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Remote Sensing, Geographical Information System, and Their Application in the Field of Water Resources, Hydrogeology, and Groundwater Management

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Abstract:- 'Remote' means far away and 'Sensing' means observing and acquiring information, which shows that remote sensing is the process of taking detailed information about any object without physical contact. In terms of geoscience, remote sensing is the process of taking detailed information about Earth using satellites, airplanes, and drones. GIS stands for geographical information system, which is computer software that stores spatial and non-spatial data in a digital form. Spatial data means the physical representation of earth features for instance location, size, and shape of rivers, lakes, etc. Non-spatial data also called attributes, are represented in the table format for instance area, population, and sex type of a particular district.

Remote sensing and GIS have various scopes in different fields, especially in water resource management, it has been used to assess surface and subsurface water. Remote sensing and GIS are modern techniques, which is helpful for hydrogeologist and engineer to have a better understanding of the topography, water resources, physical features, and climate of a particular place on the earth. In this research, the intention of the author is to illustrate the application of remote sensing and GIS in different fields, particularly in water resources, hydrogeology, and groundwater. In addition, a case study of remote sensing and GIS related to water resources assessment will be conducted to show how this technique works in the field.

Keywords: Remote Sensing, Geographic Information System, Digital Elevation Model, Natural Drainage, ArcGIS.

Theory

Remote Sensing

Remote sensing is the technique of detecting and monitoring physical features of an area from a distance by measuring reflected and emitted radiation (typically from satellites or aircraft). Remotely sensed images are collected by special cameras, allowing researchers to "sense" information about the Earth. For instance, satellite and airplane cameras capture photographs of broad portions of the Earth's surface, allowing us to view much more than we can from the ground; also, sonar equipment on ships can be used to create photographs of the ocean floor without having to travel to the ocean's bottom. Remote sensing not only provides a broad scale of observation space-time distribution, but it also saves time and money (Magesh et al. 2012). The remote sensing process involves interaction between the incoming radiation and the interest of targets. Figure 1 illustrates the complete process of remote sensing starting from radiation to data analysis also the description of each process is given below.

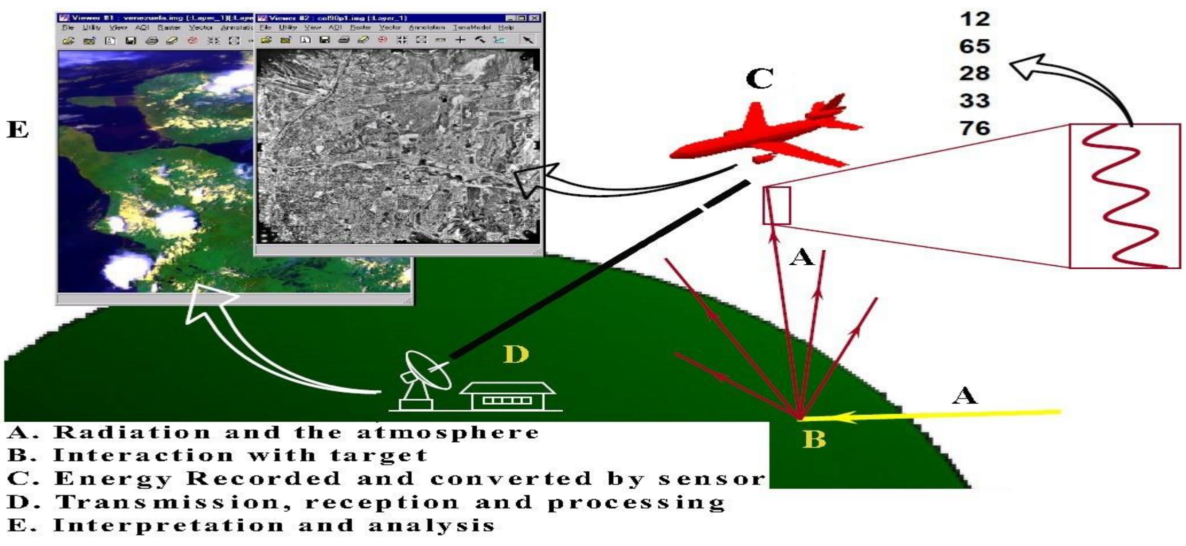

Figure 1: Complete remote sensing process. (Source: N. Adero lecture series)

