water, includes man-made reservoirs/lakes/tank/canals, besides natural lakes, rivers/streams and creeks.

**Others:** include all those, which can be treated as miscellaneous because of their nature of occurrence, physical appearance and other characteristics.

5.1 River/Stream  
5.2 Canals  
5.3 Lake/Reservoirs/Tank  
6.1 Shifting Cultivation  
6.2 Grass Land/Grazing Land  
6.3 Salt Pans  
6.4 Snow covered/ Glacial Area  
6.2.1 Dense  
6.2.2 Degraded

This table is modified time to time depending on requirements and the data used. The table shows generalised first and second level classes but satisfies the three major attributes:

- gives names to categories by simply using accepted terminology
- enables information to be transmitted
- allows inductive generalisations to be made.

Users should not consider themselves limited to categories, such as these but should develop categories of utmost utility to their particular needs. One example of sub-categorisation of residential land as keyed to the standard land use code is shown in Table 12.2. A Level III categorisation would require use of supplemental information, such as density of dwellings, tenancy, age of construction and so forth. Obviously users desiring Level IV information could employ a variety of additional criteria in discriminating among land uses. However, it can be seen that the element which allows aggregation and transfer between categories is the proper description of what is included in each individual category at whatever level the data are being classified.

### Table 12.2: Sub-categorisation of residential land

<table>
<thead>
<tr>
<th>Level I</th>
<th>Level II</th>
<th>Level III</th>
<th>Level IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Built-up</td>
<td>1.2 Residential</td>
<td>1.2.1 Urban</td>
<td>1.2.1.1 Single family unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2.2 Rural</td>
<td>1.2.1.2 Multi-family unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.2.1.3 Others</td>
</tr>
</tbody>
</table>

#### 12.2.2 Identification of Land Use / Land Cover Features

For mapping land use/land cover features from remote sensing data, we should be able to identify the features on image data. The features are identified based on certain visual characteristics, which are given in Table 12.3.
<table>
<thead>
<tr>
<th>Land cover/Land use</th>
<th>Image characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Settlements</td>
<td>Light grey clustering with particular patterns for the urban area. There may be brownish maroon patches for in between vegetation. For the rural settlement there occur no particular patterns of such image characteristics.</td>
</tr>
<tr>
<td>2. Agriculture</td>
<td>• Identify rabi crops if the month of data acquisition is January or February or March and colour is brown red.</td>
</tr>
<tr>
<td></td>
<td>• Same characteristics in image occur for the kharif crops if the image data are acquired in the month of September, October or November.</td>
</tr>
<tr>
<td></td>
<td>• Fallow land is identified by light grey colour within cropped area (red colour).</td>
</tr>
<tr>
<td></td>
<td>• Plantation occurs as brownish maroon patches.</td>
</tr>
<tr>
<td>3. Forest</td>
<td>• Dense forests are identified by dark red colour patterns.</td>
</tr>
<tr>
<td>a) Dense forests</td>
<td>• In the case of degraded forest the dark red colour patterns contain small brown or white patches.</td>
</tr>
<tr>
<td>b) Degraded forest</td>
<td>• The blanks in the forest show creamy patches in the dark red/background.</td>
</tr>
<tr>
<td>c) Forest blank</td>
<td>• Forest plantations are identified by dark red colour sign of particular pattern.</td>
</tr>
<tr>
<td>d) Forest plantation</td>
<td>• Muddy water logging occurs as blackish or deep blue spots while clear water logging area is identified by dark/bright blue patches.</td>
</tr>
<tr>
<td></td>
<td>• Comparing the images of monsoon season and post monsoon season will help in identifying temporary and permanent water logging.</td>
</tr>
<tr>
<td></td>
<td>• Marshy area is recognised as a sign of vegetation (red/pink spots) in the water logged (blackish blue/bright blue) area.</td>
</tr>
<tr>
<td></td>
<td>• Gullied land appears as white/grey spot.</td>
</tr>
<tr>
<td></td>
<td>• The image of land with scrub contains white patches in the land area.</td>
</tr>
<tr>
<td></td>
<td>• Sandy area is classified as bright white coloration along the course of river.</td>
</tr>
<tr>
<td>4. Waste Land</td>
<td>• River/stream is identified as long non-linear path coloured with dark blue/bright blue line in white background.</td>
</tr>
<tr>
<td>a) Muddy water logging</td>
<td>• Canals are identified as line segments sign of water bodies.</td>
</tr>
<tr>
<td>b) Clear water logging</td>
<td>• Lake/reservoirs are identified as patterns along the river.</td>
</tr>
<tr>
<td>c) Temporary water logging</td>
<td>• Embankment occurs as light grey structure along the river.</td>
</tr>
<tr>
<td>d) Permanent water logging</td>
<td>• Embankments</td>
</tr>
<tr>
<td>e) Marshy area water logging</td>
<td></td>
</tr>
<tr>
<td>f) Gullied land</td>
<td></td>
</tr>
<tr>
<td>g) Land with scrub</td>
<td></td>
</tr>
<tr>
<td>h) Land without scrub</td>
<td></td>
</tr>
<tr>
<td>i) Sandy area</td>
<td></td>
</tr>
<tr>
<td>5. Water bodies</td>
<td>Grasslands are identified as uneven appearance characterised by red (light to medium grey tones)</td>
</tr>
<tr>
<td>a) River/stream</td>
<td>Snow is identified as white patches on the hills.</td>
</tr>
<tr>
<td>b) Canal</td>
<td></td>
</tr>
<tr>
<td>c) Lake/ reservoirs</td>
<td></td>
</tr>
<tr>
<td>d) Embankments</td>
<td></td>
</tr>
<tr>
<td>6. Others</td>
<td></td>
</tr>
</tbody>
</table>
You will see here two examples of land use/land cover mapping; one is at national level and the other is at regional level. Fig. 12.1 shows a national land use/land cover map generated using multidate IRS AWiFS data. Fig. 12.2 shows land use/land cover map of Madurai district in Tamil Nadu where Landsat ETM data was used.
12.2.3 Data Consideration for Land Use and Land Cover Studies

Consideration of appropriate data for land use and land cover mapping is critical. This appropriateness is in following terms:

- the details which are possible to extract from the given remote sensing data
- time interval between the data acquisition for the same area by the same sensor
- timing of data acquisition with respect to the phenomena being observed.

For national and state level, you do not need to use data which provide very detailed information because these would be cost ineffective. So, data should be selected keeping in view the scale at which the map is to be prepared. Another important issue is consideration of data of appropriate timing, such as for mapping kharif crops, you need to choose data which has been acquired between months of June to September. You should also note that cropping pattern and the harvesting season varies from region to region within India. Another critical point to remember is that if you are going to compare land use/land cover patterns of an area for different date then it is best to use the data from same sensor, so that there is an uniformity in the information derived.

Check Your Progress I

1) Land use refers to

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................

2) Land cover refers to

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................

12.3 GEOINFORMATICS IN RURAL AND URBAN PLANNING AND INFRASTRUCTURE MONITORING

One of the important applications of geoinformatics is in rural and urban planning as it facilitates planners and decision makers to integrate a wide variety of data into one platform, create different scenarios and visualise them.
In this section, we will discuss about potentials of geoinformatics in rural and urban planning. A very simple distinction between urban and rural environment can be defined as land that is built over and land that is not built over. Urban represent built environments, such as the buildings, streets, and infrastructure created by the people living in those places. Rural areas represent environment, such as agriculture fields, ponds, habitations, etc.

Let us first understand what is planning.

### 12.3.1 What is Planning?

Planning refers to the process of deciding what to do and how to do it. Planning occurs at many levels, from day-to-day decisions made by us as individuals and our families, to complex decisions made by businesses and governments. Today, city, community, and regional planning mean dealing with constant change. Planners may have the technical expertise, political confidence, and fiscal understanding to translate a vision of tomorrow into a strategic action plan for today. But requirements handed down from central government and state regulatory agencies, regional bodies, and an increasingly active public have made this job even more challenging.

One of the earliest planners, Sir Patrick Geddes had formulated a simple three-step process of planning: Survey, Analysis and Plan. Survey requires the systematic collection of data and analysis refers to process the data and extract necessary information from it. Plan is the creation and means arriving at decisions regarding the future development of the area concerned, based on information from the analyses. So, a good planning requires a methodical process that clearly defines the steps that lead to optimal solutions. This process should reflect the following principles:

- a comprehensive plan considers all significant options and impacts
- an efficient plan process does not waste time or money
- an inclusive plan gives opportunities for people affected by the plan to be involved
- an informative plan results are understood by stakeholders or people affected by a decision
- an integrated plan of individual, short-term decisions supports strategic, long-term goals
- a logical plan leads each step to the next
- a transparent plan makes everyone understand how its process operates.

Planners are professionals who facilitate decision making. Planners do not make decisions themselves but support decision makers by coordinating information and activities. Their role is to create a logical, systematic decision making process that result in the best actions. Today, planners work at the intersection of many disciplines and so they need basic knowledge of many subjects including design, economics, law and management. So the planners need many skills including the ability to:

- evaluate the problems accurately, critically and objectively
- listen respectfully, collect and analyse data
• apply general concepts to specific situations and manage complex processes
• communicate complex issues with many types of people.

Planning process analyses alternatives to meet projected demands on the basis of demographic pattern of rural and urban planning. The basic aim of the planning is to improve the quality of life of people living in urban and rural area. Rural planning is of significant importance in India where more than 70% population live in villages. A suitable information system in all planning and developmental activities is the need of the day. In this regard, geoinformatics addresses the issues related to geospatial domain and causes considerable impact in rural and urban planning activities. This system allows the planner to integrate a wide variety of data into one common format, a map. 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.

12.3.2 Spatial Planning

Spatial planning refers to the methods used by the planners to influence the distribution of people and activities in spaces of various scales. At a very general level, planning how to use the Earth’s surface involves what space to use and when to use it. The ‘what’ issues are those that involve spatial planning; they typically involve the concept of scale. The ‘when’ issues involve temporal planning; they typically involve the concept of sequence.

Spatial planning includes regional planning, land use planning, urban planning and infrastructure planning. Spatial planning aims to create and maintain the qualities of urban areas. The challenges of spatial planning change as society develops. Following three challenges are faced by planners (Fig. 12.3):

• growing population
• scarcity of suitable space and
• risks from natural disasters.

![Fig. 12.3: External pressure on spatial planning](image-url)
With limited available space and population growth, there is an escalation of competition in the use of space. The problem in finding suitable location and appropriate allocation is coupled with the increasing number of disasters.

Planning zones may encompass several villages, towns, cities or even parts of different states, each of which could have its own planning office in the realm of rural/urban planning. In this regard, availability of spatial technologies, such as remote sensing and GIS can be considered as an effective tool for spatial analysis. In particular, GIS facilitates balanced regional development. Based on the spatial scales and information content, spatial plans can be classified into two categories:

- **General spatial plans** address the issues of pattern and structure spatial usage on residential, transportations and utility. The definition of developable and undevelopable zones is covered here and represented at a map scale from 1: 25 000 to 1: 100 000.

- **Detail spatial plans** contain information on zoning, density, ratios of building and open space and acceptable storey. It has a legally binding status on what type of development that can or cannot be built in any particular location at a map scale of 1:5 000 to 1: 10 000.

Let us take an example of the Adayar Park in Chennai where geoinformatics was used to prepare a spatial plan (Fig. 12.4). Adayar river is one of the six main waterways crossing the Chennai city. A unique feature of the Adayar River is the estuary at its mouth. It covers an area of roughly 358 acres and part of it (58 acres) is called the Adayar Creek. This estuarine wetland, which is part of the ‘green lungs’ of the city, provides a habitat for migratory birds and aquatic animals.

![Fig. 12.4: Adyar Poonga (Park): an example of spatial planning (source: Auroville Today, Jun-July 2008)](image-url)
12.3.3 Data Consideration for Urban and Rural Environment

Urban planners require information related to the rate of growth, pattern and extent of sprawl to provide basic amenities, such as water, sanitation, electricity, etc. In the absence of such information most of the sprawl areas lack basic infrastructure facilities. Pattern and extent of sprawl could be detected with the help of remote sensing data. In addition, information with census data, such as population size, population density in built-up areas, infrastructural characteristics, administrative boundaries and predominant economic activities are the main variables conventionally used to distinguish rural from urban. For work at the equivalent of the census-tract level of analysis, the ideal image is a relatively high resolution multispectral image.

Urban planners need large scale maps ranging from 1:10,000 to 1:4,000 and 1:1,000/1:500 for specific urban applications. But now base maps are being produced at scales ranging from 1:4,000 to 1:10,000 depending upon the specific urban applications for which they are prepared. IRS-P6 (multispectral) data with cartosat data can meet the ever-growing demand for current, accurate base maps at a scale of 1:5,000 for urban planning purposes and for developing new residential sites. Table 12.4 lists some of the remote sensing data that can be used to monitor the urban and rural environment at different scales. The table depicts that the higher spatial resolution data is essential for detailed analysis of urban features which contains less spectral information and is often expensive relative to coarse or moderate resolution imagery. Accordingly, when regional to global data coverage is desired, the only viable option is medium to coarse resolution data.

Table 12.4: Comparison of some remote sensing data

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Cost</th>
<th>Image Extent</th>
<th>Revisit Times</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>High resolution (&lt;10m)</td>
<td>Typically high</td>
<td>Local (~10 × 10 km)</td>
<td>Typically monthly (weekly for some data)</td>
<td>SPOT HRV-II (MLA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IRS-1C &amp; 1D PAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LISS IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IKONOS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Quickbird</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CARTOSAT-1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RESOURCESAT-I</td>
</tr>
<tr>
<td>Moderate resolution (10-100m)</td>
<td>Low to Medium</td>
<td>Regional (~100×100 km)</td>
<td>Typically monthly to bi-annually (16-18 days for some locations)</td>
<td>ASTER VNIR</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LISS III</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TM, ETM, MSS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SPOT-HRV</td>
</tr>
<tr>
<td>Moderate to coarse resolution (&gt;100m)</td>
<td>Typically low</td>
<td>Global (~1000×1000 km)</td>
<td>24 to 48 hours (often composited to 8 or 16 days)</td>
<td>MODIS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MERIS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OCEANSAT-1 &amp; 2</td>
</tr>
</tbody>
</table>

High resolution satellite data (Fig. 12.5) provides a tool by which these changes can be managed and planned for broad expansion of rural/urban environments. The increased spatial accuracy and frequent revisit periods allow planners to construct action scenarios and compile accurate database of spatial environments. Advancement in remote sensing technology has brought miracle in the availability of the higher and higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 meter resolution in multispectral mode, IRS-1D Pan image with 5.8 meter resolution, cartosat-I imagery of 2.5 meter resolution with stereo capabilities, Cartosat-II (Fig. 12.6) with 1 m, IKONOS images with 4 meter in multispectral mode and 1 meter in
Scope and Applications of Geoinformatics

panchromatic mode, Quickbird imagery with 61 cm resolution in panchromatic mode and so on.

