Introduction to Challenges and Future Directions in Remote Sensing and GIScience

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Abstract This book provides an overview of remote sensing and GIScience (GIS) and their challenges and future directions. Modern technology like remote sensing and GIS with timely and accurate information helps to monitor and analyze a wide range of phenomena like water, vegetation, land, and human activities. Interdisciplinary studies are also noticed in human–environment interaction between stakeholders and decision makers for real world applications. Remote sensing data products and their limitations are also discussed in the book. To overcome this situation, artificial intelligence (AI), along with cloud computing and big data analytics, is the need of the hour. Decision support system based on the AI in remote sensing and GIS is key to the implementation of decision-making and planning in a sustainable manner. The book is segregated into 5 parts spreading over 15 chapters. Part I discusses the challenges and future direction of remote sensing and GIS in various fields. Chapters 2–5 in the second part are devoted to challenges in sustainable natural resources management. Various applications of remote sensing and GIS in urban growth management are presented in Chapters 6–9 of Part III. In Part IV, challenges and future directions in GIS have been discuss in Chapters 10–14 through GIS modeling. Part V devoted to one chapter deals with the GIS revolution in science and society.

Keywords Remote sensing · GIScience · Challenges and Future direction

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Development of remote sensing and GIScience (GIS) is crucial for scientific exploration of the earth's system, such as hydrosphere, lithosphere and biosphere. The phenomenon of the earth's system such as natural and human-induced has much significance in today's world. Remote sensing and GIS are modern technologies with timely and accurate information. Information access through these technologies helps to monitor and analyze a wide range of phenomena like water, vegetation, land, and human activities. It also helps to explore the potential natural resources for human use. Therefore, it is being used widely in various disciplines and multidisciplinary subject areas for decision-making and problem-solving processes.

The human–environment interaction (HEI) plays a key role in the dynamics of global environmental system. HEI analysis uses disparate datasets for every particular study. However, there are some similarities between methods and techniques in remote sensing and GIS practitioners. It creates an inter-disciplinary study in HEI and collaboration between authors of various disciplines. Increased collaboration beyond academics is also seen nowadays by stakeholders and decision makers for real world applications. Remote sensing and GIS provide information through data mining and processing. Therefore, ground reference data inclusion in remote sensing and GIS are crucial for the relevance of every study.

In the era of industrialization and climate change, HEI deteriorates the earth's biosphere and its carbon and hydrological cycles. To overcome this problem, a large amount of data and processing power is required along with the decision-making system. This is the main challenge for remote sensing and GIS, which have large spectrum of data with various limitations. Remote sensing data products are available with various spatial, spectral, and temporal resolutions. Therefore, studies use site-specific data products to fulfill the need of the specific study. For example, temporal changes in urban land use need high spatial, which requires large storage of data with specific time interval. Therefore, storage as well as processing need time for this kind of research. Some studies need spectral resolution for identifying the objects. Hyperspectral remote sensing data products with high spectral resolution have provided satisfactory results for this kind of research.

Promising solutions for these challenges can be obtained with the help of cloud computing and big data analytics. It is obvious that artificial intelligence (AI), along with cloud computing and big data analytics, is the future of remote sensing and GIS. Decision support system based on AI in remote sensing and GIS is the key to the implementation of decision-making and planning in a sustainable manner. Visualization of spatial data in GIS is a way forward to achieve planning and decision-making for stakeholders. It helps decision makers to take action based on the data visualization through GIS, e.g., natural hazards, urban planning, environmental management, and crime. Prediction and modeling of natural hazards are extremely difficult in the real world due to its complex nature. Till date, there is no such method to predict the results with zero uncertainty. AI has achieved the deal with precision modeling for complex problems of the earth's system. It can analyze the different aspects with sufficient detail and iteration for a complex problem.

Google Earth Engine is a platform based on cloud computing to analyze the geospatial data. It has massive computational capabilities to analyze a large amount of spatial data in a short time period. The advantage of this platform is to analyze spatial data without storing them in personal computers. Therefore, it helps to process large scale studies such as those at regional and country levels with efficient results. An attempt has been made in this book by the contributors to evaluate the efficiency of remote sensing and GIS techniques through various studies. Chapters in this volume have been grouped into five parts: General, Challenges in Sustainable Natural Resources Management, Remote Sensing and GIScience in Urban Growth Management, Challenges and Future Directions in GIScience, and GIScience for Revolution in Science and Society. Part I deals with the usefulness of remote sensing and GIS in various field of study. It covers the applicability of remote sensing and GIS in HEI, natural hazards, and environmental management. The future of remote sensing and GIS in the light of AI, cloud computing, and big data analytics is also focused on in this part.

Part II deals with the Challenges in Sustainable Natural Resources Management. It comprises four chapters concentrating on flood, vegetation, landslide, and glacier retreat and their direct and indirect impact on natural resources. In chapter "Environmental and Livelihood Impact Assessment of 2013 Flash Flood in Alakananda and Mandakini River Valley, Uttarakhand (India) Using Environmental Evaluation System and Geospatial Techniques," Tripathi et al. made an attempt for environmental and livelihood impact assessment of 2013 disastrous flood in Mandakini valley. They used Landsat data product for preparing land use land cover (LULC) maps and the statistical changes were estimated in the respective LULC classes. The results showed significant changes in terms of LULC dynamics in the whole region. In chapter "Assessment of Vegetation Vigor Using Integrated Synthetic Aperture Radars," Sinha assessed the vegetation using Integrated Synthetic Aperture Radars (SAR). In the study, the author uses SAR data to estimate forest biomass. Study shows a suitable approach in assessing vegetation vigor from above ground biomass through SAR. In the chapter "Landslide Susceptibility Mapping using Bivariate Frequency Ratio Model and Geospatial Techniques: A Case from Karbi Anglong West District in ASSAM, India," Ahmed et al. made an attempt to prepare an inventory map of landslide susceptibility using geospatial technology and bivariate frequency ratio model for Karbi Anglong West district. The study revealed that frequency ratio model along with geospatial technique helped not only in identifying landslide prone areas but also proved to be instrumental in examining level of susceptibility. In the chapter "Retreating Glacier Dynamics Over the Last Quarter of a Century at Uttarakhand Region Using optical Sensors Time Series Data," Kalita et al. examined the retreating glacier dynamics over the last quarter of a century in Uttarakhand. In their study, they used optical remote sensing data products for examining the changes from 1994 to 2015 and changes detected for snow and vegetation were 1377 km^2 and 896 km^2, respectively. The study results showed the actual determination of glacier dynamics and its kinetic of change rate and how climate is impacting over snow and ice resources.