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A. **Radiation and the Atmosphere:** When the energy travels from the source to the target points, it will come in contact and interact with the atmosphere. This interaction may take a second time as energy travels from target points to the sensor.
B. **Interaction with target points:** When the energy reaches the targets, it interacts with the target depending upon the properties of both targets and radiation.
C. **Energy recorded and converted by sensor:** After the energy is emitted from the target, the sensor or remote records the electromagnetic radiation.
D. **Transmission, Reception, and Processing:** The recorded energy by the sensor must be sent, frequently in electronic form, to a station that receives the data and processes it into an image (hardcopy or digital).
E. **Interpretation and analysis:** The processed images are interpreted visually, digitally, or electronically to derive information about the illuminated target.

Some specific applications of remote sensing include:

- It is a powerful tool for planning and monitoring various industrial works such as power plants, tunnels, roads, railways and bridges, dams and canals, mineral exploration and mining, sewer projects, and so on.
- High-quality satellite imagery assists planners in creating up-to-date maps that include city boundaries, roadways, urban streets, population, and other qualities that might aid in determining urban planning goals (N. Adero lecture series).
- To determine reliable data on the quality, quantity, and location of agricultural resources.
- It is the means of drone photogrammetry, which could be helpful for site planning for engineers. For instance, corridor and mine site mapping.
- Helpful tool for damage assessment caused by natural or man-made hazards. For example, massive forest fires can be mapped from space, giving rangers a much greater view than they would have from the ground.
- Observing the development of a city as well as changes in farms or forests over several years or decades.
- Cloud tracking for weather forecasting.

Geographic Information System

A Geographic Information System (GIS) is fundamentally a computer-based information system whose ultimate objective is decision support via georeferenced data capture, integrated processing of spatial and attribute aspects in the data, management, and display of map-based results at various scales. The ultimate goal of the GIS is decision support. As compared to other information systems, GIS employs geographically referenced (georeferenced) data and information, making it different and special where location coordinates must be included in the data. The core function of GIS is an integration of spatial data (data linked to a specific location in space) and attribute data (descriptive elements of data such as the name of features). Geographic information systems have a wide range of applications in various fields, including agriculture, water, infrastructure, forestry, and others. Although a wide range of applications can be incorporated into six points, which are

- Mapping where the things are. For instance, finding the location of a specific object such as a river, lake, forest, and so on.
- Mapping the most and least. For example, precipitation occurs in different places.
- Mapping the density. For example, population density.
- Finding what is inside. For example, hospitals inside the municipality, feature inside the polygon.
- Finding what is nearby. For instance, injury near parks, nearest facilities, and restaurants near the university.
- Mapping Change. For instance, the development of fire with time and land use changes with time.

Application of GIS and RS in the field of water resource management

Remote sensing is the method of gathering information about an object or feature without making physical contact with it by employing satellites and sensors, and a geographic information system is a computer-based program that uses remotely sensed data to produce the results. The integration of RS and GIS is a rapidly growing field in which data from several sources is being used. The term "integration" has come to apply to nearly any sort of link, from the realistic computational merging of data to conceptual comprehension of how geographic characteristics are interconnected (Mesev and Walrath 2007). RS and GIS offer various utilities in the field of water resource management, which are.