Fig. 12.5: High-resolution satellite data (source: IKONOS Space Image)

Fig. 12.6: Cartosat-2B Images (source: NRSC, DOS, India)
Remotely sensed data in urban studies began with first-generation satellite sensors, such as Landsat Multispectral Scanners (MSS) given impetus by a number of second generation satellites: Landsat Thematic Mapper (TM) and SPOT High Resolution Visible (HRV). The recent advancement of very high spatial resolution (5 meter/pixel) satellite sensors is stimulating. The high resolution PAN and LISS III data can be used together effectively for urban applications. Data from IRS P6 satellite with sensors on board especially LISS IV Mono and Multispectral (MX) with 5.8 meter/pixel spatial resolution are very useful for urban studies.

Now we will discuss about some examples of geoinformatics applications in urban and rural environment and planning.

### 12.3.4 Monitoring Urban Sprawl

India’s urban population has increased to about 285 million in 2001 in comparison to 79 million in 1961 resulting into expansion of city boundaries. Urban sprawl is the unchecked spreading of a city or its suburbs. It often involves the construction of residential and commercial buildings in rural areas or otherwise undeveloped land at the outskirts of a city. Most residents of typical urban sprawl neighbourhoods live in single-family homes and commute by car to their jobs in the city. Urban sprawl is often happens quickly, as opposed to gradually. Another key characteristic is its low-density land use, where the amount of land consumed per capita is much higher than in more densely populated city areas. Wide streets, large lawns and landscaping are typical in this pattern.

Monitoring the spatial patterns of urban sprawl on a temporal scale can be undertaken using temporal remote sensing data acquired from space borne sensors. These help in inventory, mapping and monitoring linear and radial growth patterns. The spatial patterns of urban sprawl over different time periods, as shown in Fig. 12.7, using remote sensing data (LANDSAT TM & ETM+) can be systematically mapped, monitored and accurately assessed along with conventional ground data. Geoinformatics helps in identifying the pattern of growth and its rate. Mapping urban sprawl provides a picture where this type of growth is occurring and to suggest the likely future directions and patterns of sprawling growth.

![Fig. 12.7: Urban Expansion in Madurai during the period 1991-2006 (source: Saravanan & Ilangovan, 2010)](image)
Let us take an example where ISRO (Space Application Centre), Ahmedabad and Directorate of Town and Country Planning, Bhopal jointly prepared the development plan of Indore city using geoinformatics. Urban sprawl map of Indore city was prepared using multi-date remote sensing data (from year 1975 to 2000) (Fig. 12.8).

Fig. 12.8: Urban Sprawl map (source: www.planningsummerschool.org/pdfs/2003B040AU.pdf)

12.3.5 Urban Infrastructure/Facilities Mapping and Monitoring

According to Oxford English Dictionary, infrastructure means the basic physical and organisational structures needed for the operation of a society. In other words, it may be defined as the physical framework of facilities, utilities and support system through which goods and services are provided to people. The infrastructure structures facilities are:

- physical infrastructure consist of roads, water supply, drainage, sewers, electrical grids and
- social infrastructure includes education, health, telecommunication, security, firefighting services, banks, financial institutions, socio-cultural, housing and other services.

The remote sensing techniques provide accurate, orderly and reliable information repetitively for planning and management of urban utility services. Whereas the aerial photography at a scale of 1:10,000 and larger provides information about the spatial distribution of most of the urban infrastructural facilities, the SPOT and IRS-1C & 1D data in panchromatic mode offers capabilities for mapping and analysing urban transport network, effluent discharge zones and urban greenery.

In a recent example, a feasibility study for optimisation of route alignment was undertaken by a gas transmission company to prepare a plan to connect Chennai and Cuttack with Kakinada through a gas pipeline (1200kms) for supplying LPG. Geospatial techniques were used for optimisation of route
alignment. The Fig. 12.9 displays CARTOSAT-1 imagery overlaid with the final route. Village/parcel boundaries and buffers are shown in the plan.

Fig. 12.9: CARTOSAT-1 imagery overlaid with final route (source: Roy et al., 2010)

12.3.6 National Urban Information System (NUIS) Scheme

National Urban Information System (NUIS) is a three tier system which addresses planning, management and development issues. Besides, this system must be able to cater to the overall needs of urban managers, town planners and decision makers. Ministry of Urban Development has launched the National Urban Information System (NUIS) scheme in March 2006. The NUIS scheme comprises of two major components as given in Fig. 12.10:

- **Urban Spatial Information System (USIS)** includes development of GIS based multi-hierarchical database with application tools to support Master/Zonal plan preparation; Urban Local Bodies (ULB) administration and utilities management.

- **National Urban Databank and Indicators (NUDB&I)** includes designing and establishing a comprehensive data bank and integration of these parameters to support planning and derive indicators for National Urban Observatory (NUO) for monitoring the health of urban settlements.

NUIS scheme deliverables include an urban, standardised GIS database of 1:10,000 to enable preparation of development/master plan and 1:2,000 GIS database to monitor and implement most of urban local body functions at 1:1000 scale. A set of user-friendly application utilities will allow extraction of outputs from the NUIS scheme databases for planning and management.
activities. Fig. 12.11 displays an example of the geospatial databases of towns that enable the preparation of urban plans to meet the requirements of different levels of urban planning.

Fig. 12.10: Conceptualisation of National Urban Information System (NUIS) Scheme

Fig. 12.11: NUIS data base of Korba Town of Chhattisgarh (source: Roy et. al., 2010)
12.3.7 Land use Planning

Land use planning (LUP) is an iterative process based on the dialogue amongst all stakeholders aiming at the negotiation and decision for a sustainable form of land use in urban/rural areas as well as initiating and monitoring its implementation. Land use planning creates the pre-requisites required to achieve a type of land use, which is sustainable, socially and environmentally compatible, socially desirable and economically sound. Particular areas of land can be utilised by humans in diverse ways. These can include residential, institutional, business, industrial, agricultural, forestry, park, and other relatively natural land uses. Each of these broader categories can be further subdivided, based on the nature and intensity of the activities that are undertaken.

- **Residential land uses**, for example, can involve single-family dwellings on large or small lots, or aggregations of multiple-unit dwellings of various sorts. The most intensive residential land-uses are associated with clusters of apartment buildings, which can support extremely large densities of human populations.

- **Institutional land uses** are mostly associated with land that is occupied by public buildings, such as schools, universities, government office buildings, art galleries and museums. These facilities are most commonly located in urban or suburban areas.

- **Industrial land uses** are extremely varied, depending on the nature of the industry being considered. Urban industrial land usage generally refers to the site of factories, and of utilities, such as electricity generating stations, and water and sewage-treatment facilities. Industrial land use in rural areas can include mines, smelters and mills for the production of ores and metals; mines and well fields for the production of fossil fuels such as coal, oil and natural gas; and large water-holding reservoirs for the production of hydro electricity.

- **Land uses for agriculture and forestry** are also types of industrial land uses, involved with the production of food or tree-fiber as renewable resources. The nature of agricultural land uses depends on the types of crops and agronomic systems, which can vary from intensively managed monocultures, to more organic systems involving annual or perennial crops and little use of fertilizers or pesticides. Similarly, the intensity of land use in forestry varies from systems involving clear-cutting and the establishment of short-rotation plantations to selection-harvesting systems with long-spaced interventions.

- Land uses for recreational purposes associated with parks and golf courses also represent intensive modifications of the natural landscape. The management practices required to maintain these lawn-dominated ecosystems are similar to those utilised in some types of monocultural agricultural systems.

- The last major category of land use involves designation of an area as an ecological or wilderness reserve. In most cases, this sort of land-use designation precludes the exploitation of natural resources by mining, forestry, or agriculture, and usually by hunting and fishing as well.
LUP aims at achieving a balance among these goals through the use of information on trade-offs, appropriate technology, and consensus-based decision-making. Fig. 12.12 displays land use/land cover mapping and assessment for the corridor of 1km, and is for the distribution of LNG supplied by a company through a pipeline to be commissioned between Kochi-Mangalore-Bangaluru over a distance of 912 kms. This map was prepared using IRS-1D (LISS III) satellite data of 2002 and pipeline passing through each land use/land cover category was estimated with geographical extent of each land use/land cover classes.

**Fig. 12.12: Land Use/Land Cover mapping and assessment. (source: Remote Sensing Applications, NRSC)**

### 12.3.8 Planning Support System (PSS)

Numerous methods and tools have been used by professional planners over the years to support various planning activities in different contexts. Most geoinformation tools do not readily fit the changing needs of the planning profession; they are far too generic, complex, inflexible and incompatible with most planning tasks, oriented towards technology rather than problems. So, a tool, i.e. planning support systems (PSS) is developed to facilitate new planning practice. PSS consists of a wide diversity of geoinformation tools that are dedicated to support public or private planning processes at a particular spatial scale and within a specific planning context.

Currently there are few popular systems that try to emulate spatial PSS with an objective to make planning interactive and participatory. Among them *What if? PSS* is an interactive GIS-based system which supports all aspects of planning process:

- conducting a land suitability analysis
- projecting future land use demand
- preparing a land use plan, and allocating this demand to suitable locations
What If? is a collaborative GIS-based planning support system and is supported by What If? Inc.<http://www.whatifinc.biz/>. The PSS is not an academically supported planning tool rather it is a commercial off-the-shelf (COTS) software package. It includes several options including suitability, allocation demand, etc. These options are useful for identifying suitable areas for different purposes depending upon the land use demand.

PSS offers an improvement to standard GIS. The PSS reduces the complexity of using map overlays in a GIS as well as reducing the time required to explore a range of land use change scenarios. The strength of PSS tools, such as What If, is that they guide users through a straightforward land use allocation process. The procedure for allocating land is incremental and enables a degree of trade-off to occur between competing land uses, based on user defined weightings and controls. PSS holds a lot of potential for planners.

Check Your Progress II

1) Planning refers to ........................................................................................

2) List out the two major components of NUIS scheme.

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................

12.4 E-GOVERNANCE APPLICATIONS

The developments in Information and Communications Technology (ICT) impacted the world tremendously. Besides, ICT now seeps even into the political sphere and demonstrably creates opportunities for governments. E-governance uses ICT to improve the effectiveness, efficiency, service delivery and to promote democracy of the governments. It also helps to innovates services, create new approach in leaderships, to develop better policy making strategies and finds new ways of making the administration more effective and efficient. E-governance broadens the involvement of citizens and makes it possible to participate in government’s decision or the policy making processes. In addition, e-governance also helps government to access even in the remotest areas, and reduces the cost of both running and transacting with government itself. So e-government is “a government that applies ICT to transform its internal and external relationships” (UN, 2003).

Three main domains of e-governance are e-administration, e-services and e-society. The main purposes are:

- **e-administration** is to improve the internal workings of the public sector by reducing process costs, managing process performance, creating strategic connections within government bodies, and creating empowerment. Shortening the lead time for passport applications from two weeks to one day is an example of e-administration.
• **e-service** initiatives focus on improving the relationship between the government and its citizens by increasing the information flow between them. Notably, involves two-way communication and improving the service levels of government towards its citizens. Public service institutes offering citizens the opportunity to apply for business licenses through a government website is one example of e-services.

• **e-society** initiatives extend the previous e-services domain by focusing on institutional stakeholders, such as private sector service providers, other public agencies, and not-for-profit and community organisations.

### 12.4.1 Geoinformatics in e-governance

The basis for e-Governance is fusion of ICT supporting and transforming the governance by processing and communicating data. Key innovation of E-governance is computer networks, from Intranet to the Internet, creating a digital network between various user nodes. Easy access to complete information with common geographic-reference using high speed communication network (including Internet) helps employees to improve their efficiency and government to make better decisions. The potential of geoinformatics that offers better governance for the benefit of both, government and citizens are:

- **In land records management** area the benefits are mapping and updating land parcels using high resolution remote sensing data and field surveys; Computerised maps of land parcels, easy updating of changes in land mutations and ownership, linkages to data base management system (DBMS) for management of land records.

- **In industrial estate management** area the benefits are mapping of industrial plots and infrastructure using high resolution remote sensing data, field surveys, computerised maps of layout and infrastructure details, on line allotment of lands to customer, decision support system (DSS) for user departments: Land, Engineering, Planning departments and web GIS based application for providing plot level details to potential customer.

- **In disaster management** area the benefits are mapping of disaster prone at varying scales, mapping of amenities and infrastructure, required for disaster management, integration with network technology for exchange of information between and among institutions, governments, citizens, NGOs, etc. DSS built around Disaster Management Information System can address needs at all the stages such as preparedness, early warning, relief/response and mitigation.

- **In integrated development** area the benefits are mapping land use/land cover, ground water potential and soil conditions etc. Monitoring of land use/land cover and impacts, including salinity and land degradation, implementation of developmental programmes, such as hill area, drought prone area, wasteland etc.

- **In telecom network planning and management** area the benefits are mapping of components of network: land base, such as roads, parcels, etc., asset management for efficient maintenance of components, routing of the network and complaint management.
• In **electricity distribution and transmission network** area the benefits are mapping of components of network: land base, such as roads, parcels etc., asset management for efficient maintenance of components, routing of the network, fault management by locating fault location on the map and designing and optimisation of network, load management, load forecast, etc.

• In **transport network development** area the benefits are mapping of roads and other transport network, identifying pocket of poor transport network, planning new transport network and GIS based Road Information System tool to monitor road development and maintenance.

• In **law and order** area the benefits are spatial analysis of crime data, GIS based Police Information System and emergency planning.

• In **environmental management area** the benefits are mapping of environmentally sensitive areas. Issues include water, air and noise pollution, soil salinity, oil spills, deforestation, wetland depletion etc. Modeling for predicting extent of environmental degradation, inputs for mitigating negative impacts on environment and Environmental Impact Assessment based on spatial data.

In the next section, we will study about an e-governance initiative of Indian Government i.e. National e-Governance Plan.

