UNIT 1

INTEGRATION OF RS AND GIS

Structure

1.1 INTRODUCTION

Data interpretation and analysis has become common in today's world with the availability of larger volumes of digital data in various formats. Data integration relates to various approaches that combine or merge data obtainedfrom various sources to extractbetter and accurate information. It includes data of different resolution, multi-temporal, multi-sensor, or multi-data type. Data integration will offer a lot more applications through designing various models, running simulations and offering wider scope for effective decision making. Though the technique of integrating raster and vector had been there for over couple of decades now, recently there are large scale developments in analytical methods- such as machine learning based algorithms, visualisation techniques that had contributed in delivering solutions to complex problems. In this unit, we shall discuss raster and vector data integration, methods of integration and software and hardware considerations.

Expected Learning Outcomes

After studying this unit, you will be able to:

- know the key concepts of raster and vector data integration;
- describe methods and techniques of raster and vector data integration;
- explain the utilities of vector and raster data integration; and
- discuss software and hardware tasks requirements necessary to perform raster and vector data integration.

1.2 RASTER AND VECTOR DATA INTEGRATION

Recently, GIS is found to be one of the basic sources for mapping and analysis used for various applications. It is found to be a major tool in spatial data integration. For mapping and analysis spatial data integration plays a major role. Spatial data integration is “the process of combining multiple spatial data types and providing applications for its storage, retrieval, analysis and display”. Let us discuss about spatial data integration that includes vector and raster data integration in detail.

1.2.1 Data Integration

The purpose of geographical enquiry is to examine the relationship among different features at given point in space and time, also to describe or analyse a phenomenon in real world. Data alone has no worth unless a user finds trends and patterns in the data with respect to other events or objects. Therefore data integration plays an important role in enhancing the usageof data.

One of the basic ways of integration is to spatially extract an area as displayed in a raster data, using a polygon boundary of vector data. Another simple way is to extract value of given raster cell (pixel) is by overlaying a point vector layer. This interaction between the layers uses the concept of spatial overlay that allows one to transfer data between objects of different types and different layers, according to spatial relationship with each other. Analysis of a phenomenon located in the geographic space defined by the user often requires extracting information simultaneously from two or more layers.For instance, if a user wants to determine the average surface temperature of certain locations within a city, he/she can choose a raster grid representing the city's surface temperature as the source layer and a vector layer representing the specific location as the target layer. The user will be dealing with one polygon and one raster data. Geospatial analysis therefore can be done using spatial overlay operations by interaction of data between source layers to the target layer. The spatial interaction between the datasets can take place.

1.2.2 Stages of Integration

There are three stages in RS and GIS integration i.e. raster and vector integration (Fig. 1.1). Let us discuss these three stages one after another.

Stage I: In this stage the GIS and image processing are treated as separate systems.However, they are connected by means of data exchange format that

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permits to exchange data. In this first level of integration, geometric registration of images to a common coordination systemis possible.

Stage II: It is known as stage of seamless integration.Though GIS and image processing system share the same user interface, but act individually and are complementary to each otherin seamless exchange of data.

Stage III: It is the process of total integration. In this stage, vector and raster dichotomy ceases and GIS and image processing systems become a single system. In this integration, object based and phenomena based representation of geographic data can be controlled flexibly. As a part of total integration remote sensing is also treated as input functionality in connection with the handling of data.