- Water resources mapping. For example, mapping of size and location of Rivers and lakes.
- Estimation of watershed physiographic parameters. For example, the effects of land use and land cover change in a specific area.
- Estimation of Hydrological and Meteorological variables such as precipitation, evapotranspiration, and soil moisture.
- Drought Assessment
- Flood Mapping

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- Rainfall-Runoff Modeling

Application of GIS and RS in the hydrogeology and groundwater management

Groundwater is the water present below the ground surface in the rock and soil pore spaces, and the study of groundwater, its distribution, and movement in rock and soil pore spaces is termed as Hydrogeology. Remote sensing provides only surface or near-surface information. However, the spatial and temporal nature of the RS data provides excellent opportunities for a researcher to improve the understanding of hydrogeological systems in both accessible and non-accessible areas. The GIS process calculates and stores large amounts of remotely sensed and conventional data, integrating spatial and non-spatial information in a single system, providing a consistent framework for analyzing spatial variation, allowing manipulation of geographical information, and connecting entities based on geographical vicinity. The use of both RS and GIS has different applications in the field of hydrogeology and groundwater management, which are mentioned below.

- Exploration and evaluation of groundwater resources.
- Groundwater pollution hazard assessment and protection planning by using the DRASTIC model.
- Selection of artificial recharge zone.
- Estimation of natural recharge distribution.
- GIS-based subsurface flow and pollution modeling.
- Hydrogeological data analysis and process monitoring.

Case Study:

Identify the natural drainage distribution from the digital elevation model by using GIS.

A DEM (Digital Elevation Model) is a raster GIS layer that is also known as a DEM. which is usually created by remotely sensed data captured by satellites, drones, and planes. Trees, structures, and other surface objects are not included in the digital elevation model, which represents a bare ground topographic surface of the Earth. DEM can be used in geographic information systems to model water flow for hydrology or mass movement such as landslides.

The assessment for natural drainage distribution or identification of natural streamlines can be performed in ArcGIS by using a DEM image. Here, the author identifies the natural streamline in the Bharatpur municipality in Chitwan, Nepal. The aster data / digital elevation model, SRTM 1 Arc-second global 30m resolution image was downloaded from the USGS's website (Earthexplorer.usgs.gov). The downloaded digital elevation model (DEM) image is shown in figure 2 (a). Furthermore, the downloaded map was processed in ArcGIS 10.6 using a specified geo-referenced through WGS 1984 (World Geodetic System) UTM (Universal Transverse Mercator) zone 45 N, developing flow direction and natural drainage lines maps which are shown in figure 2 (b) and figure 3.