### 12.4.2 The National e-Governance Plan (NeGP)

The National e-Governance Plan (NeGP) has been formulated by the Department of Information Technology (DIT) and Department of Administrative Reforms & Public Grievances (DAR&PG). The Union Government approved the National e-Governance Plan (NeGP), comprising of 27 Mission Mode Projects (MMPs) and 10 components on May 18, 2006. MMPs encompass 10 Central MMPs, 10 State MMPs and 7 Integrated MMPs spanning multiple Ministries/ Departments (Table 12.5). The concerned Ministry/ Department are entirely responsible for all decisions related to their MMPs.

**Table 12.5: NeGP Mission Mode Projects (Source: Department of Information Technology, Government of India)**

<table>
<thead>
<tr>
<th>Central MMPs</th>
<th>State MMPs</th>
<th>Integrated MMPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Banking</td>
<td>• Agriculture</td>
<td>• CSC</td>
</tr>
<tr>
<td>• Central Excise &amp; Customs</td>
<td>• Commercial taxes</td>
<td>• e-Biz</td>
</tr>
<tr>
<td>• Income Tax</td>
<td>• e-District</td>
<td>• e-Court</td>
</tr>
<tr>
<td>• Insurance</td>
<td>• Employment Exchange</td>
<td>• e-Procurement</td>
</tr>
<tr>
<td>• MCA21</td>
<td>• Land Records</td>
<td>• EDI for e-Trade</td>
</tr>
<tr>
<td>• National Citizen database</td>
<td>• Municipalities</td>
<td>• National</td>
</tr>
<tr>
<td>• Passport</td>
<td>• Gram Panchayats</td>
<td>e-governance</td>
</tr>
<tr>
<td>• Immigration, visa and Foreigners Registration &amp; Tracking</td>
<td>• Police</td>
<td>Service delivery</td>
</tr>
<tr>
<td>• Pension</td>
<td>• Road Transport</td>
<td>Gateway</td>
</tr>
<tr>
<td>• e-office</td>
<td>• Treasuries</td>
<td>• India Portal</td>
</tr>
</tbody>
</table>
12.4.3 E-Governance Infrastructure

The key to successful implementation of any e-governance initiative is the availability of adequate infrastructure for the service delivery system. The backbone infrastructure and human resource requirements need to be determined and acquired for successful e-governance implementation. The essential infrastructure components for e-governance are: State Wide Area Network (SWAN), State Data Centre (SDC), National e-governance Service Delivery Gateway (NSDG), and Common Services Centers (CSC) (Fig. 12.13).

![E-Governance Infrastructure](image)

- **State Wide Area Network (SWAN)** is an advanced telecommunication infrastructure. It is now-a-days used extensively for exchange of data and other types of information between two or more locations, separated by significant geographical distances. Such wide area networks, in a way, create a highway for electronic transfer of information in the form of voice, video and data. This in turn brings speed, efficiency, reliability and accountability in overall system of Government-to-Government (G2G) functioning in each State/Union Territories.

- **State Data Centre (SDC)** has been identified as one of the important elements of the core infrastructure for supporting e-Governance initiatives of National e-Governance Plan (NeGP). SDCs provide better operation and management control and minimise overall cost of data management, IT resource management, deployment and other costs.

- **The National e-Governance Service Delivery Gateway (NSDG)**, an integrated MMP is a standards-based messaging switch and providing seamless inter-operability and exchange of data across the departments. NSDG acting as a nerve centre handles large number of transactions and helps in tracking and time stamping all transactions of the Government. This also includes the National Services Directory (NSD). All the Gateways that need to resolve services, which are not in their domain, need to resolve it at the NSD.

- **Common Services Centers (CSC)** is a strategic cornerstone of the National e-governance Plan (NeGP) and provides high quality and cost-effective video voice, data content and services. A highlight of the CSCs is that it will offer web-enabled e-governance services in rural areas including application forms, certificates and utility payments such as electricity, telephone and water bills.
You have studied in Unit 3 of this course about various national initiatives. Many of those initiatives, such as National Natural Resources Management System (NNRMS) would maintain an archive of digital data of different themes for use in government, business and societal needs. These will be useful for e-governance and sustainable development.

12.5 SUMMARY

In this unit, we have discussed about the applications and scope of geoinformatics in Land Use Planning, Infrastructure and e-governance. Let us summarise what we have studied in this unit.

- Land use refers to the usage of land by human beings and land cover refers to the natural landscape on the Earth’s surface.
- Remote sensing data is useful for land use/land cover mapping. The mapping is systematically done using a well defined classification system using appropriate data.
- Geoinformatics is useful for urban and rural planning processes. Some of the common examples include urban sprawl mapping, infrastructure mapping and monitoring, etc.
- National Urban Information System scheme of India is a good example, how geoinformation data and technology can be used for urban planning.
- Geoinformatics has a good scope in e-governance also, as evident by the national initiative i.e., national e-governance plan.

12.6 UNIT END QUESTIONS

1) List out the criteria for a land use/land cover classification that can employ remote sensing data.

2) Write in detail about the National Urban Information System (NUIS) scheme.

3) What do you mean by Planning Support System?

4) Discuss about the role of geoinformatics in e-governance.
In the previous two units, you have studied about natural resources studies and management, land use planning, infrastructure and e-governance. In this unit, we will study about applications of geoinformatics for climate and environment related studies, such as global warming, climate change, air pollution monitoring and natural hazards monitoring and management. Our existence, lifestyles and economy depend completely on the sun and the Earth’s natural resources, such as water, soil, forests, grasslands, wetlands, oceans, lakes, wildlife and minerals. They form our life support system. The term environment is often used to describe this life support system of the Earth.

Remote sensing and Geographic Information Systems (GIS) provide appropriate technologies and methodologies to acquire and analyse information about the environment and provides accurate information of the Earth’s terrain over diverse scales and time periods.
Scope and Applications of Geoinformatics

Objectives
After reading this unit, you should be able to:

• recognise how satellites and their sensors observe the atmosphere, hydrosphere and the lithosphere thus lending them to various environmental applications;

• describe the capabilities and limitations of remote sensing systems available for climate, environmental related applications;

• discuss the scope and application of geoinformatics for natural hazard studies; and

• explain the role of the combined use of remote sensing, in-situ measurements (i.e. ground truthing) and modeling to answer specific research questions.

13.2 STRUCTURE OF THE EARTH

To understand the applications of geoinformatics in environment related studies, it is essential to first understand the structure of the Earth. Earth consists of three layers, namely atmosphere, hydrosphere and lithosphere. The part of the Earth, i.e. the atmosphere, hydrosphere and lithosphere in which living organisms exist, or that is capable of supporting life, is called as the biosphere. Now we will discuss about atmosphere, hydrosphere and lithosphere under three sub sections.

13.2.1 Overview of the Atmosphere

The atmosphere is a thin layer of life-sustaining gases surrounding the Earth which is zoned into several subdivisions (based on altitude and on composition and physical properties) and on differences in the absorption of incoming solar energy as shown in Fig. 13.1. The atmosphere consists of four major zones: troposphere, stratosphere, mesosphere and thermosphere.

The first is the troposphere which is the innermost layer and extends up to 17 kilometers above sea level at the equator and about 8 kilometers over the poles. 99% of the volume of clean, dry air in the troposphere consists of 78% nitrogen, 21% oxygen with the remaining being composed of less than 1% argon, 0.036% carbon dioxide and trace amounts of neon, helium, methane, krypton, hydrogen, xenon water vapours. Temperature decreases with altitude in the troposphere. The tropopause is the transition layer between the troposphere and stratosphere (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

The next layer is the stratosphere which extends from 17 to 48 kilometers above the Earth’s surface. Its composition is more or less similar to the troposphere with two exceptions:

• the volume of water vapour here is 1000 times less and

• the volume of ozone is 1000 times greater making it the ‘global sunscreen’.

The presence of ozone in the stratosphere protects human beings, plants and animals from sun’s harmful ultraviolet radiation by preventing them from
reaching the Earth’s surface thus protecting us from skin and eye cancers and damage to the immune systems. Unlike the troposphere, temperature rises with altitude in the stratosphere till there is a reversal at the stratopause, which marks the end of the stratosphere and the beginning of the atmosphere’s next layer.

The layer above the stratosphere at the height of around 50 kilometers is **mesosphere**. In this layer, temperature decreases with increasing altitude because of decreasing solar heating and increasing cooling by carbondioxide radiative emission. Temperature in the upper mesosphere has been reported as low as –100°C (–158°F). The upper boundary of the mesosphere is **mesopause** which is believed to be the coldest place on Earth.

**Thermosphere** is located above the mesosphere where temperature generally increases with altitude reaching 600°F to 3000°F (600-2000°K) depending on solar activity. The **exosphere**, a zone of free helium atoms, is the most distant atmospheric region from the Earth’s surface.

---

**Fig. 13.1: Structure of the atmosphere (source www.ic.ucsc.edu)**

### 13.2.2 Overview of the Hydrosphere

About 71% of the Earth’s surface is covered with water. Out of which around 97% is found in the ocean (salty water). The remaining 3% is fresh water of
which 2.997% is locked up in ice caps or glaciers and in underground reservoirs. This means that only 0.003% is available for our direct use. However, oceans are the source of most of the precipitation that constantly recycle water. The world’s oceans help regulate the planet’s climate, dilute and degrade some of our wastes and are a major habitat for many of the planet’s living inhabitants (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

### 13.2.3 Overview of the Lithosphere

The lithosphere consists of three layers: the inner core, the mantle and the crust. The **core** is approximately 7000 kilometers in diameter, and is located at the Earth’s center. The **mantle**, which surrounds the core has a thickness of about 2900 kilometers and comprises 83% of the Earth’s volume. It is composed of the upper mantle from the base of the crust downward to a depth of about 670 kilometers. The top layer of the upper mantle, 100 to 200 kilometers below surface, is called the **asthenosphere**. Below the upper mantle is the **lower mantle** that extends from 670 to 2900 kilometers below the Earth’s surface. The **crust** floats on top of the mantle. The lithosphere is a layer that includes the crust and the upper most portion of the asthenosphere. This layer is about 100 kilometers thick and has the ability to glide over the rest of the upper mantle. The lithosphere is also the zone of earthquakes, mountain building, volcanoes, and continental drift (http://en.wikipedia.org/wiki/Atmosphere_of_Earth).

![Fig. 13.2: Structure of the Earth (source: Miller and Spoolman, 2007)](image)

**Check Your Progress I**

1) List out the three layers of the Earth.

......................................................................................................................
......................................................................................................................
......................................................................................................................
......................................................................................................................
2) The gas that protects us from harmful ultraviolet radiation from sun is known as

In the next two sub sections, we will discuss about scope and application of geoinformatics for studying atmosphere, hydrosphere and related processes.

### 13.3 GEOPHYSICS FOR ATMOSPHERIC STUDIES

The advent of satellite remote sensing has opened new horizons in directly observing atmospheric properties, weather systems, oceanographic conditions and water runoff enabling global coverage on a daily basis. Some of the common applications are:

- air pollution monitoring
- wind speed and direction monitoring
- weather forecast
- cyclone/storm tracking and providing early warnings
- solar radiation studies, etc.

In next two sub sections, we will discuss about air pollution monitoring and meteorological applications.

#### 13.3.1 Air Pollution Monitoring

Air pollution has always existed in the form of volcanic eruptions, wildfires and dust storms with their associated emissions of sulfur dioxide, carbon monoxide and particulate matter. Air pollution accelerated dramatically due to the increase of emissions since the industrial revolution to reach very alarming proportions today in most countries around the world.

Air pollution emission sources are chiefly man-made and can be categorised into the followings:

- transportation sources (such as vehicles, planes, trains and ships)
- agricultural sources (such as livestock, rice farming and land cultivation)
- industrial sources (such as by-products of manufacturing processes, plants and industries) and
- construction activities and landfill activities

Apart from the devastating long term effects on human health, plants and materials, air pollution has disastrous effects on the stratosphere. The presence of chlorofluorocarbons (CFCs) accelerates the breakdown of ozone leading to

**Chlorofluorocarbon (CFC)** is an organic compound that contains carbon, chlorine, and fluorine, produced as a volatile derivative of methane and ethane.
Scope and Applications of Geoinformatics

The greenhouse effect is a naturally occurring process that aids in heating the Earth’s surface and atmosphere. It results from the fact that certain atmospheric gases, such as carbon dioxide, water vapour, and methane, are able to change the energy balance of the planet by absorbing longwave radiation emitted from the Earth’s surface.

Once it was realised that man-made CFCs being released into the atmosphere are destroying large amounts of ozone in the stratosphere, National Aeronautics and Space Agency (NASA) and National Oceanic and Atmospheric Agency (NOAA) developed the capability to measure tropospheric composition from space using ultraviolet and visible spectroscopy. These include measurements of atmospheric pollutant gases which help in predicting air quality. Since 1979, several satellites have been equipped with sensors that collect data on ozone, as well as other atmospheric constituents that affect the amounts of ozone present. The Total Ozone Mapping Spectrometer (TOMS) is one such sensor (Fig. 13.3 and Fig. 13.4). The satellites that have flown TOMS have included Meteor-3, Nimbus-7, and most recently ADEOS (Advanced Earth Observing Satellite) and Earth Probe.

Over the last decade, the capabilities of satellite instruments for remote sensing of the lower troposphere have strongly increased. New space borne radiometers make it possible to determine aerosol parameters on spatial scales of a few kilometres, whereas the new generation of spectrometers can detect nitrogen dioxide and other trace gases on urban scales.

Fig. 13.3: Images from the Atmospheric Infrared Sounder (AIRS) instrument onboard NASA’s Aqua spacecraft. The above images show that the carbon dioxide levels in our atmosphere are rising. Both images show the spreading of carbon dioxide around the globe as it follows large-scale patterns of circulation in the atmosphere. The colour codes used in these two pictures are different in order to account for the carbon dioxide increase from 2003 to 2007. If the colour bar for 2003 were to be used for 2007, the resulting 2007 map would be saturated with reddish colours, and the fine structure of the distribution of carbon dioxide obscured (source: NASA/JPL)
Fig.13.4: This series of images above shows the Antarctic ozone hole on the day of its maximum depletion in four different years; that is, the days with the thinnest ozone layer as measured in Dobson Units (DU). The measurements were made by NASA’s Total Ozone Mapping Spectrometer (TOMS) instruments from 1979-2003 and by the Royal Netherlands Meteorological Institute (RNMI) ozone Monitoring Instrument (OMI) from 2004–present. Purple and dark blue areas are part of the ozone hole (source: NASA)

While satellite observations have the advantage of global coverage and homogeneous quality, they also have disadvantages as they cannot provide information on large scale features and phenomenon. To benefit the most from the space borne observations, the air quality community combines satellite data with information from ground based sensors and models.

