ENVIRONMENTAL GEOSCIENCES

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Lecture-62

Applications of Remote Sensing and Applications of GIS

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the module twelve, that is Remote Sensing and GIS Applications, Impact of Climate Change on Water Resources. We have already completed the lecture one and lecture two. Today we are discussing the lecture three, that is Application of Remote Sensing and Application of GIS. In this lecture, the important concepts we will cover like application of remote sensing and application of GIS.

Now, first we will discuss about the application of remote sensing. With the launching of Landsat 1 in nineteen seventy two, remote sensing technology has opened new vistas in the field of planning, surveying, monitoring and management of natural resources. It has provided easier techniques to undertake effective and efficient mapping of land, water, soil, forest, agriculture, urban area growth, floodplain mapping, crop acreage estimation, etc. Detailed information can be extracted from satellite data on a temporal basis and can be used as an input into geographic information system i.e. GIS for effective decision making. In order to carry out mapping activity using remote sensing data, the identification of features or objects is based either on the principles of visual interpretation techniques or digital image analysis.

In this lecture, some important application and case studies have been discussed in order to provide an insight regarding the methodology and approach to be adopted for different studies. Some of the applications as discussed below for understanding the processes involved in application of remote sensing technique in a particular project. The applications are in the field of land use and land cover mapping, crop identification, groundwater mapping, urban growth studies, floodplain mapping, wasteland mapping and district level planning. Now, one by one we will understand these applications. The first application is land use and land cover mapping.

Land is one of the critical natural resources on which most developmental activities are based. For success of any planning activity, detailed and accurate information regarding the land cover and the associated land use is of paramount importance. In order to undertake a proper, systematic and structured land cover land use mapping, it is important to identify land cover land use change classes, land cover land use classes as per a classification scheme such as USGS Land Cover Land Use Classification Scheme or Cowardin Wetland Classification Scheme or develop a new one. A study on land use and land cover for a part of Haridwar district was carried out for the area lying between seventy eight degree seven minute and thirty second east and seventy eight degree sixteen minute fourteen second east longitudes and thirty degree north and thirty degree eight minute twenty three second north latitudes covering an area of nearly two sixty square kilometer. You can see the flowchart of methodology adopted also.

We have taken the list three pan images, then initial statistics was done, then contrast enhancement was done, then registration, then the ground data, whatever collected was put here for the supervised classification, and then the classified image has been produced, and then we have done the accuracy assessment. The area is primarily covered with forest, vegetations, built-up, water and sand IRIS-1C LISS-III image shown in the plate seven point one of the slides of April third two thousand was used along with pan image in plate seven point two of the same date. The methodology adopted has already discussed as per the flow chart of methodology. On the basis of field visits, eleven classes were identified. These classes are thin forest, medium forest, dense forest, fallow land, shrubs, open land, shallow water, wet sand, dry sand, built up area and deep water. So eleven different classes were identified.

Now here you can see the IRS-1C LISS-III false color composite image and IRS-1C Pan image. The two different images of the area has been prepared. Training data were identified and extracted using ERDAS imaging software which has been shown in the plate seven point three. Based on the training data statistics, it was found that the average transformed divergence was nineteen ninety nine, which is an indication that all the classes had good spectral separability. Two classifiers namely minimum distance to means and maximum likelihood were used for classifying the land use and land cover of the area.

The classified image was tested for accuracy and it was found that the minimum distance to mean classifier gives an overall accuracy of ninety percent while maximum likelihood classifier gave an overall accuracy of ninety four point four four percent with kappa coefficient of zero point eight nine and zero point nine four for minimum distance to mean and maximum likelihood classifier respectively. Second application is in the crop inventory studies. Remote sensing has proved to be an ideal data set for making crop inventory. Typical spectral reflectance of a crop shows absorption due to pigments in the visual region, that is zero point four to zero point seven micrometer. High reflectance in the near infrared region because of internal cellular structure of the leaves and absorption at one point four five micrometer, one point nine five micrometer and two point six micrometer spectral bands due to water content.

Spectral response of a crop canopy is influenced by the leaf area index and percent ground cover, growth stages, differences in culture practices, stress conditions and canopy architecture. Background soil water is an important influencing factor. Each crop has its own architecture, growing period, etc., thus enabling discrimination through remote sensing data. If there are two crops with similar spectral signatures on a given data, that is confusion crops, multi-data may be used to discriminate them. Vigour of the crop is responsible for high absorption in the red and reflectance in the near-infrared. It has been observed that the ratio of near-infrared to red radiance is a good indicator of the vigour of the crop.