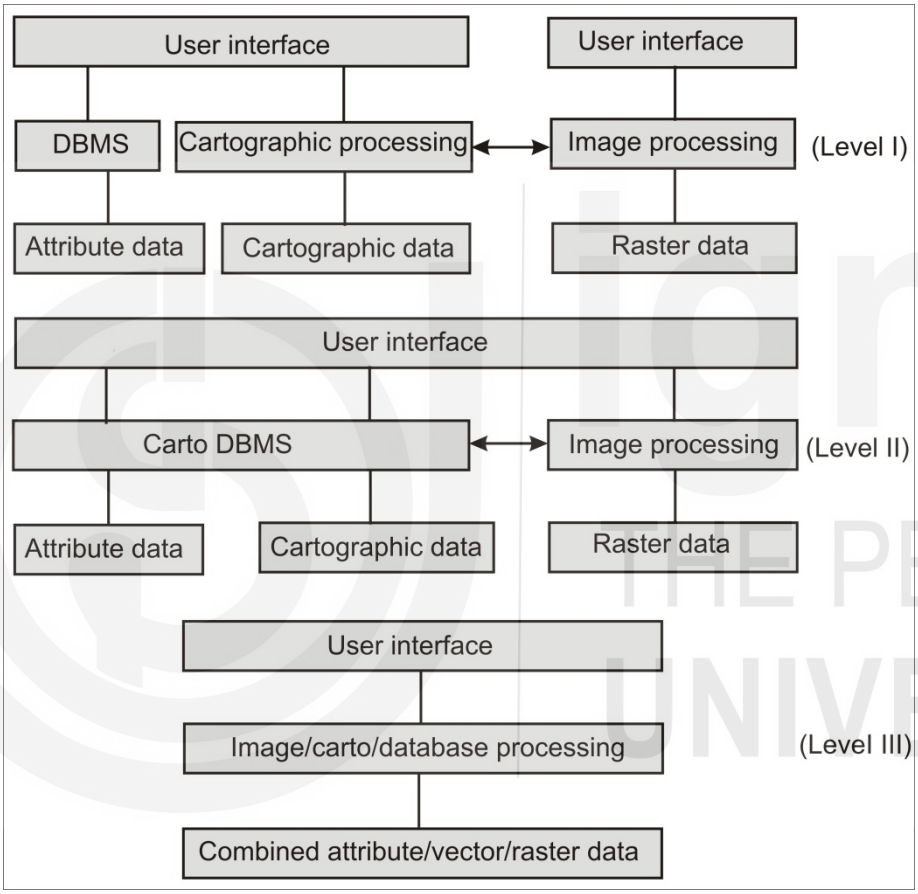

Fig. 1.1: Three stages in remote sensing and GIS integration. (Source: modified after Lo and Yeung 2009)

1.2.3 GIS Integration

Data integration in GIS is the method of combining spatial data procured for different sources and formats to create an integrated dataset used for analysis and decision making. Let us discuss GIS integration in detail.

GPS

Integration of GPS with GIS will facilitate to combine data and enhance the capabilities that cannot be provided individually either by the GIS or the GPS. When two of these technologies are combined it is possible to show the field/actual site on the monitor of the computer (PC) that helps to derive better conclusions instead of making particular site visits or referringvarious related

documents/drawings. Likewise, integration of GPS and GIS will also benefit various stake holders of different departments to seamlessly share and analyse data for their regular use. The other advancement is the supplementary viewing of the actual photographs of the features in GIS derived from the digital picture in addition to the information derived from the GIS.

Internet GIS

Commonly, the term WebGIS and Internet GIS are used as synonymous with each other. There is a slight difference between these two words. The Internet supports many services with the Web being one of these services. So we can call a system as Internet GIS if it uses many of services of Internet not only Web service and if it uses only Web we should name it Web GIS. This definition makes Internet GIS boarder than Web GIS. In real world Web is the most attractive service of Internet and it is why Web GIS is more common than Internet GIS.

Internet Map Servers

Internet Map server (IMS) application allow custodians of GIS database to easily make the spatial data accessible for end users through a web browser. For a working IMS, one component of the system handles data processing engine that runs on server side as a service and the other component is a standard web server that manages incoming requests and responds back with proper map data back to the client.

Wireless Technology

Integration of geospatial data with wireless technology provides wide variety of services and with an intention to raise the business alternatives to serve end users, industries keep on adding innovations. In recent trends, users prefer to run GIS applications on smart phone or PDAs (Personal Digital Assistants). Wireless communication, particularly now-a-days being accessed using mobile phone has opened a vast area of information and topics for the users. The information is now available at finger-tips in the real sense.