13.3.2 Meteorological Studies

As you watch in daily news channels, meteorological applications, particularly the weather forecasts, have become part of our daily lives. The first ever United States satellite in Earth orbit designed specifically to image and monitor conditions on and above the surface, was the meteorological satellite, called TIROS-1, launched on April 1, 1960 soon after NASA came into existence. The TIROS program provided the first accurate weather forecasts based on data from space, demonstrating that it was possible to use satellites to observe weather. Following this, several meteorological satellites, including India’s INSAT series were launched to provide current timely data for weather system monitoring and forecasting but also for communication purposes.

Meteorological satellites are of two types, i.e. polar orbiting and geostationary. Polar orbiting satellites can provide global coverage twice in 24 hours. Examples of the polar orbiting are NOAA, ERS-1, ERS-2, TRMM, DMSP, etc. Examples of Indian satellites include IRSP-4, Oceansat-1 and 2, etc. Geostationary satellites remain over the same location on the equator and can provide coverage every half an hour. Examples of geostationary satellites are GMS, GOES, METEOSAT -5, METEOSAT-6, etc. Examples of India satellites include INSAT Series of satellites and KALPANA-1.

A Dobson Units (DU) is the most basic measure used in ozone research. The unit is named after G.M.B. Dobson, one of the first scientists to investigate atmospheric ozone (1920 - 1960).
The meteorological sensors are classified based on their ability to collect spatial or spectral information. Spatial information includes the extent and the temperature of sea surface, clouds, vegetation, soil moisture, etc. Spectral information includes interaction of objects of interest with sun’s radiation. The AVHRR (Advanced Very High Resolution Radiometer) which has been on the NOAA series for the last thirty years is used for global measurement of cloud coverage, sea surface temperature and vegetation. Other important sensors for meteorological applications include the Total Ozone Mapping Spectrometer (TOMS) for measuring the amount of ozone in the atmosphere.

Meteorological satellites are generally used to collect following information-
- rainfall
- atmospheric water vapour
- sea surface temperature
- wind
- cloud coverage
- aerosols, etc.

As discussed earlier, the commonest example is the weather forecast as shown in Fig. 13.5 which shows water vapour image from KALPANA-1 satellite for 28 July 2011. Another useful example of meteorological satellites is tracking and forecast of cyclone and its behaviour. Satellites have greatly enhanced the ability to detect and track severe storms and also to understand the mechanisms of cyclone formation and development. Meteorologists work to constantly monitor cyclones as they move, issuing cyclone warnings. Earlier coastal residents had very little or no time to prepare or evacuate their homes.
from an oncoming cyclone. Today they can receive warnings to evacuate one to two days in advance.

Cyclones are characterised as tornadoes, hurricanes and typhoons. A tornado is a smaller kind of cyclone. When a cyclone forms over tropical waters in the North Atlantic or Eastern North Pacific oceans and has high winds of 119 km/hr or more it is called a hurricane. If the cyclone forms in the Western Pacific with winds of 119 km/hr or more it is called a typhoon. All of these storms are generally accompanied by high winds, heavy rains, severe thunder and lightning. In the north Indian Ocean they are simply called as tropical cyclones.

A typical mature tropical cyclone is a warm core vortex in the atmosphere, (anti-clockwise vortex rotation in the northern hemisphere and clockwise in the southern), cyclonic in the lower troposphere and anti-cyclonic in the upper troposphere. The circulation extends horizontally up to 1000 km from the centre and vertically to about 15 km above sea level. The cyclone has an ‘eye’ at the centre of radius 5 to 50 km and is rain-free with light winds and is surrounded by a ‘wall cloud’ made of tall cumulonimbus clouds riding up to an altitude of 15-18 km with the wall cloud thickness being about 10-15 km radially. Beyond the wall cloud, surface winds speeds decrease gradually with the radial distance from the center.

NASA’s Quick Scatterometer (QuikSCAT) spacecraft launched in June 1999 carries the SeaWinds scatterometer, a specialised microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over the Earth’s oceans. Data from the SeaWinds scatterometer augments traditional satellite images of clouds by providing direct measurements of surface winds. Comparison of winds with the observed cloud patterns helps in better determination of a cyclones location, direction of motion, structure, and strength. This data thus helps meteorologists to identify accurately the extent of the winds associated with a storm, while supplying inputs to numerical models that provide forecasts.

The Tropical Rainfall Measuring Mission (TRMM) is the first space mission dedicated to studying tropical and subtropical rainfall. The Precipitation Radar and the Microwave Imager on TRMM enables scientists to peer inside the tropical thunderstorms associated with hurricanes and cyclones giving them a three dimensional view to understand organisation of precipitation in hurricanes and its relation to storm intensity and environmental effects. This information can improve computer-based weather models enabling precise prediction of the path and intensity of hurricanes and cyclones. Together, QuikSCAT and TRMM provide opportunity to observe a hurricane’s/cyclones wind and rain before it makes landfall.

One of the greatest values of meteorological satellites lies in both their real time tracking capabilities and in their acquisition of data helpful in forecasting their future paths. Cyclone Nargis in the Indian Ocean which passed over Myanmar (Burma) on May 2 and 3, 2008, and has been the most disastrous in recent time. It is a classic example of real time tracking as shown in Fig. 13.6. The Indian Meteorological Department (IMD) is the nodal agency for providing operational cyclone forecast to Bangladesh, India, Maldives,
Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand. INSAT imagery is used to identify and locate the various stages of the cyclone.

Fig. 13.6: The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite acquired this image of Cyclone Nargis at 4:40 UTC on May 2, 2008. In this image, the sprawling storm spirals over the bay, between India in the west and Burma in the east. Bangladesh lies directly north of the storm.

Thus satellite, field observations and models developed to understand the phenomena are adding to our knowledge of the structure and mechanism of cyclones and the large-scale climate patterns that influence them.

Check Your Progress II

1) Name 5 different sensors used in meteorological studies.

..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  

2) List at least three different applications of geospatial technology associated with the atmosphere.

..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  
..........................................................................................................................................  

Spend 
5 mins
13.4 GEOINFORMATICS FOR THE STUDY OF HYDROSHERE

There are evidences to prove that though natural warming of the Earth takes place, human actions have accelerated this process manifold. This and other related phenomena are addressed as ‘global climate change’ problems. The threats are not only from the gradual rise in global temperature and sea level but the redistribution of heat over Earth’s surface. Some spots will warm while others will cool. These changes, and the accompanying shifts in rainfall patterns, could relocate agricultural regions across the planet affecting people and global biodiversity.

Satellite observations of the oceans over the past three decades have revolutionised our understanding of global climate change through global measurements and modeling of the ocean-atmosphere climate system. Global data sets available on time scales of days to years (and, looking ahead, to decades) have been and will be a vital resource for scientists and policymakers in fields from ocean commerce to disaster mitigation. Key social and economic benefits of satellite ocean data include:

- **Climate Research**: Scientists study the evolution of weather patterns by modelling changes in the distribution of the oceans’ heat
- **Hurricane/Cyclone Forecasting**: Altimeter and scatterometer data are incorporated into atmospheric models for hurricane/cyclone season forecasting and individual storm severity
- **El Nino and La Nina Prediction**: Understanding the pattern and effects of climate cycles such as El Nino helps us to predict and mitigate the disastrous effects of floods and drought
- **Fisheries Management**: Satellite data are used to identify ocean eddies as well as plankton concentrations, which bring an increase in organisms that comprise the marine food web and attract fish and fishermen
- **Marine Mammal Research**: Sperm whales, fur seals and other marine mammals are tracked and studied around ocean eddies, where nutrients and plankton are abundant
- **Coral Reef Research**: Remotely sensed data are used to monitor and assess coral reef ecosystems, which are sensitive to changes in ocean temperature

A number of satellites, such as SeaSat, TOPEX/Poseidon, ERX-1, ERX-2, Jason, Quicksat, etc., dedicated to gathering oceanic data have significantly increased our understanding of the behaviour of large bodies of water. The key to measuring ocean currents from space is ocean-surface topography through the use of radar altimeters, a microwave sensor which map the height of the sea surface at all points on the globe.

Scatterometer data has wide coverage, and thus contributes to improving the forecast accuracy of weather forecasting models. Launched in 1999 on the QuikSCAT satellite, the SeaWinds scatterometer has provided information on **El Nino/La Nina** is a quasiperiodic climate pattern that occurs across the tropical Pacific Ocean roughly every five years. It is characterised by variations in the temperature of the surface of the tropical eastern Pacific Ocean-warming or cooling known as El Nino and La Nina respectively.
changes in the polar sea-ice masses besides providing the longest continuous, global view of ocean-surface winds to date, including the detailed structure of hurricanes, wind-driven circulation.

A radiometer is used to measure sea surface temperature, wind speed, salinity, soil moisture, sea ice, precipitation, integrated water vapour and liquid water content of the atmosphere. They operate in the visible, infrared and microwave range thus lending themselves to a wide range of environmental applications. We will discuss here about one of the common applications i.e. flood forecasting.

Applications in Flood Forecasting

Being a tropical country India is prone to floods. Traditionally gathering and analysing hydraulic and hydrologic data related to floodplains and river catchments has been a time consuming effort requiring extensive field observations and calculations. With the development of remote sensing and computer analysis techniques, traditional techniques can be supplemented with these new methods of acquiring quantitative and qualitative flood hazard information. Most of the flood prone rivers in India change their course frequently after every flood causing enormous damage. It is, thus, essential to understand the behaviour of the river and its latest configuration to plan flood control measures, it is also important to monitor the existing flood control structures periodically to avoid breaches in view of the frequent changes in river configuration. In such cases, it is important to monitor the river both in time and space which cannot be done by conventional. In this regard satellite remote sensing provides an excellent source of information and coupled with GIS is an effective tool for river/flood monitoring (Fig. 13.7).

Topography of the river catchment is a basic need for flood forecasting. Remote sensing provides quantitative topographic information that is extremely valuable for model inputs. Satellite remote sensing can play a major role in rainfall runoff modeling which is a part of the flood forecasting model. The real time rainfall data provided by meteorological satellites is used as an input in the flood forecast models.

Today urban flooding is an inevitable problem in many cities, and is on the rise. Wetlands have been reclaimed effectively annihilating flood buffers due to the increased demand for land for various developmental purposes. This has led to a substantial decrease in the proportion of rainfall that infiltrates into the ground and a consequent increase in surface runoff, in terms of both volume and flow rate. Urbanisation has changed natural run-off pattern and accelerated transport of water, pollutants and sediment from the urban areas. One of the typical features of urban flooding is shortening the runoff travel time making it a flash event. The continuous development of urban settlements necessitates data on flow rates, physical and topographical settings for more periodic assessment, and monitoring to cope up with storm water flooding. Recent advances have greatly enhanced the satellite remote sensing data capabilities in supplementing the data needs for management of urban flooding.
Fig. 13.7: This image was acquired by MODIS on the Aqua satellite during the floods in Assam highlights the standing water, which appears dark blue or black. The river makes a thin line through the pale tan flood plain, which contrasts against the green vegetation. Flooded areas are seen along the foothills of the Himalayas, which run across the top of the images (source: http://visibleearth.nasa.gov/view.php?id=66805)

Check Your Progress III
1) Match the following

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar images</td>
<td>Measures sea surface temperature</td>
</tr>
<tr>
<td>Radiometer</td>
<td>Measures height of the sea surface</td>
</tr>
<tr>
<td>Scatterometer</td>
<td>Used to assess flood extent</td>
</tr>
<tr>
<td>Radar altimeters</td>
<td>Identifies potential fishing zones</td>
</tr>
<tr>
<td>Ocean colour monitor</td>
<td>Measures sea surface roughness</td>
</tr>
</tbody>
</table>

13.5 GEOINFORMATICS IN NATURAL AND MAN-MADE DISASTERS

India has traditionally been vulnerable to natural disasters on account of its unique geo-climatic conditions. Floods, droughts, cyclones, earthquakes and landslides have been recurrent phenomena. About 60% of the landmass is prone to earthquakes of various intensities, over 40 million hectares is prone to floods, about 8% of the total area is prone to cyclones and 68% of the area is susceptible to drought (www.ndmindia.nic.in/GoIUNDP/ReportPub/DM-Statu-%20Report.pdf).
Although natural disasters cannot be controlled, they can be reduced through a proper disaster management plan 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. Mitigation of natural disasters can be successful only when adequate knowledge is obtained about the expected frequency, character and magnitude of hazardous events. The use of 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 to successfully predict the occurrence of disastrous phenomena and to provide early warning to people. Natural disaster includes flooding, volcanoes, forest fire, earthquake, landslide, etc., Human induced disaster includes mine subsidence, oil spills, etc. Here we will discuss about the application of geoinformatics in monitoring volcanoes, forest fire, earthquake and landslides. We will also discuss about the oil spills which is not a natural disaster but a man-made.

### 13.5.1 Monitoring Volcanoes

When we think of volcanoes, the first image that comes to mind is probably a tall, conical mountain with orange lava spewing out the top. There are certainly many volcanoes of this type. But the term volcano actually describes a much wider range of geological phenomena. Generally speaking, a volcano is any place on a planet where some material from the inside of the planet makes its way through to the planet’s surface. This material is its magma, fluid molten rock which is partially liquid, partially solid and partially gaseous.

More than 1,500 potentially active volcanoes dot the Earth’s landscape, of which approximately 500 are active at any given time. Satellite technology now makes it possible to monitor volcanic activity in even the most isolated corners of the globe and to routinely observe changes in the Earth’s surface that may signal an impending eruption. In addition, remote sensing data offer scientists the chance to prevent catastrophic damage to life and property by determining how and where volcanic debris spreads after an eruption. Fig. 13.8 provides concentration of sulphur dioxide erupted from the Sarychev Peak Volcano on Matua Island.

The MODIS Thermal Alert System, known as MODVOLC, now enables scientists to detect volcanic activity anywhere in the world within hours of its occurrence (http://earthobservatory.nasa.gov/Features/monvoc). MODVOLC uses data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors, which fly aboard NASA’s Terra and Aqua satellites. A developed algorithm scans each 1-kilometer pixel within every MODIS image to see if it contains high-temperature heat sources or hot spots. MODIS achieves complete global coverage every 48 hours, which means that this system checks every square kilometer of the globe for volcanic activity once every two days. Using this system, remote volcanoes that would normally not have been detected even for weeks can now be monitored. For each hot spot identified, MODVOLC records the date and time at which it was observed and its geographic coordinates. Since active lava flows or growing lava domes emit vast amounts of energy, these hot spots are relatively easy to detect in MODIS imagery. Because of its global coverage every alternate day MODIS
data are useful for quickly providing researchers with information about new eruptions.