Some of these properties are utilized in crop identification, yield forecasting and crop condition assessment. Then third application in the groundwater mapping. Groundwater occurs at any place on the earth is not a matter of chance but a consequence of the interaction of climatic, geologic, hydrologic, physiographic and ecological factors. The groundwater in India occurs mainly in three types of geological formations that is unconsolidated, semi-consolidated and consolidated. Search for groundwater is confined to the most promising zones in terms of porosity and permeability.

Porosity, the volume of available pore spaces in rocks, determines the amount of water which can be held in storage. And permeability determines the ease with which water moves through the pores and fractures and hence can be extracted. Remotely sensed data provide quick and useful baseline information on the factors controlling the occurrence and movement of groundwater like geology that is lithology, structure, geomorphology, soils, land use, land cover, etc. A systematic study of these factors lead to the better delineation of prospective groundwater zones in a region. Such prospective zones identified from a satellite imagery are normally followed up on the ground through detailed hydrogeological and geophysical investigations before actual drilling is carried out for exact quantitative assessment and exploration.

The usefulness of the satellite data in identifying linear features such as fracture faults that are usually the zones of localization of groundwater in hard rock areas, and certain geomorphic features such as alluvial fans, buried channels etc which often form good aquifer is well established. The general keys for detection of groundwater aquifers relate to identification of springs, seeps and phreatophytes indicating presence of shallow water table conditions, differentiation of vegetation that are closely related to depth and salinity of groundwater, and location of monitoring of groundwater systems under stress. Groundwater potential maps using Landsat data in hardrock areas have been prepared in India using either the geomorphology as the base or through an integrated approach of studying various themes, depending upon the complexity of control over the groundwater occurrence and movement. A major thrust to the utilization of IRS 1A data on a national level was provided by the National Drinking Water Mission, one of the technology missions launched by the Government of India in nineteen eighty six. The primary objective of NDWM was to provide potable drinking water to all the villages that is forty litres per capita per day and an additional thirty litres per capita per day for cattle in desert areas.

It was stipulated that the source should be located within a distance of one point six kilometers from a village. The methodology adopted for the preparation of district-wise hydro-geomorphological maps on one is to two fifty thousand scale as shown in the figure comprise the following six steps. The steps are Data procurement first, second the base map preparation, third the preliminary interpretation, fourth the ground checking, fifth the final interpretation and sixth the final map preparation. So here you can see the different steps for first is the acquisition of satellite data that is FCC print at one is to two thousand scale, then base map preparation, then preliminary interpretation of enlarged image, then collateral data also adding, then ground checking, final interpretation, and then preparation of final hypergeomorphological maps. So in this way, we can find out the groundwater potential zones by the application of remote sensing.

Next is the urban growth studies. Urban development and migration from rural to urban areas are common global phenomena. The expansion of urban area is a great problem and if not tackled properly can lead to haphazard urban growth. Remote sensing data with its unique characteristics of synoptic view, repetitive coverage and reliability has opened the immense possibility for urban area mapping and its growth. A study of Dehradun city has been carried out using existing guide maps and satellite data.

As you can see in the table also, the different maps, toposheets and the satellite imageries list to IRS LISS, IRS 1D PAN, IKONOS. So these digital data and topographical sheet and some guide map of Dehradun was taken for the carrying out the urban growth studies of Dehradun districts. Now you can see the different land use map, different land uses of the Dehradun and its surrounding areas for the year nineteen forty five, nineteen sixty five, nineteen eighty eight, nineteen ninety nine and two thousand one in plate number seven point six with the application of remote sensing. With the help of these land use maps, the urban expansion of Dehradun during the period of nineteen forty five to two thousand one has been studied and shown in the plate number seven point seven. It shows the different types of land use changes during the period nineteen forty five to two thousand one while the adjacent table A shows the different types of land use changes during the period nineteen forty five to two thousand one and the table B is showing the land use change matrix for the same period.

The different parameters of the land use are urban areas, then agriculture, forest area, then scrub areas, then rivers. So in this way, from nineteen forty five to two thousand one, the land use map has been prepared. It may be noted that in the case of Dehradun city, the major urban growth has taken place on barren land that is twenty two square kilometer area followed by agricultural land which is eleven square kilometer area. One of the encouraging aspects of urban growth in Dehradun is that very little forest land has been encroached. However, there has been a continuous encroachment along the length of the rivers Rispana Rao and Bindal Rao passing through the city.