Wireless technology implemented on hand-held devices allows users to take GIS out of the working (office) place and directly in the field. For majority of the applications, it is an extension of Desktop GIS, but since users have access to measure and directly upload or feed the data to the online tools, the technology has been most popular in recent years. Furthermore, there is increasing demand and scope in use of drones and small size UAVs which are also governed using wireless technology has enabled task of data collection and real-time assessment of events, in order to make quick decisions.

Web Services

GIS software has enabled users to view spatial data that exists locally or typically over intranet connection within an organisation. In its early age, it has been quite costly, needs huge investment and specialised skills. Increasing demand and reducing cost of computers and peripherals has made use and access of GIS data to reach common users. It has enabled easy interpretation of spatial data. Unfortunately, not every user has access to GIS software, nor be able to spend the time necessary to use it efficiently. Web services that are

offered via internet technology have become a cheap and easy way of disseminating geospatial data and processing tools.

This integration of GIS with the Internet technology has revolutionary effects like interactive access to geospatial data, real-time data integration and transmission, and access to platform-independent GIS analysis tools.

SAQ I

a) What is data integration in GIS?

b) What is the Stage II of GIS integration?

c) Define Internet GIS.

1.3 METHODS OF INTEGRATION

In Unit 11 of the MGY 103 Course, you have been introduced to basic concepts and methods of raster and vector data integration. In addition, we will discuss thethree methods by which remote sensing and GIS technologies can be combined to support and improve the processof integration. Let us discuss these methods in detail.

1.3.1 Contributions of RS in Integration with GIS

In the process of integration, RS is used as resource for collecting data in order to use it in GIS.Let us discuss about these contributions in detail.

a) Thematic information extraction

The thematic data extracted from RS images is used in creation of thematic layers in GIS. There are three methods to integrate the resulting thematic layers in GIS. They are

i) The aerial photographs or satellite imageries interpreted manually, results in production of maps that portray boundaries between the thematic classes (e.g., forest or agriculture classes). The boundaries separating various thematic classes are digitised in such as way that they are made compatible to be used in GIS environment.

ii) Digital RS data that is classified by applying automated methods to producepaper maps and images are digitised to be used as input in the GIS environment.

iii) Digital RS data that is classified using automated method is retained in its digital form and used as input in GIS. On the other hand, digital RS data can be directly entered in its raw form for further analyses.

b) Cartographic Information Extraction

The automatic procedures adopted in extraction of cartographic information such as lines, polylines, polygons and other geographical entities is one of the major achievements in the RS data input in GIS. The task of geographic feature extraction is accomplished by applying pattern recognition, edge extraction, and segmentation algorithm techniques.Hence, RS images will aid in better production and improving the existing base maps. Further the extracted cartographic information can be applied to enhance the process of image classification.

In recent times the availability of high resolution satellite imageries like IKONOS and QuickBird imageries had been proved to be potential source for feature extraction by applying automated extraction techniques. These imageries hadbeing used in topographic mapping and 3D object reconstruction. In addition, the light detection and ranging (LiDAR) data, is being applied in cartographic information extraction as it is helpful in providing land surface elevation information with less than 1 m (vertical and horizontal) accuracy.

c) Data Used in Updating GIS Database

It is quite essential to update GIS database from time to time. For which RS data is found to be one of the important economical source of updating. Additionally, RS data is used in change detection studies in GIS. In recent times, RS and GIS integration are applied for querying raster pixels covering vector polygons and also for carrying out analyses without adopting format conversions and overlays. The derivedimage statistics of the associated vector polygons can be applied to detect the possible changes that have occurred and necessary updating of maps can be initiated.

d) RS Used as a Backdrop inRepresentation of GIS and Cartographic Database

RS imageries are used in cartographic representation as input to GIS. The RS images applied in Terrain visualisation with digital elevation models (DEM) has been proved to be a promising tool in environmental applications. Recent development in cartographic animation technology had progressed in terrain visualisation from static to dynamic state. Therefore, all these advances had shown an extensive development in the implication of traditional 2D to 3D method of representation of GIS as proved to be significant in various modelling studies such as geology, soil sciences, climatology, and marine sciences.