![Image of average column sulfur dioxide concentrations between June 10 and 17, 2009, from the Sarychev Peak Volcano on Matua Island in the northwest Pacific based on data from Ozone Monitoring Instrument (OMI). High concentrations of sulfur dioxide stretched westward from the volcano as far as Sakhalin Island and mainland Russia and eastward as far as Alaska (source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=38975)]

Other types of satellite data, such as Synthetic Aperture Radar (SAR), are better suited to look at the changes that often precede an eruption and provide the coverage necessary to see how the ground surface is deforming over a broad region.

Although scientists will continue to use ground-monitoring techniques to keep an eye on the Earth’s volcanoes, satellite data will increasingly allow scientists to see ‘the big picture’ and, as a result, better predict volcanic activity.

### 13.5.2 Forest Fire Monitoring

Fire is part of the natural reproductive cycle of many forests revitalising growth by opening seeds and releasing nutrients from the soil. However, fires can also spread quickly and threaten settlements and wildlife, eliminate timber supplies and temporarily damage conservation areas. In tropical deciduous forests, fire is a natural phenomenon due to the high levels of water stress during summer. Fires are also deliberately lit by local people to elicit a fresh flush of grass for their cattle during the dry summer months. Forest fires can have large impacts on both ecosystems and economy. Thus the cause of fires may be both intentional and unintentional.

Forest fires have tremendous impacts on the physical environment, including land cover, land use, biodiversity, climate change and forest ecosystem as well as on human health and socio-economic system of the affected countries. The more pronounced consequences of forest fires are their potential effects on climate change. Biomass burning contributes to the global budgets of many...
radioactively and chemically active gases, such as carbon dioxide, carbon monoxide, tropospheric ozone, etc. It is recognised as a significant global source of emission contributing as much as 40% of gross carbon dioxide and 30% of tropospheric ozone. This has sparked a renewed interest in detection, monitoring and assessment of forest fires.

Traditionally forest fires have been detected using fire lookout towers located at high points in a forested area. Today however advanced forest fire detection systems are based on satellite imagery. AVHRR, MODIS, IRS-WIFS sensors are being used for active forest fire detection.

Remote sensing can be used to detect and monitor forest fires and the regrowth following a fire as a surveillance tool for routine sensing facilitates observing remote and inaccessible areas as well as alerting monitoring agencies to the presence and extent of a fire. NOAA AVHRR thermal data and GOES meteorological data can be used to delineate active fires and remaining ‘hot-spots’ when optical sensors are hindered by smoke, haze, and/or darkness. Comparing burned areas to active fire areas provides information about the rate and direction of movement of the fire. Remote sensing data can also facilitate route planning for both access to and escape from a fire. Information about the behaviour of the forest after a forest fire event can also be obtained from remote sensing data.

While thermal data is best for detecting and mapping ongoing fires, multispectral (optical and near-infrared) data are preferred for observing stages of growth and phenology in a previous burn area. Moderate spatial coverage, high to moderate resolution and a low turnaround time are required for burn mapping. On the other hand, fire detection and monitoring requires a large spatial coverage, moderate resolution and a very quick turnaround to facilitate response.

India has developed a forest fire response and assessment system, named as INFFRAS (Indian Forest Fire Response and Management System), to facilitate forest fire management (http://applications.nrsc.gov.in/fire/). INFFRAS integrates multisensor satellite data with GIS databases to address forest fire management at following three levels:

- **Pre fire**: Preparatory planning for fire control
- **During fire**: Near real time active fire detection and monitoring and
- **Post fire**: Damage and recovery assessment and mitigation planning

With the advent of a series of satellite onboard, it is possible to detect active fires to a minimum of four times in a day (i.e. MODIS-Terra/Aqua, NOAA-17/18, IRS P6) and at least two times during the night by DMSP-OLS (F15 and F16). In an integrated approach, daytime fire signals using MODIS Terra/Aqua and night-time fire signals using DMSP-OLS are disseminated to the user (State Forest Department), through INFFRAS. Different spatial and temporal satellite data i.e. IRS 1D/P6, MODIS are analysed for fire monitoring and burnt area assessment on the basis of daily fire alert or based on special request from any user and are made available at INFFRAS for the users.
13.5.3 Earthquake Related Studies

Among the natural disasters, earthquakes cause immense damage to life and property. Occurrences of earthquakes are quite uncertain. An earthquake is the result of a sudden release of energy in the Earth’s crust that creates seismic waves. Remote sensing data can be used for earthquake monitoring, prediction, hazard zonation and damage assessment.

Although researchers relentlessly work on earthquake prediction; operationally earthquakes are difficult to predict or forecast. Researchers have used following information for monitoring and prediction of earthquakes-

- ground movement
- thermal and
- ionospheric changes.

Remote sensing based studies are being attempted to detect thermal anomaly associated with earthquake to demonstrate its potentials in earthquake-related studies. Generally, intensity and magnitude of earthquake is known only after the Earthquake has actually occurred in a region and causes immense destruction and loss of life and property. This requires all time preparedness for the authorities and the people. The use of high resolution satellite data with short revisit satellite imagery plays a vital role in post-earthquake management. The integrated analysis of geologic and seismologic data, field observations, lineament data, derived from satellite radar images, if integrated with historical data on earthquake, demographic data, soil type, soil deformation analysis, etc., would help to generate seismic hazard zonation map of an area. This can help evaluate the potential of occurrences of earthquake in an area enabling pre-earthquake management/engineering practices to be chalked out.

While no earthquakes have been predicted based on remote sensing alone, it has proved to be very useful in detecting active faults and thus delineating these zones for establishing the seismic stations. Today extensive research has resulted in the identification of many precursors to earthquakes. One of the important ones is thermal anomaly, i.e. a sudden rise in land surface temperature (LST) a few days or weeks before the occurrence of the earthquake. Prior to the earthquake various physical and electrical changes along with a change in the thermal regime of the epicentre region occur. This can be detected by space borne sensors, like Advanced Very High Resolution Radiometer (AVHRR) and MODIS.

Remote sensing can thus play an important role in earthquake prediction, seismic micro-zonation and post-earthquake disaster management-related studies. The major limitations of remote sensing based earthquake studies are ascribed to rare validation of satellite based measurement with ground data.

13.5.4 Landslide Studies

Landslide is a downward movement of mass of rock, soil, down a slope. Factors, such as terrain slope, lithology, geological structure, land use, lineament density, geomorphology, etc., can induce a landslide. Landslides can be triggered by rainfall, undercutting of slopes due to flooding or excavation, earthquakes, snowmelt and other natural as well as human-made causes, such
as over grazing by cattle, terrain cutting and filling and excessive development. Rainfall increases the pore water pressure decreasing the shear strength of the rock, leading to landslides in an area. In India, most of the landslides occur during rainy season due to heavy downpour in a short period of time. Geoinformatics can be used to prepare landslide inventory, landslide hazard zonation map and for assessment of damages.

Comprehensive landslide inventory is a prerequisite for landslide hazard and risk analysis. A landslide inventory map not only shows the time and date of occurrence but also the types of landslide.

Lidar data have been used to prepare landslide inventory under forest areas in hilly regions and to refine the boundaries of landslides prepared during field investigations. This data is not only useful for mapping old landslides but also can improve field survey based investigations in regions with subdued morphology.

SAR has all weather monitoring ability and the images are useful in identifying critical terrain elements such as faults and slope characteristics. Also subtle movements due to landslides can be picked up from interferograms generated from SAR images.

Very high resolution imagery (QuickBird, IKONOS, CARTOSAT-1 and 2) has become the best option now for landslide mapping, and the numbers of operational sensors with similar characteristics are growing year by year. Other remote sensing approaches of landslide inventory mapping include shaded relief images produced from Light Detection and Ranging (LIDAR) DEM and Synthetic Aperture Radar (SAR) interferometry. In India, different agencies, such as ISRO, DRDO, DST, etc., have prepared landslide hazard zonation maps and landslide information system for different parts of the country utilising geoinformatic technology.

![Fig. 13.9: 3D visualisation of landslide hazard zonation map of Kelani area in Uttarakhand (source: www.ias.ac.in/currsci/jul252000/RESEARCH%20COMMUNICATIONS2.pdf)](image)


13.5.5 Monitoring Oil Spills

Petroleum products play an important role in modern society, particularly in the transportation, plastics and the fertilizer industry. There are typically ten to fifteen transfers involved in moving oil from the oil field to the final consumer. Oil spills can occur during oil transportation or storage, and spillage can occur in water, ice or on land. Marine oil spills can be highly dangerous since wind, waves and currents can scatter a large oil spill over a wide area within a short span of time. Thus uncontrolled leakage of oil from and around a well drilling site or a tanker accident as that which happened recently in the Gulf of Mexico in 2010 is a dreaded ecological disaster.

There are many sensors available to detect marine oil spills on various types of water surfaces and multiple sea-states and they can provide the following information for oil spill contingency planning:

- detection, location and spread of oil spill over both large and small areas
- thickness distribution of an oil spill to estimate the quantity of spilled oil
- classification of the oil type in order to estimate environmental damage and to take appropriate response action
- timely and valuable information to assist in response and clean-up operations
- stored and time-stamped, real-time data on any spills and response efforts

Oil spill remote sensing is invaluable in organising cleanup operations and controlling the oil spill response but perhaps most importantly, for the early and rapid detection of the actual oil spills themselves.

Fig. 13.10: NASA’s Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) over Gulf of Mexico to image the deepwater horizon oil spill on June 2010 took this image (source: www.nasa.gov/topics/earth/features/oilspill/pia13233.html)

Researchers have used variety of techniques, such as radar, infrared, optical and laser for oil spill detection and monitoring. Radar can be used to detect oil over a large area and at long distances, making it an effective tool for a detection and assessment in determining the possible location of an oil spill. SAR (Synthetic Aperture Radar) and SLAR (Side- Looking Airborne Radar)
are the two most common types of radar which can be used for oil spill studies.

Infrared/Ultraviolet (IR/UV) line-scanners capture the infrared and ultraviolet radiation reflected by the sea surface. The ultraviolet images can be overlaid with infrared images to generate an oil spill relative thickness map. UV images are based on the reflected sunlight, and hence cannot operate in the night.

A laser fluorosensor is the most useful and reliable instrument to detect oil on various backgrounds including water, soil, weeds, ice and snow. The disadvantage is that laser fluorosensors cannot measure oil thickness greater than 10-20 microns as the UV laser light is completely absorbed by oil and cannot reach the underlying water.

Optical and multi-spectral imaging systems are widely used in oil spill remote sensing. Visible sensors are useful only for close-range detection and documentation purposes as there are no methods to ensure the positive detection of an oil spill at longer distances.

Satellite remote sensing is most effective when the position of the oil spill is already established. The limitations with using satellite remote sensing are that it has a lower spatial resolution than airborne remote sensing and very few sensors except visible detection and radar can be used on a space-borne platform.

**13.6 ACTIVITY**

Identify one case study each in the fields of assessment of global climate change, air pollution modeling, oil pollution mitigation, management of cyclones, earthquakes and volcanoes or any other environmental application from research papers (You could access research papers from Google scholar). From the case study assess the following:

- What has been the remote sensing input? Identify the sensor used, its properties and role.
- What has been other in-situ/ancillary data used?
- What have been the possible analytical steps?
- Present the methodology as a flow chart.

**13.7 SUMMARY**

Geospatial technology today is a very vital tool that has opened new horizons in directly observing atmospheric properties, weather systems, oceanographic conditions, water runoff, natural hazards, etc., enabling global coverage on a daily basis. In this unit, we have studied that:

- Applications such as weather monitoring has brought geospatial technology into our homes. Meteorologists use satellites to track and forecast cyclone behaviour, detect and track storms. The greatest value of meteorological satellites lies in both their real time tracking capabilities and in their acquisition of data helpful in forecasting their future paths.
• Today satellite data is useful for climate research, hurricane/cyclone forecasting, El Nino and La Nina prediction, fisheries management, coral reef research, etc.

• Geoinformatics provides reliable information and is an effective tool for river/flood monitoring. Meteorological satellites also provide the real time rainfall data that is used as an input in the flood forecast models.

• Geoinformatics is used to monitor natural disaster such as volcanic activity, forest fire, earthquakes, landsides, etc., and prepare hazard zonation plan and also enabling disaster management.

• Geoinformatics has also been used for detecting human induced disaster, such as oil spills.

13.8 UNIT END QUESTIONS

1) What according to you have been the benefits of the space program for environment conservation?

2) Highlight the role of geospatial technology in mitigating global climate change.

3) What is the role of geospatial technology in oil spill monitoring, prevention and management?

13.9 REFERENCES

• http://applications.nrsc.gov.in/fire.
• http://earthobservatory.nasa.gov/Features/monvoc.
• http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=38975.
• www.ias.ac.in/currsci/jul252000/RESEARCH%20COMMUNICATIONS2.pdf.
• www.ic.ucsc.edu.
• www.imd.gov.in/section/satmet/dynamic/compositewv.htm.
• www.nasa.gov/topics/earth/features/oilspill/pia13233.html.

Data from links was retrieved between 29th July to 7th December 2011.

13.10 FURTHER/SUGGESTED READING

13.11 ANSWERS

Check Your Progress I
1) Atmosphere, hydrosphere and lithosphere.
2) Ozone.

Check Your Progress II
1) Meteorological sensors: High Resolution Infrared Sounder (HIRS), Total Ozone mapping Spectrometer (TOMS), Moderate Resolution Imaging Spectroradiometer (MODIS), Synthetic Aperture Radar (SAR), Advanced High Resolution Radiometer (AVHRR).
2) Geospatial applications associated with the atmosphere are measurement of ozone, prediction of cyclones, measurement of air pollution.

Check Your Progress III
1) Information of location of oil spill, size and extent of the spill, direction and magnitude of oil movement, wind, current and waves are needed for controlling an oil spill.

2) Radar images Used to assess flood extent
Radiometer Measures sea surface temperature
Scatterometer Measures sea surface roughness
Radar altimeters Measures height of the sea surface
Ocean colour monitor Identifies potential fishing zones

Unit End Questions
1) The answer to this question should provide a brief overview of the various applications in ozone monitoring, climate change studies, monitoring and management of disasters highlighting the sensors used and process in brief. Role of remote sensing, in-situ data collection, modelling should be highlighted.

