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EDITORIAL

Remote sensing is a powerful tool, but not a panacea in itself

Remote sensing (RS), in particular spaceborne remote sensing has come a long way, ever since the successful launch of Earth Resources Technology Satellite-1 (renamed as LANDSAT-1) in 1972 by the National Aeronautics and Space Administration (NASA) of the United States. A large number of remote sensing satellites launched subsequently by different national space agencies, including India and a few commercial private operators have provided a variety of data to study the earth's surface and, measurements of the atmosphere and the oceans. These datasets have been utilized in a number of programmes to inventory earth's resources, study their condition and investigate changes over a period of time. A variety of application programmes, viz. agricultural crop production forecasts at national/sub national level, forest extents, identifying areas of deforestation, inventory of surface water bodies, snow cover, glaciers and their retreat, coastal zones, urban areas and their sprawl, geological resources, desertification, updation of topographic and thematic maps, etc., have been developed and used in many countries to advance national development. Data obtained from some of the specific satellites devoted to ocean and atmospheric observations have been used to improve ocean state forecasting, exploitation of some of the ocean resources and improved weather forecasting. Satellite observations have found an important and crucial role in facilitating early warning of some of the disasters, in monitoring and mitigation exercises, and in damage assessment. RS data have also been used in studying earth system science and in understanding various earth processes. RS has thus assumed the role of an indispensable tool.

Many international organizations, forums have strongly encouraged adoption of this technology in solving many of the issues related to sustainable development; the most recent being the UN flagship programme of 2030 Global Agenda of Sustainable Development. Many of the policy makers, political leadership, implementing authorities have started believing RS to be a solution for all problems of resource management and are making stringent demands on the technology. Some of the enthusiastic practitioners of the technology are joining this band wagon. Obviously in some cases, this leads to disappointment and sometimes negative perception and overselling of this technology. We need to critically examine the potential usefulness and also the limits of utility.

Remote sensing of the earth refers to studying the earth surface features through measurements made from instruments placed on platforms stationed above the earth surface. In case of passive remote sensing, the reflected solar radiation and that emitted by the earth surface is detected at different wavelength regions, viz. ultraviolet to microwaves, at different scales/details and at frequent time intervals. In order to provide observations at the same illumination conditions, the sensors are placed on platforms in sun synchronous orbits. To provide constant surveillance, for example to monitor the movement of cyclones, some sensors are placed in geostationary platforms. While some sensors can operate in passive mode using the sun's illumination or the earth's emission, some use their own source of electromagnetic radiation (active sensors, like RADAR or a LIDAR). Ability to measure polarized radiance becomes necessary as well, in some instances.

Data obtained from these sensors, thus consists reflected/emitted radiation values at different wavelength ranges corresponding to field of view of the instrument. One needs to subtract contribution of the intervening atmosphere to arrive at the values corresponding to the surface object. A set of such reflectance/emittance values corresponding to the earth surface are termed as spectral signatures and are used to characterize/classify the object. Texture, the spatial characteristic of the surface, association, size, shape add other dimensions to classification. However, signatures are not deterministic but statistical in nature. So, identification and or classification of the surface has certain uncertainty depending on the natural heterogeneity of the surface feature. As the resolution of the sensor increases, this uncertainty increases as well. The spectral, spatial and radiometric characteristics of the sensor together affect target surface identification. If the spatial resolution is decreased, a large number of ground resolution elements are likely to include a greater proportion of boundary information and, secondly if the spatial resolution is increased, the smaller ground resolution elements are likely to pick up the fine details of the field contents, resulting in increased spectral overlap (scene noise) between cover classes. Generally, it is believed that higher the spatial resolution, better is the accuracy of classification but it is not always true. With higher spatial resolution, spectral heterogeneity increases, leading to higher overlap between classes and decreased classification accuracy.

Physical/geophysical parameters of the remotely sensed objects are derived inverting radiance values received at the top of atmosphere. Precision at which the radiance is detected or surface reflectance is estimated through atmospheric correction model determines the accuracy of the biophysical products. They need to be validated and cross calibrated. In this entire chain of computation there are uncertainties, which may get compounded. Hence, RS data, while being very useful, also exhibit limitations in providing end solutions in a number of application areas.