1.3.2 Contributions of GIS in Integration with RS

In the process of integration, GIS data plays an important role in use of its data that will enhance the functionality of RS at various stages of image processing such as selection of area of interest for processing, pre-processing, and image classification. Let us discuss these contributions in detail.

a) Use of GIS Database as a Source of Ancillary Data in RS Image Classification

Ancillary data are the data which are collected separately from that of the remotely sensed data. Since for a long time the ancillary data have been helpful in manual interpretation of aerial photos. These supplementary data are used during the process of identification and delineation of aerial photos. Similarly, in digital RS ancillary data are supplemented during analysis in an organised manner such that the data are in directly connected to RS dataanalysis.

Ancillary data are used to improve during the whole process of image classification that includes pre-classification stratification, classifier modification, and post-classification sorting. During pre-classification stage, ancillary data are helpful to select the training samples or in dividing the study scene into smaller areas or strata following certain designated standards or set of procedures. During the process of post-classification sorting ancillary data are applied in

modification of misclassified pixels by following the expert designated standards. Table 1.1 shows linking of ancillary data with RS imageries for establishing improved image classification. For example, ancillary data derived from topographicmaps are considered to be valuable when applied to improve the land cover classification accuracy as distribution of land cover is associated to topography. Moreover, in addition to elevation the other constituents derived from DEM such as slope and aspectare been used in image classification. Topographic data will also aid in all the three stages of image classification- as a pre-classification stratification tool, as an additional modification channel in the course of classification, and inpost-classification smoothing process.

Table 1.1: Major approaches to link ancillary data with remote sensing images to establish enhanced classification accuracy. (Source: modified after Weng 2010).

Method	Features
Ancillary data usage	Topography, land use, and soil maps
	Road density
	road coverage
	Census data
Stratification	Created on the basison topography
	Created on the basis illumination and ecologic zone
	Created on the basis on census data
	On the basis of shape index of the patches
Post classification processing	Karnel-based spatial reclassification
	Use of zoning and housing-density data to modify the initial classification result
	Use of contextual correction
	Use of co-occurrence matrix-based filtering
	Using polygon and rectangular mode filters
	Using an expert system to perform post-classification sorting
	Useof knowledge-based system to correct misclassification
Multisource data usage	Spectral, texture, and ancillary data (like DEM, geology, soil, existing GIS-based maps)

b) Ancillary Data Usage in Image Pre-processing

During image rectification of image pre-processing stage the use of ancillary GIS data like vector points, area data, and DEMs are being noticed increasingly for geometric and radiometric corrections. Now-a-days topographic data of high resolution are being used intensively in radar image interpretation. The influence of undulating topography on the radiometric characteristics in a digital imagery can be rectified with the help of DEM. During the image pre-processing stage the variables resulting from DEM are applied for topographic correction to normalise the terrain influence of land-cover reflectance. Interestingly, the most

commonly used ancillary data (vector data sets) in image rectification are the ground control points where more accurately recognisable points are carefully picked from the related existing map with defined coordinates and used for image registration.

c) Ancillary Data Usage for Selection of the Area of Interest

The usage of vector polygons to confine to the area of interest of an image intended for processing can be carried with the help of presently available image processing software (e.g., ERDAS IMAGINE software). Therefore, this process permits masking operations without applying raster masks and enabling faster image processing without any intermediate data storage requirement. Thus, reducing the problems associated with data integration.

But there are certain unusual problems (practical and conceptual) with the ancillary data used in image analysis. Preferably the ancillary data must be compatible with the RS imagery in terms of scale, accuracy, geographic reference system and acquired date. In few occasions ancillary data is represented as discrete classes (nominal or ordinal data). But at the same time RS data is represented as ratio or interval data creating a situation where the issue of compatibility between the two data has to be addressed sensitively.

d) GIS as tool to Organise Field/Reference Data for Use in RS Applications

Besides aiding RS at various stages of image processing, GIS favours in facilitating several digital operations (entering, analysing, managing, and displaying) of data obtained from various sources essential for RS applications. For most of the RS projects GIS database is required for storing, organising and displaying ancillary, reference, and field data in addition to the aerial photographs and satellite imageries. Likewise, GPS technologies are also required in RS projects for collection and observation of in situ sample data.