The settlements in this region are under high risk of damage during floods. Plate eleven point one is illustrating the change in land use from nineteen forty five to two thousand one. Next application of remote sensing is the flood plain mapping. Floods have become an unfailing event almost every year in the Indian states of Assam, Bihar, Uttar Pradesh, North Bengal, etc. Millions of hectares of land are inundated, especially by Brahmaputra, Ganga and their tributaries, resulting in damage to crops worth millions of rupees.

It is recognized that floods cannot be totally controlled, but with suitable basin-wise flood management measures like construction of detention storages with or without the flood storage, embankments and drainage channels, anti-erosion, river training and protection works, watershed afforestation and soil conservation, flood hazard zoning, flood forecasting, disaster preparedness, etc., the flood damages can be vastly minimized. For implementing these measures and providing flood relief, it is necessary to acquire, besides historic conventional data, latest and reliable information about extent of flood in undated areas, duration of flooding, river configuration during and after the floods, areas of silt deposits and shoals, drainage congested areas and blocked outfalls, watershed characteristics and vulnerable areas of bank erosion etc. It is here that remote sensing has more efficiently and effective role over ground based survey methods that are arduous, time consuming and beset with limitations. In fact, flood mapping using remote sensing is considered as one of the important applications of remote sensing technology in real-time operational mode since maps on one is to fifty thousand scale can be prepared within a week's time from the date of acquisition of the satellite image.

Both visual interpretation and digital analysis techniques have been adopted in flood studies. In the digital analysis, the low-radius evaluation of water bodies in the near-infrared region is done by scanning of pixels as water and no water classes, which gives an accurate distribution of the water features. Subsequent analysis of water pixels could provide further information about quality, depth, sediment loading, etc. Visual interpretation being fast and less expensive has been most preferred approach. So floodplain mapping using satellite data in order to carry out floodplain analysis, certain flood susceptibility indicators as visible on single band satellite imagery can be identified.

These are upland physiographic, water characteristics, such as safe drainage density, etc., degree of abandonment of natural levees, occurrence of stabilized sand dunes on river terraces, channels configuration, back swamp areas, soil moisture availability, soil difference, vegetation differences, land use boundaries, agricultural development, flood control measures on the flood plain. Next application of remote sensing is wasteland mapping. National Wasteland Development Board, Ministry of Environment, Forest and Climate Change, Government of India, describes wasteland as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and the land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. Waste lands are known to result from inherent or imposed disabilities related to location, environment or soil as well as financial and management constraints. In India, there is an urgent need to restore the waste lands to their production potential in order to meet the demands of increasing population and other developmental activities.

Although several agencies have estimated the total extent of wastelands and their figures vary considerably. Their definition of wastelands were equally variable. Reliable information on location, nature, and extent of the different wastelands on a large scale is essential for launching a program on wasteland development. Remote sensing has provided a major technological breakthrough in the method of acquiring information on wastelands and other natural resource. Remote sensing from space with its unique characteristic of synoptic view, repetitive coverage, and reliability has opened immense possibilities for resource mapping and monitoring, resource targeting, and management to achieve optimization in resource utilization and conservation. A task force was identified by the Planning Commission nineteen eighty six to evolve a suitable baseline classification system.

The classification system evolved and approved by the Planning Commission comprises of the following categories. The categories are Gullied and Ravenous land, upland with or without scrub, waterlogged and marshy land, shifting cultivation, sandy that is desert or coastal, mining industrial wastelands, degraded pastures, grazing land, degraded land under plantation crops, barren rocky stony waste seed rock areas, land affected by salinity alkalinity, underutilized degraded notified forest land, steep sloping areas and snow covered or glacial areas. Next application of remote sensing is the district level planning. District level planning is an integrated planning aimed at all-round development of the area. The development plan should meet the basic needs and aspirations of the local people within the overall framework of the multi-level planning.