2) The answer to this question should provide an overview of process of global climate change, its causes and the role of geospatial technology highlighting sensors and the various parameters they measure.

3) This answer should provide an overview of the causes of oil pollution, parameters needed for oil spill detection, role of remote sensing data long with pros and cons of sensors and need for in-situ measurements.
UNIT 14  OTHER APPLICATIONS

Structure

14.1 Introduction
   Objectives

14.2 Geoinformatics in Agriculture
   Crop Identification and Inventorisation
   Crop Area/Acreage Estimation and Production Forecasting
   Cropping Pattern and Cropping System Analysis
   Crop Stress Detection

14.3 Geoinformatics in Social Sciences
   Demography
   Archeology
   Business

14.4 Geoinformatics in Health

14.5 Geoinformatics in Forensic Science

14.6 Summary

14.7 Unit End Questions

14.8 References

14.9 Further/Suggested Reading

14.10 Answers

14.1 INTRODUCTION

In the previous three units, application and role of geoinformatics in natural resources studies and management, land use planning, infrastructure, e-governance, climate, environment and disaster management have been described. In this unit, some other applications of geoinformatics that are not covered earlier are discussed. Thus, it offers a concrete discussion of how geoinformatics can be integrated with various activities viz. agriculture, health, archeology, humanities, social sciences, business and forensic sciences.

Objectives

After reading this unit, you should be able to:

• analyse various application of geoinformatics in agriculture;
• discuss the scope of geoinformatics for social sciences and humanities;
• describe the role of geoinformatics for health related studies;
• elucidate the role of geoinformatics in archeology and forensic science; and
• judge the scope of geoinformatics in business.

14.2 GEOINFORMATICS IN AGRICULTURE

Efficiency in the agricultural sector can be augmented effectively by using geoinformatics technology. The spatial as well as temporal database
preparation for generating information in the agriculture sector can ensure greater reliability of estimates and forecasting. These databases will help in the process of planning and policy making. Geoinformatics technology for retrieval of agricultural information, such as identification of crop type, assessment of crop condition and crop yield estimation is a well-established fact. For ease of understanding, we will discuss about it under the heads of different kinds of studies possible.

### 14.2.1 Crop Identification and Inventorisation

Optical remote sensing of crop identification, monitoring and condition assessment involves the utilization of visible and infrared region of the electromagnetic spectrum. Crop identification and discrimination are based upon the fact that each crop has a unique spectral signature (Fig. 14.1), which is analysed by percent ground cover, growth stage, pigment, internal cell structure, crop geometry, the equivalent water content, differences in cultural practices, stress conditions, vegetative indices, etc. such as *Normalised Difference Vegetative Index (NDVI)*, *Leaf Area Index (LAI)*. These vegetation indices enables data analyst to discriminate different crop types using remote sensing data.

The differences between crop (plant) types can be fairly small in the near-infrared (NRI), part of electromagnetic spectrum as shown in these spectral signatures (in which other variables such as soil type, ground moisture, etc., are in constant). The similarity in shape of graph as shown in Fig. 14.1 for different kinds of crop types is explained by the fact, that most vegetation matter has the same basic cell structure and similar chlorophyll contents. However, the difference in percentage of reflectance suggests difference in crop types. Yet remote sensing is reasonably more effective in distinguishing and identifying different crop types.

Multi-temporal satellite data can capture the dynamic behaviour of identification of crop growth pattern at different stages of their growth, if data are acquired corresponding to their key phenological stages. This increases the feasibility to detect and monitor crop phenological variations and timings over large areas, at a lower cost, and frequently several times each week based on temporal resolution of the data. Temporal resolution of a sensor may vary from 5 days to a month as per the availability of present remote sensors. This
Vegetation indices (VIs) have been extensively used for monitoring and detecting crop and its dynamic pattern. The vegetative indices are based on the reflectance values in the NIR (near-infrared) and red regions of the electromagnetic spectrum obtained from observations throughout the growing season of a given crop. Reflectance signals from a crop canopy also comprises of reflectance or emittance from bare soil. The seasonal trend of reflectance from a canopy shows the red reflectance reaching a minimum with increasing leaf area while the NIR reflectance increases with increasing leaf area. This causes the ratio to increase as the canopy develops, with a range of NIR/red values about 1 to over 20. NDVI has been used extensively as one of the standard vegetation indices for crop discrimination and can be represented as:

\[
NDVI = \frac{(\text{Reflectance}_{\text{NIR}} - \text{Reflectance}_{\text{Red}})}{\text{Reflectance}_{\text{NIR}} + \text{Reflectance}_{\text{Red}}}
\]

where,

- \( \text{Reflectance}_{\text{NIR}} \) is reflectance in NIR band and
- \( \text{Reflectance}_{\text{Red}} \) is reflectance in RED band.

Each crop has its own growth cycle with a definite duration in each growth stage, such as germination, canopy growth, flowering, maturity and harvesting stage. The growth cycle can be characterised using time series analysis of NDVI of the cropping area as shown in Fig. 14.3. The generation of multi-date NDVI can identify two or more crops with similar spectral signatures on a given date.
In microwave domain, both sensor as well as target parameter influence radar interaction and backscatter characteristics. The microwave remote sensing has the advantage in crop inventory programme due to its sensitivity to crop geometry, moisture content and dielectric property. It enables to monitor the crop growth from early stages. The frequency, polarisation and incidence angle are the major sensor parameters that influence SAR backscatter ($\sigma$) use of microwave data for crop identification is given in Fig. 14.4.

Hyperspectral analysis of crop involves obtaining spectral reflectance measurements in hundreds of bands in the electromagnetic spectrum. Hyperspectral remote sensing imagers acquire many, very narrow, contiguous spectral bands throughout the visible, near-infrared, mid-infrared, and thermal infrared portions of the electromagnetic spectrum. These measurements may be obtained using hand-held spectro-radiometer or hyperspectral remote
sensing instruments placed onboard aircraft or satellites. Hyperspectral remote sensing provides valuable information about crop type, LAI, biomass, chlorophyll, and leaf nutrient concentration, which are used to understand ecosystem functions, crop growth pattern and nutrient cycling.

14.2.2 Crop Area/Acreage Estimation and Production Forecasting

Crop production estimation comprises identification of crops, acreage estimation and yield forecasting. Acreage estimation broadly consists of identification of crops on a digital image based on ground data collected, generation of spectral signatures of crops for different ground data collection sites and interpreting the image data using ground and image derived information. The spectral indices and parameters, such as NDVI, LAI, etc., that are directly linked with the crop yield can be computed for the ground truth sites. These spectral indices and parameters are related with the temporal spectral reflectance properties with the help of which a map of such parameter can be generated. The resultant NDVI/LAI images of crop class will be used for productivity estimation. Productivity modelling will be based on NDVI, LAI and combined values of NDVI and LAI and the corresponding crop area statistics generated from the analysis of remote sensing data. The regression equations of crop productivity and NDVI, LAI and NDVI + LAI are used for productivity estimation. The total production of crop can be calculated by using the following relationship:

Production (Tons) = Acreage (ha) × Productivity (kg/ha)

The remote sensing and GIS based acreage, productivity and production estimates of crop is then compared with the values reported by State Department of Agriculture (SDA), i.e. field value collected by the state agricultural department, as illustrated in Fig. 14.5. The comparison can be made by computing the Relative Deviation (RD) percentage by using the following formula:

RD (%) = (RS – SDA) / RS × 100

where,
RS = Remote Sensing and GIS based estimates; and
SDA = Values reported by State Department of Agriculture.

Fig. 14.5: District wise wheat acreage and production estimation using remote sensing data and its comparison with Bureau of Economics and Statistics (source: Hooda et al., 2008)
Finally, the output map can be generated as shown in Fig. 14.6.


14.2.3 Cropping Pattern and Cropping System Analysis

Information on existing cropping systems in a region with respect to crop’s areal extent, crop vigour/yield and yearly crop rotation/sequence practices is important for finding out agricultural areas with low to medium crop productivity. Sustainable increase in crop production in such regions can be achieved by adoption of suitable agronomic management packages including introduction of new crops, etc. Geoinformatics can play a vital role in cropping system and pattern analysis of an area by spatially integrating temporal crop inventory information of various crop season of that area. This methodology of cropping system mapping is primarily based on the use of digital image analysis technique and GIS. Various components of the methodology are:

i) Designing remote sensing database
ii) Pre-processing of RS data
iii) Preparation of registered dataset using temporal data
iv) Creating temporal dataset
v) Image classification, etc.

In this process, multi-date image classification technique is used to generate seasonal cropping patterns. The classification steps include:

i) Removal of non-agricultural classes by using a non-crop mask by selecting appropriate thresholding of temporal NDVI, and

ii) Crop classification using multi-date data.

The cropping pattern maps such, as in Fig. 14.7, can be generated using a logical combination of classified images corresponding to crops grown in a season.
14.2.4 Crop Stress Detection

It is feasible to detect crop stress using remote sensing generally from moisture deficiency or disease and pests. Hence, sometimes it is possible to suggest treatment and make information available to farmers before its arrival. Stress is indicated by a progressive decrease in Near-IR (NIR) reflectance accompanied by a reversal in Short-Wave IR (SWIR) reflectance, as shown in Fig. 14.8.

![Crop stress detection using remote sensing](source: http://rst.gsfc.nasa.gov/Sect3/Sect3_1.html, retrieved on June 10, 2011)

The present need of agriculture is to increase the production by optimum utilization of resources. Hyperspectral remote sensing can be a valid option for detection of water and nutrient (nitrogen) requirement of the crop as well as the early detection of the stress, disease of plants. Hyperspectral remote sensing can also be useful for monitoring the health status of the crop, ultimately increase in the crop yield.
Check Your Progress I

1) List out the studies related to agriculture which can be carried out employing geoinformatics.

......................................................................................................................
......................................................................................................................
......................................................................................................................

14.3 GEOINFORMATICS IN SOCIAL SCIENCES

Social sciences term is commonly used as an umbrella term to refer it as a plurality of fields outside the natural sciences. These include: demography, anthropology, archeology, business administration, criminology, economics, education, geography, linguistics, political science, sociology, international relations, communication, and, in some contexts, history, law and psychology. Generation of spatial information in social sciences research using geoinformatics is growing rapidly. This is largely based upon the more readily available GIS tools along with spatial data identifiers such as census data, demography, other attribute data in tabular form incorporated in GIS platform to generate highly interactive thematic maps for better visualisation across geographic location and decision making.

Social sciences research includes wide range of studies, such as archeological investigations of ancient settlement patterns, sociological and anthropological studies of social networks, demographic analyses of geographical trends in mortality and fertility, policy analysis, etc. All these studies require data, such as socio-economic variables, population figures, unemployment rates, households and its consumer demand, settlement area, etc., as well as location information, which can be integrated together in a spatial format by means of the geometric features of points or polygons. This spatial referencing of observations is also the salient feature of geoinformatics, which makes it a natural tool to aid in the analysis of social sciences data in a spatial as well as thematic format. Spatial pattern in social sciences research interlinks the interrelated social, behavioural, economic as well as environmental phenomena, which can improve the understanding of relationships among variables in georeferenced data for resolving societal issues for example, crime incidence in urban environments or the diffusion of fertility decline, etc.

14.3.1 Demography

Demography is one of the important parameters of social science research that can be assessed using geoinformatics. Satellite imageries provide information on land use/land cover pattern and data on socio-economic parameters as attributes can be integrated using GIS software packages and GPS can be used to assemble locational information. All these information can be integrated together using GIS software package to generate thematic maps of demographic and socio-economic structure of a particular area. Following kinds of spatial and locational information on demography can thus be generated:

- population growth
- population distribution and density
- biological characteristics of population (male and female population, sex ratio)
- social characteristics (literacy rate of male and female population; population with castes) as depicted in Fig. 14.9
- economic characteristics (workers category and their percentage in each category; household income
- occupation and per capita income of various categories of people
- road and transportation network, built-up area and land use maps, etc.

Using spatial analysis model, relationship between all the parameters can be generated and mapped as shown in Fig. 14.10. This leads to the generation of socio-economic status of a particular area with proper dissemination of information. It can be helpful for policy and decision making strategy for suitable planning and management in various sectors such as administrative, education, institution, commercial, industrial, tourism, etc.

### 14.3.2 Archeology

Archeology is a science of the human past and its spread over space and through time. It is the study of human society, primarily through the recovery and analysis of the material culture and environmental data, which they have left behind that includes artifacts, architecture, biofacts and cultural landscapes (the archaeological record). Man has invaded every environment on Earth successfully. He has explored, and eventually colonised the delicate surrounding environments. It is important for the success of current and future civilisations to understand how ancient man successfully managed Earth.

![Spatial pattern of socio-economic pattern in Dehradun City](source: Banerjee et al., 2002)
Archaeological researchers these days are aware of the capabilities and the importance of modern technologies, such as remote sensing, photogrammetry and GIS, and their role in mapping and management of archeological sites and data. Geoinformatics can be used as a methodological procedure for detecting, acquiring inventory and prioritising surface and shallow-depth archeological information in a rapid, accurate, and quantified manner. Remote sensing and GIS have become increasingly important tools for archaeologists, as these systems link information to precisely calibrated physical locations, and integrate information drawn from multiple sources. Aerial photographs were first used in 1921 for archaeological applications in North America. This marks the birth of archaeological applications of remote sensing. The usefulness of satellite images and aerial photographs for identifying and analysing archaeological sites was recognised from the early days of aviation and the imagery is now available from an array of aircraft and high resolution satellite borne sensors, such as GeoEye-1, WorldView-1, Worldview-2, QuickBird, IKONOS, SPOT-5 and LIDAR that provide even greater potential for investigating archaeological sites.

The spectrum of sunlight reflected by the Earth’s surface contains information about the composition of the surface, and it may reveal traces of past human activities, such as agriculture, structures and roads. Differences in soil texture are revealed by fractional temperature variations. So it is possible to identify loose soil that had been prehistoric agricultural fields, or was covering buried remains. Some of the advanced sensors can detect irrigation ditches filled with sediment because they hold more moisture and thus have a temperature different from other soil. The ground above a buried stone wall, for instance, may be a touch hotter than the surrounding terrain because the stone absorbs more heat. Radar can penetrate darkness, cloud cover, thick jungle canopies, and even the ground. The utility of remote sensing is mainly for reconstructing historical geography as it provides confirmatory scientific evidences for the same, such as location and spread of palaeo-channels, palaeo-mudflats, settlements and agricultural area, etc.

