Landsat again – continuing remote sensing, monitoring, mapping and measuring

On 11 February 2013, the National Aeronautics and Space Administration (NASA), USA, launched the Landsat Data Continuity Mission (LDCM) satellite (Landsat 8), continuing the record-breaking 40 years of Earth observations under the Landsat programne. The Landsat data are freely shared with the global scientific community, and are used by a wide range of researchers for mapping and monitoring natural resources and decision-making that provide maximum benefit for the environment and people. Here we touch upon the brief history of Landsat series, discuss the specifications of Landsat 8 and prospective applications of its data pertaining to India, in continuation with earlier utilization of such data.

The journey of space remote sensing started with Earth Resources Technology Satellite (ERTS), the first step to put remote sensing instruments in space to get a quick inventory of and manage the Earth's resources[1]. ERTS, later named Landsat 1, was launched on 23 July 1972 with the intent to study, monitor and assess the Earth's land masses. The satellite carried two instruments: a camera system called Return Beam Vidicon (RBV) and Multispectral Scanner (MSS). The MSS recorded data in four spectral bands (green, red and two infrared bands) were found to be superior to RBV after the data were captured. The satellite acquired over 300,000 images and operated until January 1978, enduring its designed lifespan by five years and exceeding all expectations of quantity, quality and impact of the information extracted.

Following the success story of Landsat 1, Landsat 2 was launched on 22 January 1975 carrying the same sensors as its predecessor. On 25 February 1982, after seven years of service, it was taken-off from operations and was officially decommissioned on 27 July 1983. Subsequently, Landsat 3 was launched on 5 March 1978, carrying the same sensors as Landsat 1 and 2 with an additional thermal band. However, the thermal channel failed shortly after launch. In March 1983, Landsat 3 was put into standby mode and was decommissioned on 7 September 1983.

Landsat 4, which was significantly different from its predecessors, was launched on 16 July 1982. In addition to MSS, it carried a new instrument known as Thematic Mapper (TM). The TM had seven spectral bands (blue, green, red, near-infrared, mid-infrared (two bands) and thermal infrared). It experienced severe problems with solar panels and data downlink systems within the first few years of its launch and was finally decommissioned in 2001. The next in the series, Landsat 5 with similar specifications was launched in 1 March 1984. It was operational till 6 January 2013 (with the help of its MSS instrument). On 5 October 1993, the launch of Landsat 6, carrying an Enhanced Thematic Mapper (ETM) failed after the velocity necessary to reach the orbit, was not obtained.

Landsat 7, replicating and advancing the capabilities of Landsat 4 and 5 was launched on 15 April 1999. The on-board Enhanced Thematic Mapper Plus (ETM+) included a panchromatic (PAN) band with 15 m and thermal IR with 60 m spatial resolution. ETM+ included additional features. The set up and characteristics proved it relatively more versatile and effective, for global change studies, land-use/land-cover monitoring and assessment, and large area mapping than its designed forebears. It worked flawlessly until May 2003, when spaces of missing data started appearing due to hardware failure (loss of its scan line corrector (SLC)). Therefore, in order to fulfil the requirements of the user communities for full coverage single scenes, data from multiple acquisitions were being merged to fill the data gaps arising due to SLC-off condition. Figure 1 shows the Landsat series timeline[2].

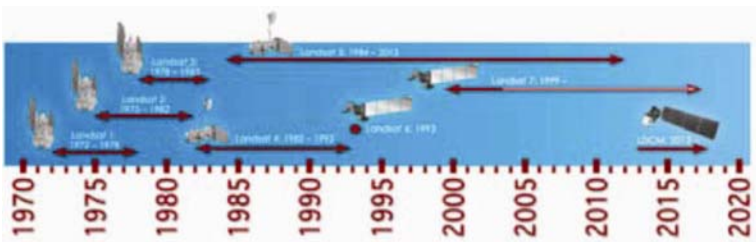

Figure 1. The Landsat series timeline. (The small white arrow within the Landsat 7 arrow indicates the collection of data without the scan line corrector. The Landsat 5 arrow stops when Landsat 5 was officially decommissioned.) Source: Ref. 2.

In October 2008, USGS made all Landsat 7 data freely available to the general users. In December 2009, all the data captured during Landsat missions in the USGS archive followed the same suit. This opened a new window of opportunities to explore and use remotely sensed satellite images for academic, research and even commercial purposes. The free access to Landsat data was exploited by countries all over the globe, including India. Before that, Landsat was used for many application activities in different countries. For example, the Indian Space Research Organisation (ISRO) used Landsat from the early 1970s by becoming a principal investigator in the Landsat programme, which led to the Indian Remote Sensing Programme. The committee looking at the possible remote sensing programmes in India, presented a report in 1976 which recommended an optical MSS similar to that carried by Landsat to be launched by an Indian launch vehicle[3]. Till the indigenous satellites were launched, Landsat was of prime interest for many experimental and operation activities in the country.