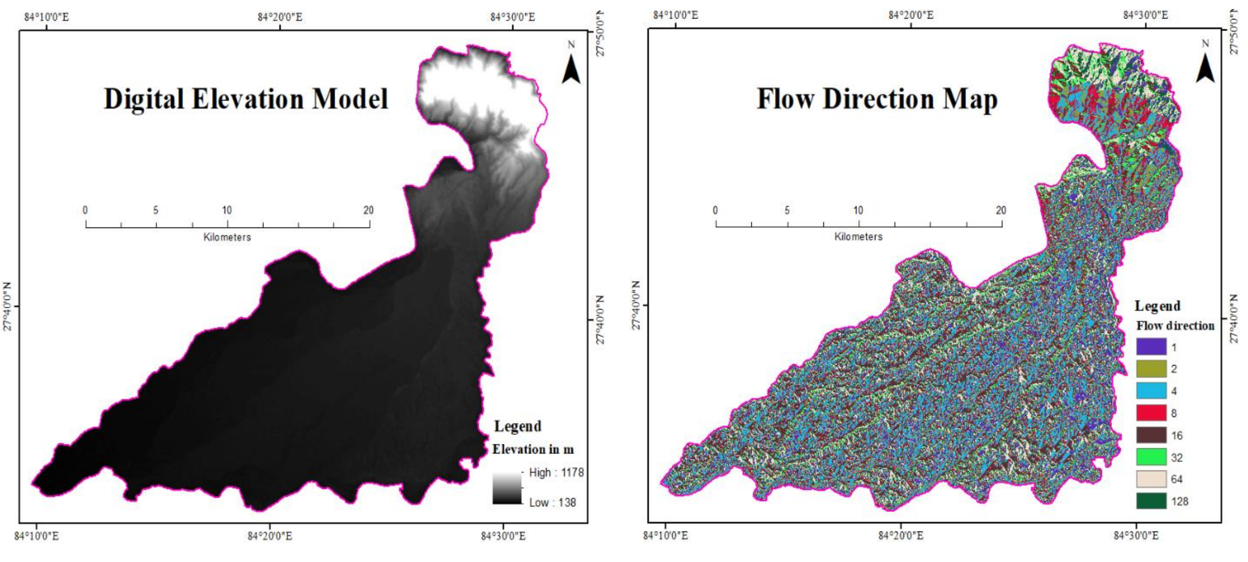

Figure 2: Digital elevation model (a) and flow direction map (b) of Bharatpur municipality, Chitwan, Nepal.

For the DEM (Digital Elevation Model) processing, it was taken as a rough surface bin for using hydrological tools in ArcGIS software, where we determined how much water may accumulate in the area or bin. First, the water was filled in the area using the fill tool, and the flow direction of the water was determined using the flow direction tool. The flow direction map is shown in figure 2 (b) and the flow direction runs through the D8 flow model below showing the flow direction from each cell to its steepest

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downslope neighbour.

32	64	128
16		1
8	4	2

Figure 3: D8 flow model shows possible eight flow directions in cells. (Source: ArcGIS 10.6/Flow direction/Tool Help)

This approach is generally referred to as the eight directions (D8) flow model since eight possible output directions are connected to the eight adjacent cells into which flow could travel. 1 (East), 2 (Southeast), 4 (South), 8 (Southwest), 16 (West), 32 (Northwest), 64 (North), 128 (Northeast).
For example, if the steepest drop is to the left of the present processing cell, the flow direction is coded as 16 (west).

After determining the direction of the water, the flow accumulation tool was used to determine how much volume of water might accumulate or fit in the research area. Again, streamlines in the research region have been determined using flow direction and flow accumulation by using the hydrological tool in ArcGIS software. Figure 4 shows the different-sized natural drainage lines of Bharatpur municipality, where the size of the drainage channel increases from 1 to 5. The drainage map shows the very small natural drainage line to big water channels in the study area, where small drainage channels may not be seen in the field because of their size and flow depth. However, big channels can be found directly in the field also even seen from the airspace. These natural drainage lines could be surface and sub-surface drainage systems in a few depths, although these lines are not groundwater flow in an aquifer. Hydrologically, these drainage lines represent overland and interflow.