The archaeologist must have the information about the location of sites. This information is itself can be valuable for studies in location analysis and
settlement pattern. Both oblique and vertical aerial photography have been used extensively for the identification of marks linked to the presence of buried archaeological remains. The different marks are generally known as soil, shadow and crop marks. Their characteristics strongly depend on vegetation cover and/or soil types. Following features are used to discover archaeological site locations from satellite data:

- Interpretation of soil marks
- Observation and interpretation of vegetation marks
- Delineation of anomalous landforms
- Interpretation of palaeo-channel and palaeo-mudflats
- Interpretation of coastal markings, strand lines, river mouth, etc.

**Soil Marks**

Marks on bare soil on cultivated land are useful in detecting certain areas of archaeological interest. Soil marks as shown in Fig. 14.11 can appear as changes of colour or texture of the surface provides the most important means by which ancient structures may be detected. The colour variations are due to the differences in the mineral and organic content of the soil. Partially obscured features may also be revealed. The positions of buried ditch fillings can be detected by variations in the water content of the soil, which also affect its colour. The various wavelengths regions of the electromagnetic spectrum can identify these variations in colour and texture, and can help to detect archeological sites.

![Fig. 14.11: Soil marks in the IRS data of Gujarat (source: Dasgupta et al., 2000)](image)

**Vegetation/Crop Marks**

*Vegetation/crop marks* are simply patterns in vegetation reflecting differences in the rate of germination, growth and ripening of a crop. These differences are caused by variations in the moisture and nutrient content of the soil. These variations in turn are caused by differences in the structure and profile of the subsoil, and can also be due to the presence of buried features. For example, natural crevices or man-made ditches in the underlying rock or subsoil are usually filled with deeper soils and will retain more moisture than the surrounding undisturbed ground.
Crops planted over a buried ditch will germinate quicker and grow more rapidly than the surrounding crop. Plants growing immediately over buried stone walls or pavements will tend to exhibit stunted growth or yellowing as compared to other areas. Organically rich sediments that may have in-filled a ditch or house depression will tend to exhibit enhanced growth. In dry weather conditions, they will grow taller and ripen later due to the extra reserves of moisture held in the buried ditch. The vegetation may be greener on the ditches and paler on the banks, which shows different moisture content of the palaeo-channels, palaeo-mudflats or coastal areas. In arid areas, the scanty vegetation may similarly show the positions of ancient remains. Shrubs may grow in favourable places at the base of ruined walls, and vegetation may be denser in ditches but almost absent on the banks. Soil and moisture changes within near-surface archaeological deposits together with surface vegetation patterns yield thermal variations recordable at the surface. Patterns in archaeological deposits can be expressed through minute temperature changes (e.g., 0.02° C) at the surface. Under proper conditions, airborne or ground-based thermal sensors can record these variations. Soil and plant growing over the archeological remains show following difference from their neighbouring soils and plants. These characteristics difference of plant and soils can be identified in remote sensing data.

- unusual growth pattern and biomass
- temperature variation
- moisture content, etc.

**Anomalous Landforms**

Occasionally, flood water outlines ancient earthworks. They may protrude from a sheet of water on low ground or the water may fill the hollows. Wetter or drier patches may form above the buried features producing darker or lighter marks which are usually described as damp marks and when the soil dries, they fade out.

Interpretation of soil marks, observation and interpretation of vegetation marks, delineation of anomalous landforms, interpretation of palaeo-channels and palaeo-mudflats and interpretation of coastal markings, strand lines, river mouth, etc., have all facilitated discovering new archaeological sites using remote sensing data.

To fully exploit the potential of geoinformatics for site detection, archeology needs to develop appropriate approaches defining the wide range of natural and social variables that are responsible for the behaviour of people in their geographical environment (Kuna, 2000). For this purpose, we have to develop a corresponding information system, in which fundamental geoecological parameters can be evaluated and visualised. During several field campaigns, the geomorphological parameters, the vegetation, the hydrology and rock types of the area of investigation can be studied and mapped. The locations of archaeological sites can be tracked down with GPS for subsequent integration into the information system. One of the examples is the study by Siart et al., 2008, who identified several remains of the Aegean Bronze Age, using geoinformatics as shown in Fig. 14.12.
Based on spatial information about the location of several archaeological sites, such as buildings, cemeteries and peak sanctuaries, loose sediment accumulation and areas filled with thick soils which are favourable for agriculture, and roads, potential archaeological sites were also identified as shown in Fig. 14.13.
Thus, remote sensing technology can play an important role in understanding the past in the context of available historical and ancient literature. Remote sensing data can successfully be used for building up historical records and changes that might have taken place on the surface of the Earth in the past. The data may also be used for upgrading historical atlases, which might have been prepared using only limited traditional knowledge, and as per the imagination of certain scholars.

The proper planning, use and application of remote sensing techniques in archeology will result in economic benefits through reduction of costs of survey. Remote sensing technique can increase efficiency, speed and data extraction at all stages of archaeological research. Aided by the broad, interdisciplinary scope injected by remote sensing data, archeology may, in the near future, transcend its traditional narrow focus.

Following kinds of remote sensing data are employed for archeological investigations:

- Aerial photographs
- Multispectral and Hyperspectral data
- Thermal data
- Microwave data
- Laser altimeters or light detection and ranging (LIDAR) data
- Ground-based geophysical methods such as Ground Penetrating Radar and Magnetometry, etc.

### 14.3.3 Business

In today’s business marketplace perspective, effective use of information is the important key to success. There are various business information parameters, like sales, customer inventory, potential market segmentation and demographic profile. Since most of this data has geographical location, it becomes important to use geoinformatics for analysing them spatially. This enables the corporate world to use spatial information to manage their business. By combining information, such as sales data, demographics, and competitor locations, with geographic data, such as census boundaries, territories, or store locations, this technology help to better understand market, customers, and competition. Following task can be performed using geoinformatics:

- planning for maximum coverage of sale regions
- to identify uncovered markets
- to find suitable sites for opening a particular kind of business/store
- planning optimum and shortest routes for delivery
- to identify areas where maximum sales can be achieved
- to act as Decision Support System and help in reducing risk in setting up business.

Using geoinformatics, all above informations can be brought together at common spatial platform that can reveal trends and patterns which are not apparent with tabular databases. The technology enables to better understand and evaluate data using various tools as well as software to display information. It is possible to generate a stacked layer maps where each layer
represents a unique phenomenon. Thereafter, it can again be superimposed and queried (Fig. 14.14).

Geoinformatics can be used in marketing, advertising, real estate, retail, etc., to

- analyse the markets
- model spending patterns
- analyse parcels of land
- optimise media campaigns
- create sales territories
- select future business sites.

A highly effective and meaningful marketing strategy can be developed in this vast and highly heterogeneous market using GIS tools for detection of potential zone, dealer and distributorship, zonation by market growth, etc. Fig. 14.15 depicts an example showing potential growth areas for business by number of consumers.
Marketing and Advertising

Marketing and advertising professionals have been aided by combining GIS software with demographic databases and consumer lifestyle segmentation systems to analyse distribution of the population. Consumer lifestyle segmentation systems are created based on the fact that people with similar incomes, backgrounds, lifestyles, and tastes tend to live near one another and have similar buying habits. Consumer lifestyle segmentation databases combine demographic, consumer behaviour, and geographic data to summarise complex consumer profiles in a way that is intuitive and easy to communicate. Consumer lifestyle data along with GIS mapping can be used to define market segments, optimise promotional programs, acquire new customers, and retain existing customers. Marketers can better understand their customers and prospects, where these customers or prospects are located, and target them with tailored messages designed just for the target segments.

Geoinformatics provides geo-demographic research and location intelligence to advise its clients on where to advertise and through which type of medium. Geoinformatics can help to map a client’s best customer’s locations along with consumer lifestyle data, which can show where these target customers live and which new markets they should target to find more customers.

Business can be innovative with GIS tools and consumer segmentation systems. These tools would allow them to increase subscribers, increase advertising revenue, and provide location intelligence to their advertisers for targeted marketing campaigns through a better understanding of the consumers who read their papers. The Washington Times mapped the location of each of its paid subscribers to identify the zip codes with the highest concentrations of subscribers. The market penetration analysis produced codes that the paper should target in the Washington-Baltimore metro areas. The subscriber records were then assigned a consumer lifestyle classification code to refine the readership profile. Nearly 46 percent of all paid subscribers fell into three consumer lifestyle segments. Analysts at the Washington Times discovered a great opportunity for new customer acquisition within eight additional segments that were similar to the three core lifestyle segments. One of its largest consumer lifestyle segments noted that residents preferred drinking coffee and owning their own espresso/cappuccino machines. The Washington Times placed additional newspaper boxes near coffee shops and coffee repair shops in these zip codes, which resulted in an increase in the number of newspapers sold (ESRI, 2005).

Transportation/Logistics

Geoinformatics can be beneficial to the transportation and logistics industry to improve delivery schedules and to reduce shipping costs associated with delivering products, fleet management, and vehicle tracking. GIS provides network algorithms to compute optimal routes along a transportation network saving both time and money. Accurate street data are critical for supporting geocoding and routing functionality in a GIS application. In vehicle navigation and mapping system that leverages on-board GPS, satellite, and terrestrial data communication are also helpful in route planning for transportation.
Real Estate

The main motto of the real estate business is location and geoinformatics is best suited for providing locational information. Real estate professionals, especially restaurants and retailers, use GIS for market analysis, store location research, store assessment, market cannibalisation, and market optimisation studies. Market analysis involves studying geographic areas to determine if there is a large concentration of potential customers and possibly weak competition to identify areas for an expansion opportunity. Store location research is the process of identifying the ideal parcel of real estate to build a new store. Store assessment concerns an evaluation of the existing stores held by a company. Market cannibalisation is the process of when a new store is opened, how its sales will affect sales from existing stores and competitors because patrons of other stores will alter their shopping patterns and shop at the new store. Market optimisation is the process of identifying gaps in a market where a new store could serve an existing population base that the retailer is not currently serving.

Financial Services

The Financial services industry has benefited from geoinformatics for business processes, such as branch site location and target marketing of specific financial products to customers. Financial service organisations have large, rich databases of their customers that contain geographic elements. Customer information can be geocoded, and the location of the bank’s customers can be displayed on a map for analysis. Financial service companies were among the first companies to develop Web based GIS applications to display locations of Automated Teller Machines (ATMs). Visa and MasterCard pioneered the development of Web-based GIS locator applications that allowed their customers to search for the nearest ATM based on their location. MasterCard owns the Cirrus ATM network with over 900,000 ATMs in 120 countries. MasterCard deployed an online ATM locator on its Website, Mastercard.com, in 1997. The ATM locator Website has been integrated with MasterCard’s phone-based AT locator. The locator service gives customers ATM information by phone, the Internet, and wireless technology, driving profit-generating traffic to participating banks. The successful launch of online locator applications has now proliferated to the business sector overall, as many retailers have online store locator applications built into their Websites to help customers locate the store closest to them.

It has been understood from the above discussion that geoinformatics has grown and permeated into business applications from its roots in the public as well as private sector. The abundance and breadth of application will continue to develop with technological advances. Declining prices for hardware and data storage while increasing functionality from GIS software products will make geoinformatics more affordable and user-friendly for end-users. As this technology continues to grow into larger deployments and has a wider adoption among organizations, it will become increasingly important for companies who are not familiar with this technology to understand the costs and benefits of GIS implementation. The examples presented above demonstrate that companies in the public and private sector can earn higher profits by reducing costs, increasing revenue or improving production as a result of implementing geoinformatics.
Check Your Progress II

1) List out the features to discover archaeological site locations from satellite data.

............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................

2) Point out the advantages of geoinformatics in business.

............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................
............................................................................................................................................................

14.4 GEOINFORMATICS IN HEALTH

Health is considered as being a geographic issue, where geoinformatics can be useful as an important tool in health services to analyse the geographic elements of health and human services science. It can be used for the analysis of disease vulnerability, health patterning and clinical management. GIS is an excellent means of collecting, updating and managing health data. It serves as a common platform for convergence of multi-disease surveillance activities. GIS plays a vital role in strengthening the whole process of epidemiological surveillance information management and analysis. It provides a means for visualising and analysing epidemiological data, revealing trends, dependencies and inter-relationships that would be more difficult to discover in tabular formats. GIS also allows for association of surveillance data with background information, like demographic data, administrative boundaries, hydrological data and vegetation type. It is a powerful tool to present disease information to the level of individual occurrence and also can be used to display geographical distribution and pattern of disease and its prevalence and incidence. Thematic maps can be generated to denote the intensity of the disease or vector. GIS keeps track of the geographical locations of service providers, customers, resources, and health plans and programmes. It permits dynamic link between data bases and maps so that data updates are automatically reflected on the maps. Similarly, remote sensing data helps to identify and track environmental characteristics and changes useful to the study of diseases. Satellite data can be used to monitor vegetation, land use patterns, surface waters, soil moisture and quality, built-up area and climate changes. It may be integrated with other types of data and information within a GIS. The technology allows users to extrapolate local level measurement to regional scale and, therefore, to discern spatial and temporal patterns that could not otherwise be seen. Various researchers show that geoinformatics has been used to map population with
Other Applications

infectious diseases, such as Malaria and AIDS as well as children with malnutrition. These studies provide the clues to spread the disease further and also help to adopt appropriate measures to control the disease. The display of the data pertaining to the study area provided an overview of the disease incidence and health condition in relation to geographically and ecologically important entities.

Now, let us understand the use of geoinformatics in health related studies.

Malaria

Malaria is still a major public health problem. In India, nearly 2-3 million cases occur every year with about 1000 deaths cases. Control of malaria requires case detection and treatment of affected individuals and for curbing of malarial transmission, control of mosquito vectors is undertaken. Vector control requires knowledge of the ecology of breeding and resting habitats and behaviour of various species of mosquitoes. The life of mosquitoes is influenced by variations in climatic conditions, and hence, there is diversity in the distribution and habitats of different vector species. Periodical surveys are essential for arriving at any conclusion for developing vector control strategy. Routine entomological surveys over vast geographic areas are impractical, time consuming and expensive and, therefore, are confined to limited areas.

