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DOI

DEVELOPMENTS IN SATELLITE REMOTE SENSING AND GIS FOR SOLVING SOCIO-ENVIRONMENTAL PROBLEMS IN 21ST CENTURY

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Introduction. The world today is grappling with myriads of socio-environmental challenges, many of which are exacerbated by anthropogenic climate change. However, the science and technology has provided many tools and resources to deal with these challenges which, some people will consider, have originated because of unregulated/unethical use of scientific developments. One of the most coveted scientific advancements relate to the employment of data from space-borne instruments. This discipline popularly called as Remote Sensing has become the backbone of data procurement and analysis in 21st century in many domains.

By definition, “Remote Sensing” is the science of acquiring, processing, and interpreting data obtained from aircraft and satellites that record the interaction between matter and electromagnetic radiations (Sabins, 1978). The scientific basis behind remote sensing is the interaction between matter and electromagnetic energy which is determined by the physical properties of the matter, and the wavelength of the electromagnetic energy that is remotely sensed.

In addition to remote sensing, the modern world has also seen the advent of GIS which has enabled apparently limitless exploitation of a variety of remotely sensed data in a relatively lesser amount of time and space. A Geographic Information System (GIS) is an organized collection of computer hardware and software, with supporting data and personnel, that captures, stores, manipulates, analyzes, and displays all forms of geographically referenced information (Sabins, 1978). Thus a GIS allows for the integration and collective analysis of geospatial data from multiple sources including satellite imagery, GPS (Global Positioning System) recordings and textual (non-spatial) attributes associated with a particular space/location. One of the biggest advantages of GIS is the seamless integration of spatial and non-spatial data in a human-controlled artificial system/environment and organized in an appropriate format, for the further retrieval, manipulation and analysis

Through this paper, we demonstrate the developments in the satellite remote sensing and GIS using their applications in coastal, urban and mountain environments.

Coastal Zone Studies: Coastal environments are characterized by unique habitats such as mangroves and coral reefs which remain partly under water (Figure 1) and therefore pose some challenge compared to other ecological domains. It is also difficult to frequently carry out ground-based studies in such environments because of complexity and dangers of wild fauna. Therefore there are increasing efforts to develop satellite data based techniques for mangrove studies, which have obvious advantages of providing more reliable and accurate information due to synoptic view, multispectral, multi-temporal capabilities. Moreover, advancements in digital image processing, availability of GIS techniques and use of GPS while collecting ground truth data at selected locations have further facilitated research work in the mangrove eco-systems. Recent research has also seen the emphasis on employing the spectral differences between various mangrove communities to understand their spatial distribution and ecological importance. More importantly, the emphasis is on exploiting the spectral signature captured by multiple sensors in various domains of electromagnetic spectrum to map the spatial distribution of mangroves. For example, Kumar et al. (2017) employed the signatures of mangrove communities captured by RISAT-1 andResourcesat-2 LISS-IV satellite sensors to improve mangrove community discrimination in the Marine National Park and Sanctuary (MNP&S), Gulf of Kachchh, Gujarat, India. These authors found that merging the signatures captured in microwave domain of electro-magnetic spectrum by RISAT-1 (Radar Imaging Satellite-1) and those captured by LISS-IV (Linear Imaging Self-Scanning-IV) sensors did improve the classification of mangrove communities.

Figure 1. Mangroves (*Rhizophora* sp.)

Another important area relates to understanding the impacts of sea level rise on coastal environments. The average global sea level has increased by 76 mm in the last 25 years due to increasing concentrations of green house gases in the atmosphere (Willoughby et al., 2020). The main risks arising from a rising sea level are shoreline erosion and degradation potentially threatening the lives and properties of coastal population. Using satellite data, NASA (National Aeronautics and Space Administration) has developed a visualization tool which showcases the impact of sea level rise along the Indian coast using IPCC (Intergovernmental Panel on Climate Change) projections (Figure 2) (https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool).

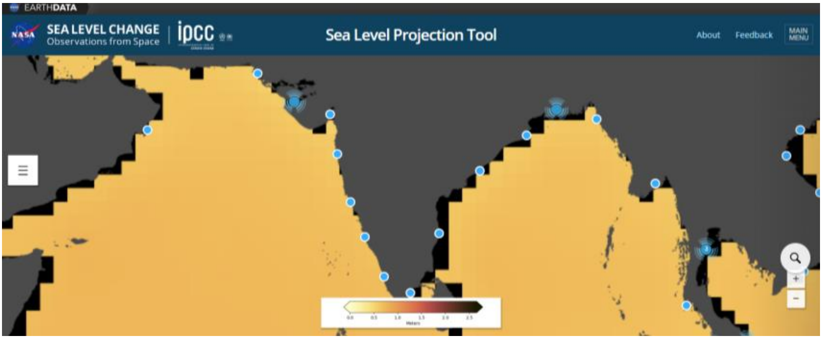

Figure 2. Sea Level Projection Tool developed by NASA

The tool is very helpful in understanding the future sea level rise along the coastal belts and can be used for urban planning and mitigation accordingly.