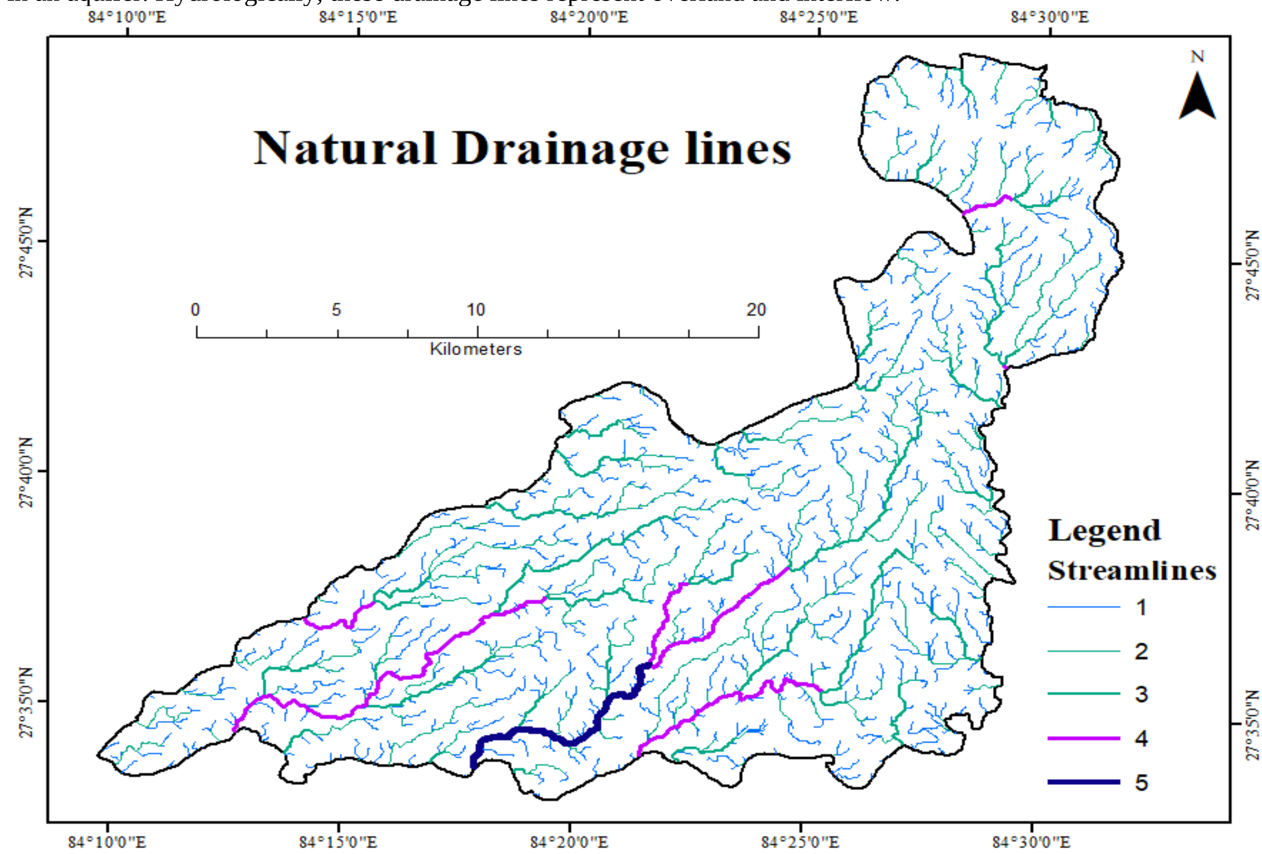

Figure 4: Natural distribution of drainage lines in the Bharatpur municipality, Chitwan, Nepal.

CONCLUSION

Remote sensing and GIS are modern techniques, and the integration of these techniques can be used by hydrogeologists, engineers, policymakers, and planners for different purposes. It can be used to study and understand geology, geography, water, and natural resources also useful for rural and urban planning. GIS and remote sensing have proven to be practical tools for handling

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multidisciplinary data, which helps to minimize time, cost, and manpower. The use of GIS and remote sensing, coupled with different methodologies has a high significance in understanding water resources, hydrogeology, and groundwater.

In this research, the authors discussed remote sensing, geographic information system, and their integration and application in different fields. In addition, a case study of the integration of remote sensing and GIS to identify the natural drainage system in the Bharatpur municipality, Chitwan, Nepal using aster DEM image. The findings prove that remote sensing and GIS techniques are the economical and efficient methods for groundwater assessment also integration of GIS and remote sensing with various data such as satellite data, conventional data, and field data must be used scientifically by engineers, hydrogeologists, and urban planners to use natural resources in a sustainable way that can help the sustainable development of the particular region.

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Author contribution: - Ramji Kshetri and Dipesh Dahal had the original idea for the paper and took overall responsibility for the study, including data collection and analysis, preparation of figures, and finalization of the manuscript.
Conflict of interest: - The authors reported no potential conflict of interest.
Data availability: - The data that support the finding of this study are available from the corresponding author.

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