1.3.3 Integration of RS and GIS for Analysis and Modelling

The integration of RS and GIS technologies has a wider application and is acknowledged as an effective tool in various analyses and modelling. Thecombinations of several RS derived variables with GIS thematic layers are known to be probabledata sources for most of the analysis. The data (multispectral, multiresolution, and multitemporal) collected from different sources are converted to information which isto be used in monitoring several land processes and for extracting various biophysical and socioeconomic variables. GIS is responsible for providing favourable environment for carrying out various functionalities (entering, analysing, and displaying) of digital data derived from different sources and used for feature identification, change detection, and database development of different applications.

1.4 SOFTWARE AND HARDWARE CONSIDERATIONS

In the previous section you have read the methods of RS and GIS integration. In this section let us discuss the software and hardware considerations.

GIS applications and GIS-based projects form core of the work for many industries and small-scale companies that work in geo-spatial domain. Other than this, a large number of service provider industries also acquire satellite datasets, generate vector datasets, attribute datasets, use various automate techniques for data processing and data extraction in order to achieve and deliver desired outputs. These individuals/industries need infrastructure to handle database efficiently.

Hardware and software considerations can vary significantly depending on the task in hand. Recent trends show that data volumes are increasing day-by-day. Hence, system requirements are also growing higher to store and process large volumes of data. Yet, below are few minimum configurations that will allow proper functioning of modern applications to work with sub-components.These specifications indicate recommended requirements and packages that may run on very small spatial extent and less below these specifications also.

Hardware Requirements

The following are the essential hardware requirements for a well-equipped GIS Lab:

- **Computer Workstations**: High-performance desktop or laptop computers with sufficient processing power, RAM, and storage are essential. For intensive GIS tasks, a multi-core processor (e.g., Intel Core i7 or AMD Ryzen series) with at least 16 GB of RAM is recommended. Additionally, solid-state drives (SSD) provide faster data access and reduce loading times.
- **Graphics Processing Unit (GPU)**: A dedicated GPU with good processing capabilities can significantly enhance GIS performance, especially when working with large datasets and 3D visualizations. NVIDIA GeForce or AMD Radeon graphics cards are popular choices for GIS applications.
- **Display Monitors**: High-resolution monitors (e.g., 24 inches or larger) with accurate color reproduction are necessary for better visualization and data analysis. Dual monitors can improve productivity by allowing users to view multiple maps and applications simultaneously.
- **Storage Solutions**: Ample storage capacity is crucial to accommodate GIS data and projects. A combination of fast SSDs for the operating system and applications, along with larger capacity HDDs for data storage, is a recommended setup.
- **Peripherals**: Standard peripherals like keyboard, mouse, and speakers are required. Additionally, a digitizing tablet can be beneficial for precise mapping and digitization tasks.Large format scanners play a vital role in digitizing large, old paper maps, or hard copy satellite images, enabling their conversion into digital formats for further processing.
- **Network Infrastructure**: A reliable and high-speed network connection is essential to enable data sharing and collaboration within the GIS Lab.A high-speed internet connection is crucial for leveraging cloud computing, accessing GIS and RS data from diverse online sources, and effectively working with web/internet GIS.

Software Requirements

Choice of software depends on the needs of functionalities desired by the user, user's ability for expenditure to be incurred, number of intranet and internet GIS users, etc. Here are some of the most widely used GIS and image processing software options to choose from.