Urban Studies: The world is urbanizing at a rapid pace. By 2050, nearly 68% of people will live in cities (UN, 2018). Increased urbanization has modified many biophysical processes. One of the alarming concerns of urbanization is a rapid increase of local air temperature as well as land surface temperature. Higher temperature in urban areas, relative to the surrounding peri-urban /rural areas, gives rise to what is popularly known as Urban Heat Island (UHI). The intra-city urban heat islands form when the land cover dominated by natural vegetation, crops and water bodies is replaced by heat-absorbing impervious surfaces composed of materials like concrete and asphalt (Simwanda et al., 2019; Buyantuyev and Wu, 2010). These urban heat islands occurring continuously over the same area for a few days create heat waves and adversely affect human health. It is therefore important to spatially identify the distribution of UHIs within the cities so that appropriate mitigation and adaptation measures can be framed and loss of human lives in such areas can be minimized. However, the ground-based temperature measurements are mostly taken at a point and may not sufficiently represent the temperature of the entire locality. Satellite remote sensing provides an attractive alternative as the satellites cover a large swath of the earth's surface. In particular, the land surface temperature measured by satellites in the thermal infrared region of the electromagnetic spectrum has been used by various researchers across the globe. For example, Kumar et al. (2019) identified UHIs within the Rajkot city of India using Landsat satellite data pertaining to May 2018. They identified localities within the city experiencing land surface temperatures in excess of 42 °C (Figure 2).

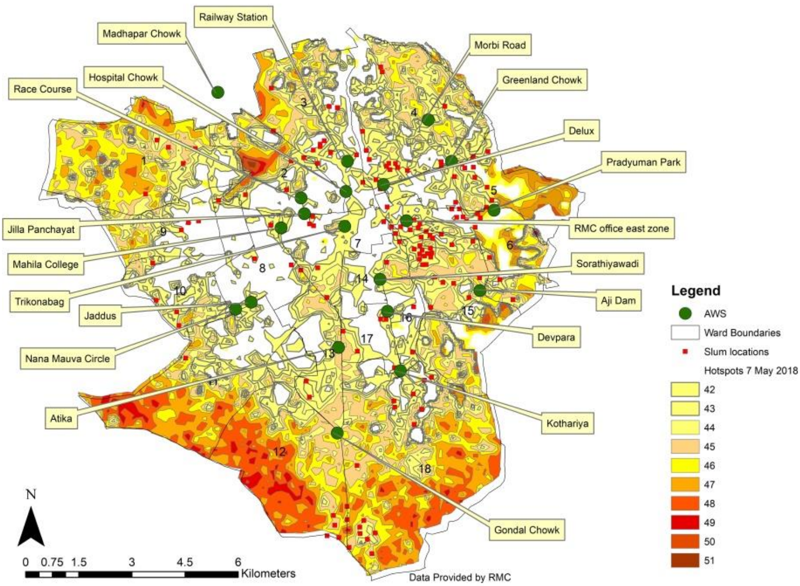

Figure 2. UHIs within the Rajkot city of India
(Source: Kumar et al., 2019)

The urban planners can use such maps to prepare the city in the advent of heat waves.

Studies in Mountain Environments: Remote sensing and GIS offer a variety of resources to study the mountain environments, in particular with respect to urbanization and disaster management. Mountain areas are prone to various disasters and satellite data provide a repetitive and cost-effective way to understand the changes in the environment and manage the disasters in a way to minimize the loss of lives and properties. Lahiri et al. (2019) used satellite data and GIS to map the landslide and flash floods in Gangtok city of Northeast India. Their work led to the identification of wards which are more susceptible to disasters like landslides and floods in Gangtok.

Kumar et al. (2021) used Landsat satellite data to study the impact of urbanization in another mountainous city named Shillong. These works are very useful for understanding the dynamics of mountains areas and planning in advance so that people's lives and properties can be saved from geological disasters.

Conclusion: The potential of satellite data is virtually in every walk of life. The need of the hour is to develop the human resource to capitalize the vast wealth of remote sensing data and tools like GIS. This is all the more required to prepare the world as we move into Anthropocene era in which the impacts of climate change can be catastrophic in some areas.

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