Part III deals with the Remote Sensing and GIScience in Urban Growth Management. It contains four chapters focusing on the impact of urbanization on agriculture, impervious built-up, building subsidence, and LULC for land resource development.

In the chapter "Studying the Impact of Urbanization on HYV Rice Fields at a Local Level Using Fine Resolution Temporal RISAT-1 Datasets," Roychowdhury and Bhanja assessed the Impact of urbanization on High Yielding Variety (HYV) rice fields at a local level. Their study estimates the HYV rice fields vulnerable to conversion due to non-farm uses around sprawling urban settlements. In the chapter "Identification of Impervious Built-Up Surface Features Using Resources at 2 LISS-III Based Novel Optical Built-Up Index," Santra et al. tried to identify the impervious built-up surface through built-up index. In their study, they used several built-up indices for comparison. Their newly developed Impervious Built-up Index shows the maximum accuracy, i.e., 92.33%. In the chapter "Subsidence Assessment of Building Blocks in Hanoi Urban Area from 2011 to 2014 Using TerraSAR-X and COSMO-SkyMed Images and PSInSAR," Anh et al. assessed building subsidence in Hanoi urban area from 2011 to 2014 by high resolution radar satellite images. Their results revealed that high precision leveling is the key to assess the accuracy of subsidence determination of buildings. In the chapter "Analysis of Land Use/Land Cover Mapping for Sustainable Land Resources Development of Hisar District, Haryana, India," Rani et al. mapped the LULC for sustainable land resource development in Hisar district. They used IRS/LANDSAT data products to analyze various land resource constraints by taking collateral information on soil types, groundwater quality, and depth along with geomorphological constraints.

Part IV deals with the challenges and future directions in GIScience. The part consists of five chapters concentrating on solar energy potential, rice growth stage mapping, habitat suitability mapping, air pollution modeling, and agricultural productivity mapping. In the chapter "A Spatial Investigation of the Feasibility of Solar Resource Energy Potential in Planning the Solar Cities of INDIA," Roychowdhury and Bhanja investigated the feasibility of solar resource energy potential in planning the solar cities of India. Their study focused on identifying solar hotspots of India and how the spatial distribution of solar energy resources accentuate or hinder the performance of the solar cities. The study also conducted a techno-economic feasibility using solar resource datasets derived from high resolution satellites. In the chapter "Mapping Rice Growth Stages Employing MODIS NDVI and ALOS AVNIR-2," Panuju et al. mapped rice growth stages using MODIS NDVI and ALOS AVNIR-2. They used time-series NDVI for growth-stage indication and five classifiers for mapping the growth stages. The study revealed the efficiency of neural network and support vector machine in mapping growth stages. In the chapter "Habitat Suitability Mapping of Sloth Bear (Melursusursinus) in the Sariska Tiger Reserve (India) Using a GIS-Based Fuzzy Analytical Hierarchy Process," Jain et al. mapped the habitat suitability of the sloth bear (Melursusursinus) in the Sariska Tiger Reserve (India) using a GIS-based fuzzy analytical hierarchy process. Nine parameters have been used for assessing sloth bear habitat suitability in the study. Their suitability classes were validated through zonal statistics of beat wise habitat intensity data of sloth bear in the Reserve. In the chapter "Estimation of Air Pollution Using Regression Modelling Approach for Mumbai Region Maharashtra, India," Kumari et al. estimated air pollution using regression model for Mumbai. The study was an integrated approach to attain the spatio-temporal attributes of air pollution index of particulate matter (PM_{10} and $PM_{2.5}$) and trace gas (O_3, NO_2, and CO) pollutants in Mumbai. They used spatial variation of API for different air pollutants to simulate the Inverse Distance Weighted method of interpolation. In the chapter "Mapping of Agriculture Productivity Variability for the SAARC Nations in Response to Climate Change Scenario for the Year 2050," Singh et al. mapped the agriculture productivity variability for the SAARC nations in response to climate change scenario for the year 2050. They assessed the impacts of climate change on agriculture productivity net primary productivity using Joint UK Land Environment Simulator. Results of the study revealed a slight decrease in productivity with spatial variability across the SAARC nations.

Part V deals with the GIScience for Revolution in Science and Society. It comprises one chapter focused on the revolution of GIS in science and society for solving the future challenges in spatial information. In the chapter "Future Direction of GIScience for Revolution in Science and Society Over the Past Twenty Years," Lal et al. emphasized the need of GIS in society for problem-solving with the help of spatial data and modeling as GIS plays a vital role in monitoring the physical characteristics of the earth's surface over decades. The advancement of GIS technologies, specifically in GIS geomorphologic mapping, has provided us with core data of landform development, including those due to geophysical or climatic events such as earthquake, volcanic eruption, landslides, and cyclone.