Agricultural crop production forecasting is an important area of RS application. Crop production forecast comprises determining/estimating area under a specific crop grown in a given region and then multiplying it with the likely yield per unit area of the crop. Determining area under a specific crop requires identifying all pixels belonging to that crop. If the area under a pixel has more than one crop cover, then it introduces error in our counting. This happens in particular to the pixels at the boundaries of a class, termed as mixed pixels. Various factors such as fragmented fields, diversity in crop growth caused by cultural practices, varietal differences, intercropping, mixed cropping all add to uncertainties in the final estimation of area under a specific crop. On the other hand, if one uses statistical sampling for crop identification and then one aggregates, it has its own uncertainties. Forecasting yield is a much more complicated process. Grain yield is the culmination of the crop growth influenced by a large number of variables. What RS measures is the reflected radiation predominantly from the crop canopy. This provides an estimate of crop vigour as manifested by the leaf area index, a proxy, perhaps for the biomass. However, conversion of this biomass into the grain yield is not necessarily a linear process. Grain yield, in case of wheat may be influenced by the ambient temperatures during the grain filling stage, not necessarily manifested in RS data. So, one requires to run process models, wherein only a few measurements may be available from remote sensing. While reduction in yield due to moisture stress may manifest in some RS indices including thermal, effect due to pest and disease may only be a post-mortem exercise.

While forest extent, types and density may be quite amenable to RS data, estimating biomass has similar constraints/limitations whether through process models or mensuration techniques. Spread of surface water bodies is a given application of RS data, estimating total volume of water would require knowledge of various cross sections of the water body, which may require *in situ* measurements. While snow cover is readily available from the RS data, snow melt run-off estimation would in addition require snow depth, temperature regimes, and modelling. Characterizing glacier retreat is another multi-dimensional issue. Identifying genesis of cyclones, predicting their track and landfall point may have become routine using RS data, accurate prediction of intensity/wind speeds needs further efforts. While damage estimation due to landslides and earthquakes using RS data is quite common, early warning of these disasters using RS and other data, has been only a research area.

In view of its ability to make measurements in both optical and microwave frequencies over large areas very frequently, remote sensing has been a great boon to oceanography in many ways. A large number of parameters such as sea-surface temperature (SST), sea-surface winds, sea-surface salinity, sea-surface heights, waves, ocean colour are amenable to RS measurements. Not all parameters are direct measurements. For example, sea-surface wind vector is estimated using back scattering coefficient of the sea surface, influenced by the roughness, which in turn is a measure of wind vector. Most of the properties amenable to RS are related to sea surface and vertical profiles are not easily available. While locating potential areas of schools of fish using ocean colour and SST has been a very popular application of remote sensing, it is limited to being probable and also not species-specific. While remote sensing of the cloud top temperatures, motion vectors, etc. has been greatly facilitated by the sensors placed on geosynchronous platforms, there are certain limitations in measuring vertical profiles of temperatures, humidity to the desired levels of details.

In recent years, there have been great advances in instrumentation and measuring abilities of RS technology. Spatial resolutions have improved from tens of metres a couple of decades ago to fraction of metres these days. These high-resolution images, combined with ever growing smart phone technology, has led to new dimension of RS applications in terms of location specific services, transportation analysis, crowd sourcing and also navigation to answer everyday's query of the human 'where is what?'. Drone-mounted sensors are the new entrants. It was the hyperspectral data onboard the Chandrayaan-1 mission which answered if there is water on moon's surface. Constellation of identical satellites in staggered mode/formation flying are able to provide very frequent measurements to facilitate observing dynamic phenomena. Open and free access data policies of various international space agencies are making it possible for every interested user to access data and products quite easily from his desk. Spaceborne remote sensing has come a long way and it could be used as an indispensable tool over a period of four decades. However, one should also keep in view the associated uncertainties.

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