Geoinformatics can be used as a helpful tool for the surveillance of habitats, densities of vector species and even prediction of the incidence of diseases and hence, it has opened up new vistas in the epidemiology of malaria and other vector-borne diseases. GIS facilitates the integration of quantitative malaria determination and control data with data obtained from maps, satellite images, and aerial photos. Frequently, socio-economic data and qualitative information on health facilities have a spatial basis, and can also be integrated with malaria data from the same area. The integration of operational and logistical data for malaria control program planning with epidemiological data will serve to strengthen both the epidemiological analysis, and the planning and execution.
of control programs. There are various ecological parameters viz. vegetation types, surface water, flood conditions, soil moisture, climate, etc. (Fig. 14.16), that are associated with malaria disease and can be monitored through remote sensing techniques.

Information about mosquito breeding habitats, vegetation with mosquito density, source of blood meal such as livestock can be derived from remote sensing data. Masuoko et al., 2003 used IKONOS and Landsat TM data for one such study as shown in Fig. 14.17.

They found out that the two data types could be used together in planning and implementing a malaria control program. Landsat, in conjunction with information on the location and number of cases in a GIS, could be used in the first stages of planning to estimate the costs and to plan the location of the spraying. The size of the area to be treated could be adjusted within the GIS depending on the budget available for the control program. Once local treatment areas are selected, IKONOS imagery could be used to locate habitats and track the local spraying efforts. Worldwide, mosquitoes breed in a wide variety of habitats. Many mosquito habitats, such as small marshes and streams can be mapped only on high spatial resolution data, which would be very useful for studying and controlling malaria and other mosquito-borne diseases.

Fig. 14.17: IKONOS image with buffer zone around Camp Greaves and larval sampling sites (source: Masuoka et al., 2003)

The role of environmental factors viz., temperature, rainfall and relative humidity in the epidemiology of vector-borne diseases is well known. Meteorological data obtained from various satellite images, i.e. Advanced Very High Resolution Radiometer (AVHRR) sensor on polar orbiting meteorological satellites of National Oceanic and Atmospheric Administration
(NOAA), MODIS, ASTER, Meteosat, etc., provide data about rainfall, vegetation state (NDVI, the reliable indicator of rainfall), land surface temperature (LST), and soil and vegetation moisture contents, etc. All these parameters are vital for detecting vector borne disease. Fig. 14.18 shows prediction of the distribution of various mosquito species for Africa.

There are various climatic and non-climatic determinants of malaria transmission intensity as stated below:

- temperature
- rainfall and humidity
- seasonality of climate
- altitude and frost
- soils and agricultural landuse
- man-made changes to the environment
- availability of permanent breeding sites
- population, settlement and urbanisation
- malaria control interventions.

All these parameters can be incorporated together in a GIS platform, and can be analysed and interpreted using geoinformatics. Therefore, we can develop an information system using geoinformatics technology, as depicted in Fig. 14.19, to identify the areas of risks and to assist decision makers in directing resources and strategies for better management and control of malaria disease.

Fig. 14.18: The predictions of the distributions of *Anophelesgambiae s.s.*, *Anophelesarabiensis*, *Anophelesmerus*, *Anophelesmelas* and *Anophelesquadriannulatus* have been made for Africa between latitudes 18°N–30°S using data from NOAA-AVHRR and Meteosat satellites (source: Rogers et al., 2002)
Geoinformatics is relevant to healthcare as it can establish relationships between many complex health factors, like population, environment, economic and social factors, and therefore can generate spatial information system (SIS) and provide location based services (LBS). LBS is useful as people need information related to their location and position. Such information is especially important when there is an emergency situation. Therefore, it can be concluded that the geoinformatics with the support of health data can be used to model for disease surveillance and control. These also help us to understand changing environment/climate scenarios and its impact on public health.

Check Your Progress III

1) List out the climatic and non-climatic determinants of malaria transmission intensity.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

14.5 GEOINFORMATICS IN FORENSIC SCIENCE

In forensic science, geoinformatics can be used to display and analyse patterns in maps showing crime scene locations, transportation routes, and potentially important forensic information, such as bedrock or soil types. As we are aware that forensic investigations concern locating, identifying, collecting, and cataloging physical evidence for the purpose of presenting it in court. Therefore, one aspect of forensic investigations concerns locating secret evidence, which is often concealed in the subsurface. This task is typically
Other Applications

Remote sensing methods, which are non-destructive, are currently being applied with promising results in forensic investigations. Some of the promising methods include infrared, magnetics, electromagnetics, and ground penetrating radar.

Remote sensing methods when properly applied can provide the forensic investigator tremendous savings in time and cost in the search for physical evidence. The forensic investigators must be educated to understand that there is no remote sensing method that will consistently find a body or physical evidence. These methods locate anomalous areas, and the cause of these anomalies will only be fully understood upon examination by others.

The use of geographic information to help identify suspects is known as geographic profiling. Using geographic profiling, it has been assumed that most offenders commit crimes close to their homes; crime patterns follow a distance-decay function (the number of crimes committed decreases with distance from the offender’s home). Juvenile crimes are more highly clustered than adult crimes because juveniles lack easy access to transportation and the distance travelled varies according to the kind of crime. The output of geographic profiling programs consists of hit score maps that use coloured contour maps or three-dimensional surface maps to indicate the likelihood that a perpetrator lives in a certain area. Hit score maps can be combined with additional information, for example, the addresses of known offenders or other suspects, and displayed using GIS software. Because of the amount of information required, geographic profiling works best in large cities where many crimes are committed. It can also require officials to recognise that a series of crimes are related and have likely been committed by the same person.

Using geoinformatics, crime mapping can be done to identify the offenders and offending as shown in Fig. 14.20. GIS software is also used by many agencies for so called hot spot analysis, i.e. recognition that the crime incidents are clustered in small areas, in which the locations of crimes such as murder, burglary, and auto theft can be plotted on maps as shown in Fig. 14.20 – Fig. 14.22.

Fig. 14.21 and Fig. 14.22 outline crime statistics in the Washington, D.C. area. The map (Fig. 14.21) shows density scales of three different crimes viz., sex abuse, homicides, and burglaries. Population density map is also included to help relate the crime rate to population figures. The map (Fig. 14.22) shows the amount of crimes in relations to police station locations. Buffers are used to determine distances within 0.5, 1, and 2 miles. These maps are useful in determining a need for increased manpower and more substations in high crime areas. The maps are very easy to interpret and would serve well in a decision making process. Various information, such as incident reporting (address collection and validation) and address matching/geocoding, i.e.
assigning map coordinates to incident record can be generated using GIS technology. Crime mapping using geoinformatics not only shows where crimes occur but it can also:

- identify and highlight suspicious incidents and events that may require further investigations
- identify where offenders and victims live and analyse how offenders travel to the crime/incident
- identify emerging neighborhood issues
- profiling the characteristics of areas and how these contribute to the causes of crime/incidents
- identify why crime/incidents may have occurred in one location and not other

Fig. 14.20: Crime mapping using geoinformatics technology showing crime hot spots in a part of London, UK. (source:http://www.met.police.uk/foi/pdfs/priorities_and_how_we_are_doing/archive/2003/hackney_crime_and_disorder_audit_2001.pdf, retrieved on June 15, 2011). The numbers in the bottom right corner represent the number of allegations recorded within 150m of point of interest

- enhancing the implementation of various policing methodologies to reduce overall crime and disorder
- educating the public with visual information to clarify crime concerns and enlist community action and
- providing tools and techniques to capture crime series and forecast future crime occurrence.
Crime maps can be useful to provide various services, which can support a number of fundamentals police functions, as stated below:

- responding to calls for service to reduce ambiguity in responding to scenes and allows the reduced response time
- collecting data at crime scene locations
- targeting responses and deploying patrols
- analysis and the generation of intelligence products, which includes tactical analysis i.e. who, what, where, when
- information sharing with partnerships
- reassuring the public.


![Crime maps showing the relationship of crime rate to population](source: DLEPTIEN: GIS BLOG; www.dleptienblogspot.com, retrieved on June 5, 2011)
When combined with GPS receivers and transmitters, GIS software can be used to track the movements of criminals released on parole or probation to determine if they are related to newly reported crimes. GPS receivers installed in police vehicles can likewise transmit their locations and help to more efficiently dispatch law enforcement officials in the minutes after a crime has been committed.

### 14.6 SUMMARY

The science of geoinformatics has emerged as one of the most fascinating fields over the past three decades. In this unit, we have studied that:

- In today’s world geoinformatics is becoming an essential tool for planers and decision makers to meet challenges in solving many problems in various fields, such as agriculture, social sciences (demography, archeology, and business), health, forensic science, etc.

- In agriculture, geoinformatics is being utilised for geoinformatics crop identification and inventorisation, crop area/acreage estimation and production forecasting, cropping pattern and cropping system analysis, crop stress detection, etc.

- Geoinformatics can be used to generate thematic maps of demographic and socio-economic structure.

- Archeological sites can be identified on remote sensing data based on soil marks, vegetation marks, anomalous land forms, etc.

- Geoinformatics can also be used to manage business by identifying uncovered markets, finding suitable sites for a particular business activity and act as decision support system for reducing risks involved.

- In health care sector, geoinformatics can help in generating spatial information system for identifying vector borne disease prone areas, predicting disease transmission to monitor and control them and manage emergency situation.

- In forensic science, geoinformatics can be used to identify crime prone areas, crime hotspots and to track the movements of criminals, etc.

### 14.7 UNIT END QUESTIONS

1) Write down the applications of geoinformatics in agriculture.

2) Discuss the scope of geoinformatics for social sciences.

3) Discuss the role of geoinformatics for health related studies.

4) Write down the applications of geoinformatics in forensic studies.

### 14.8 REFERENCES


14.9 Further/Suggested Reading


14.10 Answers

Check Your Progress I

1) Crop inventory, crop condition assessment, crop production and yield estimation.

Check Your Progress II

1) a) Interpretation of soil marks,
   b) Observation and interpretation of vegetation marks,
   c) Delineation of anomalous landforms,
   d) Interpretation of palaeo-channel and palaeo-mudflats,
   e) Interpretation of coastal markings, strand lines, river mouth, etc.
2) a) Planning for maximum coverage of sale regions.
   b) To identify uncovered markets.
   c) To find suitable sites for opening a particular kind of business/store.
   d) Planning optimum and shortest routes for delivery.
   e) To identify areas where maximum sales can be achieved.
   f) To act as Decision Support System and help in reducing risk in setting up business.

Check Your Progress III

1) a) Temperature
   b) Rainfall and humidity
   c) Seasonality of climate
   d) Altitude and frost
   e) Soils and agricultural landuse
   f) Man-made changes to the environment
   g) Availability of permanent breeding sites
   h) Population, settlement and urbanisation
   i) Malaria control interventions

Unit End Questions

1) You should include all the following points to answer the question (refer to section 14.2); Crop Identification and Inventorisation, Crop Area/Acreage Estimation and Production Forecasting, Cropping Pattern, Cropping System Analysis and Crop Stress Detection.

2) Section 14.3 would help you to answer this question, where you should write in brief about the application and advantages of geoinformatics in demography, archaeology and business.

3) Section 14.4 would help you to answer this question.

4) Section 14.5 would help you to answer this question.
• **Ancillary data**: Any data which is accessory or related to the main topic and not of remote sensing origin.

• **Aquatic Ecosystem**: An aquatic ecosystem is an ecosystem located in a body of water.

• **Crop Maps**: Crop area maps provide crop identification and detailed location information within the specific region under analysis.

• **Crime Hot Spot**: Hot spot is defined “as small places in which the occurrence of crime is so frequent that it is highly predictable, at least over a 1-year period.”

• **Crime mapping**: Crime mapping is a law enforcement tool, which allows personnel to represent crimes visually on a map or grid of a region. By organising crimes this way, law enforcement personnel can identify patterns, areas of concern, and other information of interest which they can use in order to be more effective.

• **Ecosystem Management**: An approach to natural resource management which aims to sustain ecosystems to meet both ecological and human needs in the future.

• **E-Governance**: A network of organisations to include government, nonprofit and private-sector entities; in e-governance there are no distinct boundaries.

• **Land cover**: It refers to the vegetative or non-vegetative characteristics of a portion of the Earth’s surface.

• **Forensic science** (often shortened to **forensics**): Forensic science is the application of a broad spectrum of sciences to answer questions of interest to a legal system. This may be in relation to a crime or a civil action.

• **Geostationary orbit**: An orbit around the Earth whereby a satellite travels in the same direction and completes the orbit in the same time as the Earth completes a revolution. Hence, the satellite maintains a fixed position relative to the surface of the Earth.

• **Geosynchronous orbit**: An orbit around the Earth whereby a satellite travels in a general west-to-east direction and completes the orbit in the same time as the Earth completes a revolution.

• **Land use**: It describes some human activity on the Earth’s surface.

• **Land use classification**: A classification providing information on land cover and the types of human activity involved in land use. It may also facilitate the assessment of environmental impacts on potential or alternative uses of land.

• **Malaria Information System**: It includes a spatial component based on GIS, which is being customised to minimise end-user skill requirements and optimize access to the different data sets.
Scope and Applications of Geoinformatics

- **Mudflate**: Mudflate is relatively flat area of fine sediment along a shore which is alternatively covered and uncovered by the tide. It may also be covered by shallow water.

- **Paleo Channel**: Paleo refers to old or ancient. Paleo channel is a channel which existed in past but has disappeared at present.

- **Planning**: Preparing a sequence of action steps to achieve some specific goal.

- **Planning Support System (PSS)**: It consists of a wide diversity of geoinformation tools that are dedicated to support public or private planning processes at any particular spatial scale and within a specific planning context.

- **Radiometer**: It is a device for measuring the radiant flux (power) of electromagnetic radiation.

- **Spatial planning**: Methods used by the public sectors to influence the distribution of people and activities in spaces of various scales. Spatial planning includes land use planning, urban planning, regional planning, transport planning and environmental planning.

- **Spectrometer**: It is an instrument used to measure properties of light over a specific portion of the electromagnetic spectrum.

- **Spectroradiometer**: An instrument for determining the radiant energy distribution in a spectrum combining the functions of a spectrometer with those of a radiometer.

- **Terrestrial Ecosystem**: All living and non-living elements of a land-based environment and the relationship between them.

- **Urban Area**: An area characterised by higher population density and vast human features in comparison to areas surrounding it. Urban areas may be cities, towns, but the term is not commonly extended to rural settlements such as villages and hamlets.

- **Urban or municipal infrastructure**: Hard infrastructure systems generally owned and operated by municipalities, such as streets, water distribution and sewers. It may also include some of the facilities associated with soft infrastructure, such as parks, public pools and libraries.

- **Urban Sprawl**: Urban sprawl is the outgrowth along the periphery of cities and along highways.