1) **ESRI GIS software packages**: ESRI (Environmental Systems Research Institute) offers several products for different categories of users. Few leading and common products include ArcGIS, ArcSDE, ArcIMS and ArcWeb services. ESRI ArcGIS is a powerful and widely-used geographic information system (GIS) software. It offers comprehensive tools for spatial analysis, mapping, data integration, management, and visualization, making it a go-to solution for professionals in various fields, such as urban planning, environmental science, and geospatial research. With its user-friendly interface and extensive geospatial capabilities, ArcGIS empowers users to explore, interpret, and present complex geographical data, facilitating better decision-making and understanding of the world around us.

2) **QGIS**: It is one of the most powerful open source GIS software packages that can be freely downloaded. It works on the basis of user developed plug-ins which is the key to its success. User has to look for desired plug-ins in the repository and simply download the same and install. Because of this support and online help available among user groups, this software has become one of the most popular open source GIS software.

3) **Hexagon Geospatial software packages**: Intergraph Geomedia and ERDAS Imagine are two powerful geospatial software offerings by Hexagon Geospatial, a leader in the geospatial industry. Geomedia is a versatile Geographic Information System (GIS) platform that enables users to collect, manage, analyze, and visualize geospatial data from various sources. It offers advanced tools for spatial analysis, cartography, and data integration.

   ERDAS Imagine, on the other hand, is a specialized and one of the most widely used remote sensing and image processing software. It allows users to process, analyze, and interpret satellite and aerial imagery, enabling tasks such as image classification, change detection, and 3D visualization. ERDAS Imagine is widely used in agriculture, forestry, and environmental research, providing essential insights for land use mapping, crop monitoring, and natural resource management. In addition, ERDAS Imagine offers photogrammetry and Radar mapping suites.ERDAS Imagine also offers support for LiDAR data processing.

4) **Autodesk GIS software packages**: Autodesk offers a range of powerful GIS software packages that cater to various geospatial needs. With products like Autodesk AutoCAD Map and Autodesk InfraWorks, professionals can efficiently create, manage, and analyze geographic data, enhancing their design and planning workflows. These software solutions facilitate seamless integration with industry-standard CAD tools, providing a comprehensive platform for geospatial modeling, visualization, and data sharing. Whether it's urban planning, infrastructure design, or environmental

analysis, Autodesk's GIS software empowers users with the tools to make informed decisions and drive efficiency in their geospatial projects.

5) **ENVI**: ENVI is a widely used and powerful image processing software designed specifically for remote sensing and geospatial analysis. Developed byNV5 Geospatial Solutions, ENVI enables users to process, analyze, and interpret various types of remotely sensed data, such as optical, Radar and hyperspectral satellite images. With advanced algorithms and tools, ENVI supports tasks like image classification, change detection, and vegetation analysis. It also offers support for photogrammetric analysis and module for SAR interferometry. Its user-friendly interface and extensive capabilities allow researchers, scientists, and professionals to extract valuable insights from complex geospatial data, ultimately supporting informed decision-making and enhancing geospatial research and applications.

6) **Sentinel Toolbox**: The Sentinel Toolbox consists of 3 separate applications:

   Sentinel-1 Toolbox (SAR applications)

   Sentinel-2 Toolbox (High-resolution optical applications)

   Sentinel-3 Toolbox (High-resolution optical applications)

   One of the standout features of the Sen2cor plugin is its capability to correct for atmospheric effects and classify images. Moreover, if you have downloaded Sentinel-1 synthetic aperture radar data, it can be efficiently processed with the Sentinel-1 toolbox. This enables the application of advanced techniques such as interferometry. Should you require additional support, the open STEP Forum offers a vibrant community of remote sensing enthusiasts ready to assist and address any questions you may have.

7) **PCI Geomatica**: PCI Geomatica is an all-encompassing and advanced geospatial software developed by PCI Geomatics, centered around image processing. With a strong emphasis on geospatial analysis and image manipulation, Geomatica provides a diverse array of tools for effectively handling satellite images of various types. Its capabilities include image rectification, ortho rectification, image classification, and change detection. Geomatica seamlessly integrates conventional divisions in remote sensing, photogrammetry, GIS, cartography, web, and development tools into one cohesive environment, resulting in reduced errors, minimized time wastage, and increased productivity.