Development of remote sensing techniques in the last three decades and their proven application in the efficient survey and mapping of natural resources have provided quick assessment of natural resources in context of district level mapping, in context of district level planning. Based on application of IRS 1A and GIS, a methodology has been developed by the scientists of Department of Space for district level planning. This methodology adopts the guidelines of planning commission working groups on district and block level planning and provides the resource data integration from available sources and socio-economic and demographic database devised by the national informatics centers under its DISNIC programme. Here you can see the detailed flowchart of the district level planning objectives that is economic growth, basic needs and ecological balance and the informations required in terms of natural physical resources, contemporary technology and socio-economic and demographic data. So this is in continuity with the previous slides where all the data are required and then we are coming for the implementation and then evaluation and lastly the feedback. So these are the methodology for integrated district level mapping.

Now we will discuss the application of GIS. GIS application involves practical aspects of designing and managing a GIS for a project. Good project design and management are essential for producing useful and effective GIS application. Design techniques help in identifying the nature and scope of a problem at defining the system requirements, quantifying the amount and type of necessary data, and indicating the data model needed and the analysis required. Delivering a completed project on time and ensuring its quality are a part of the management techniques.

In general, a GIS application may include problem identification, designing of a data model, project management, identifying implementation problems, and project evaluation. First is the problem identification. The first step towards the GIS application is to identify the problem that has to be addressed by the GIS. There can be two approaches. First approach is creating a rich picture.

Second is developing a root definition. So now let us understand rich picture. A schematic view of the problem to be addressed in a project is referred to as rich picture. This schematic view presents the main components of the problems in a project as well as any interactions that exist and helps to organize the ideas that arise during discussions between, for example, a property dealer and a property buyer. A rich picture may adopt symbols to indicate certain activities.

For example, cross swords are used to express conflicts, eyes to represent external observers, and speech bubbles to indicate personal or group opinions. Now second is the root definition. Different users may have different views of problem. The root definition is a view of problem from a specific perspective. The system developer must arrive at a common root definition considering all viewpoints.

This helps others to evaluate and understand the way GIS is being constructed. In designing a GIS application, it should be ensured that it addresses to a range of needs and solutions. Now, soft system approach. The soft system approach originally developed by Checkland nineteen eighty one to problem identification is a method of addressing unstructured problems. A problem is said to be a structured problem when a definite location is identified for a particular problem, whereas in unstructured problem, instead of definite location, a neighborhood is known.

Soft systems approach depends on the context or worldview from which the problem is being considered. Designing a data model. Data model has different meaning in different context. In the context of design and management of a project, it can be viewed as consisting of conceptual model and physical model. In a conceptual data model, elements of spatial form and processes are included in the rich picture.

The detailing to represent the conceptual model within the computer is done through physical data model. It includes details about the spatial data model, the data structure, and the analysis scheme. GIS application requires a well-planned data modeling to meet out expectations of GIS users. One way of creating a conceptual data model is to identify clearly the elements of data model that is the entirety their states and their interrelationships and present them in the form of flowcharts using standard symbols that illustrate different aspects of the model. The advantage of using a flow chart is that it illustrates all the stages involved modeling of the problem from data requirements to output requirements. To create physical data model, additional data details are required that describe modeling of special entities, their associated attributes, and interrelationship of entities in the computer.

In other words, in physical data model, the emphasis is on developing a model of the relationships between the entities, and it is referred to as analysis of the scheme. Cartographic modeling is one of the most frequently used techniques of designing an analysis scheme. Cartographic modeling is an acceptable methodology for processing of spatial information. It is a generic way of expressing and organizing the methods by which spatial variables of spatial operations are selected and used to develop a GIS data model. Cartographic modeling involves geographic data processing methodology that views maps as variables in algebraic equations.

In map algebra, the symbols are assigned numeric attributes of map elements or even whole maps instead of x, y, z as algebra. Using mathematical operations such as addition, subtraction, multiplication, and division, new numbers are generated by interaction of numbers assigned to symbols in an equation, producing new maps by use of specific spatial operations. The various stages in the development of cartographic model consists of identifying the required map layers or spatial data sets, using natural language to explain the process of moving from the data available to a solution, drawing a flowchart representing graphically the process, and annotating the flowchart with the commands necessary to perform these operations within GIS being used. Now, project management. A good project management is an essential prerequisite for a success of a GIS project.

After constructing the data model, the GIS must be implemented and in many cases integrated into a wider information strategy of an organization. An information technology project can be managed by different approaches. The commonly used approaches are the system lifecycle and prototyping. The system lifecycle is a linear approach used to manage the development and implementation of an information technology system. It provides very structured framework for the management of a GIS project.