   The majority of the software packages mentioned above allow the utilization of geo-located data from various features or events, finding widespread applications across diverse fields. Geospatial data integration finds application in numerous domains, spanning from mineral mapping and precision farming to resource management, land use policy making, transport management, environmental monitoring, emergency response, and business development, among others. These applications leverage web technology, enabling online decision-making, policy formulation, and scenario building for users worldwide.

SAQ II

a) List the methods of GIS integration.

b) What is the important role played by GIS in integration with RS?

c) What is QGIS?

1.5 SUMMARY

Let us summarise what we have studied in this unit.

- GIS is found to be one of the basic sources for mapping and analysis used for various applications. It is found to be a major tool in spatial data integration. For mapping and analysis spatial data integration plays a major role.
- Data integration plays an important role in enhancing the usage of data. One of the basic ways of integration is to spatially extract an area as displayed in a raster data, using a polygon boundary of vector data. And the other simple way is to extract value of given raster cell is by overlaying a point vector layer.
- There are three stages in RS and GIS integration. In stage I, the GIS and image processing are treated as separate systems. But, they are connected by means of data exchange format that permits to exchange data. The Stage II is known as stage of seamless integration and Stage IIIis considered as process of total integration.
- Integration of GPS with GIS will facilitate to combine data and enhance the capabilities that cannot be provided individually either by the GIS or the GPS. Normally, the term WebGIS and Internet GIS are used as synonymous with each other where the Internet supports many services with the Web being one of these services.
- Internet Map Server (IMS) application allow custodians of GIS database to easily make the spatial data accessible for end users through a web browser.Integration of geospatial data with wireless technology provides wide variety of services and with an intention to raise the business alternatives to serve end users, industries keep on adding innovations.
- Web services that are offered via internet technology have become a cheap and easy way of disseminating geospatial data and processing tools. Integration of GIS with the Internet technology has revolutionary effects like interactive access to geospatial data, real-time data integration and transmission, and access to platform-independent GIS analysis tools.
- There are three methods of RS and GIS technologies that can be combined to support and improve the process of their integration. They are contributions of RS in Integration with GIS, contributions of GIS in integration with RS and integration of RS and GIS for analysis and modelling
- GIS applications and GIS-based projects form core of the work for many industries and small-scale companies that work in geo-spatial

domain.Hardware and software considerations can vary significantly depending on the system requirements.

1.6 ACTIVITY

- You have read in this Unit that QGIS works on the basis of user developed plugins. List the popularly used plugins in QGIS.

1.7 TERMINAL QUESTIONS

1. What is data integration? Describe the stages in RS and GIS integration.
2. Discuss the contributions of RS in Integration with GIS.
3. Discuss the contributions of GIS in Integration with RS.
4. Describe the software and hardware considerations in RS and GIS integration.

1.8 REFERENCES

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1.9 FURTHER/SUGGESTED READINGS

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1.10 ANSWERS

SAQ I

a) Data integration in GIS is the method of combining spatial data procured for different sources and formats to create an integrated dataset used for analysis and decision making.

b) Stage II of GIS integration is also known as stage of seamless integration. In this stage GIS and image processing system share the same user interface, but act individually and are complementary to each other in seamless exchange of data.

c) If GIS uses many services of internet including web services is known as Internet GIS.

SAQ II

a) The three methods of integration are i) Contributions of RS in integration with GIS ii) Contributions of GIS in integration with RS iii) Integration of RS and GIS for analysis and modelling.

b) In the process of integration, GIS data plays an important role in its use that will enhance the functionality of RS at various stages of image processing such as selection of area of interest for processing, pre-processing, and image classification.

c) QGIS is open source GIS software works on the basis of user developed plug-ins.

Terminal Questions

1. Please refer to subsection 1.2.1 and 1.2.2.
2. Please refer to subsection 1.3.1.
3. Please refer to subsection 1.3.2.
4. Please refer to section 1.4.