In this approach, also referred to as waterfall model, the outputs from the first stage of the process are used in the second and the output from the second stage is in the third stage and so on. Various stages may be feasibility study like system investigation and system analysis, system design and implementation, review and maintenance. Though the system lifecycle approach is a popular management tool for information technology projects, it has a number of limitations also. Designers who use the system lifecycle approach often fail to address the context of the business for which the system is being developed. The timescale and linear nature of the system lifecycle approach fails to allow for change in the scope and character of the problem.

This approach does not put the user at the center of the system design, and also it is often considered to favor hierarchical and centralized system of information provision. In the prototype approach to manage information technology projects, the basic requirements of the system are defined by user using the rich picture and root definition techniques. These basic ideas are utilized by the system designer to create a prototype structure fulfilling the needs identified by the user. This developed system is then experimented by the user to find out if it fulfills the requirement as expected. The system designer may improve the system on the recommendation of the user and potential users to make it of wider value. The prototype approach also has some problems such as difficulty in managing the prototyping, changing of resources implications following the development of the first prototype system, and knowing when to stop the development.

Now, implementation problems. GIS design and management will always have problems which cannot be predicted by any mean. These problems, for example, may be non-availability of data in the format required by the GIS software, lack of knowledge about the GIS being used, imposing technical and conceptual problems in implementation, users changing their requirements. When the GIS data available is not in the desired format, the GIS designer has two options. First, the designer should look for a supplier who can provide the data in the desired format or the second option is to convert the available data into the desired format.

Many times it is found that a better and easier approach to employ an independent expert to undertake application development or specific analysis when it is inevitable that application will be limited by technical and conceptual knowledge of the users about which spatial data model, data structure or analytical operation is most appropriate for the project. The solution to the problem of changing needs of users is to get frequent feedback from the end users of the GIS. Now project evolution. The fifth one, the project evolution requires that the output produced by the system is usable, valid, and meets the objective of the project. Testing the GIS and validating output are a crucial part of the design process.

If the results are in the form of predicted values, then validation becomes difficult. GIS can be made more economical and appropriate by taking prototyping approach in which frequent testing and evaluation take place automatically. To determine that the developed GIS application meet the objectives defined at the beginning of design process, the following approaches may be adopted. Number one, feedback can be obtained from all the parties involved in the process of design and development of the GIS about achieving the goals for which it was designed. GIS output can be checked against reality and the third, the adaptations and changes that had to be made at the time of moving from the rich picture through the GIS data model to the implementation can be evaluated.

Now you can see some of the GIS maps prepared for a study area. This is the geological map which is telling about the details of the geology of the area. Mentioning the different types of rocks also. Then the geomorphological maps, the different parameters of the geomorphology as we have shown here. Then groundwater potential maps, you can see the excellent, very good, very good, good, good, poor.

So in this way, you can see the different areas which has been prepared with the help of the GIS. Then land use land cover map, as we have discussed in the slides about the land use land cover, we can prepare with the help of remote sensing and GIS maps. Then drainage and water study, water body map also we can prepare in this way. Then the soil map, mentioning the different types of the soil at different, different locations with the help of GIS. Then watershed map, this has also been prepared for the study area, mentioning the details, drainage pattern of the area.

Then the road and settlement map, the different types of the NH, National Highway State, Highway District Road, Village Road, Settlement Sector. In this way, we can prepare a detailed map of any locations with the help of application of remote sensing and GIS. Now, just summarizing the lecture, firstly, we have discussed about the application of remote sensing, where we have seen that with the launching of Landsat-1 in nineteen seventy two, remote sensing technology has opened the new vistas in the field of planning, surveying, monitoring, and management of natural resources. It has provided easier techniques to undertake effective and efficient mapping of land, water, soil, forest and culture, urban area growth, floodplain mapping, crop acreage estimation, etc. Some of the applications discussed here with the help of remote sensing techniques are land use and land cover mapping, crop identification, groundwater mapping, urban growth, floodplain mapping, wasteland mapping and district level plan mapping, and district level planning.

Then we have discussed about the application of GIS in which we have seen that GIS application involves practical aspects of designing and managing a GIS for a project. Good project design and management are essential for producing a useful and effective GIS applications. So in general, a GIS application may include problem identification, designing of a data model, project management, identifying implementation problems, and project evolution. Thank you very much to all.