Landsat data have been used for scientific research in India since the 1970s. These datasets have been widely employed for studies covering various fields of research (geology, hydrology, agriculture and coastal studies to mention a few). Figure 2 shows a word cloud to get an overall perspective and direction of research using Landsat data in India by Indian researchers. The figure illustrates significant research from 1975 to the present (March 2013), published in peer-reviewed journals. However, the usage of Landsat dataset in India is much beyond this. They have been used for forest management such as assessing forest cover for the first time[4] apart from assessing vegetation cover, monitoring forests at various scales[5] from District to State and to national level, and for forest characterization. For geological studies, researchers have used Landsat TM and ETM+ data for mapping sodicity and estimating its magnitude in the Gangetic plains[6]. The data have been explored by scientists to study structures of Precambrian metamorphics in Singhbhum[7]. The data have been also utilized for mapping saline soils in northwestern parts of the country[8]. In the light of the current status of a rapidly urbanizing nation, many Indian cities are being studied for urban sprawl and its impacts through Landsat data-derived information[9]. Coastal ecosystem and biodiversity studies also utilize Landsat-derived information for monitoring and analysis[10]. Nowadays researchers are increasingly exploring the data for climate change studies as well. The data have also found their way to environmental planning and policy framing through various environmental impact assessment (EIA) studies[11]. Landsat data are widely being employed not only to cover diverse issues where they could be applied, but also to study them across the geographical extent of this vast nation. The applications of using Landsat data prove to be highly beneficial for making decisions, not only at the grassroots level, but also to support policies and protocols at the national and sub-national level[12] and for issues aimed at sustainable and societal benefit. However, attempts to use Landsat data at the national level have not been reported.

Since Landsat datasets were available free, many Indian scientists, academicians and researchers started relying heavily on them. As mentioned above, the utility of information produced with Landsat data and their applications got further enhanced for earth surface analysis (in fields of soil science, forestry, agriculture, biodiversity, geology, hydrology, meteorology, etc.). The Landsat data have also been used for disaster management, hazard analysis and damage assessments[13]. This being the oldest source of the space remote sensing supports all studies that date back to the 1970s and 1980s; however, Landsat data have been comprehensively used by many researchers during the last two decades (1990s and 2000s). To some extent an undocumented usage of this data is geometric correction of other satellite datasets using the Landsat scenes as a master for image-to-image rectification. The usage has been mostly at the regional and state levels, and in many cases, at the District and city levels.

One of the major advantages of the Landsat series (TM and ETM+) is the availability of thermal band, which is unlikely with other medium-resolution sensors, including Indian satellites. This has supported many environment-related issues which require information based on the thermal band. For example, delineation and mapping of wastelands was conducted by digital analysis of Landsat TM data[14]. The ground temperature and depth of subsurface coal fire in the Jharia coalfield was estimated with Landsat TM data[15]. The absence of thermal band due to failure of Landsat 7 recently has compelled researchers to exploit MODIS and other thermal sensors like ASTER.

With the image quality of Landsat 7, now being partially compromised in addition to the factor of limited fuel, a new satellite system was required to continue the journey of capturing and distributing the medium-resolution satellite data worldwide. On 11 February 2013, NASA launched the LDCM satellite, continuing the record-breaking 40 years of Earth observations. It is the 8th satellite in the Landsat series (aka Landsat 8). This will continue providing unbiased worldwide view, with the standardized scientific data – information crucial for enhanced tracking of world's natural resources. The payload consists of two science instruments: (i) the Operational Land Imager (OLI) and (ii) the Thermal Infrared Sensor (TIRS). Figure 3 shows the bandpass wavelengths for Landsat 8 OLI and TIRS sensor, compared to Landsat 7 ETM+ sensor[16]. These two sensors are planned to provide seasonal coverage of the global land mass at a spatial resolution of 30 m (visible, near infrared, short-wave infrared), 100 m (thermal) and 15 m (panchromatic). The OLI provides two new spectral bands [cirrus (infrared) and coastal (deep blue visible)], one tailored especially for detecting cirrus clouds and the other for coastal zone observations and water resources, as well as the heritage Landsat multispectral bands. Operating on the complex principles of quantum mechanics, the TIRS will collect data in two more narrow spectral bands of the thermal region formerly covered by one wide spectral band on Landsat 4–7. Additionally, the bandwidth has been refined for six of the heritage bands to avoid atmospheric absorption features. For example, band 5 in OLI (NIR, 845–885 nm) is redesigned to exclude an atmospheric water vapour absorption feature at 825 nm, which is present in the middle of ETM + NIR band (band 4; 775–900 nm). The newly available coastal band will be primarily useful for ocean colour observation in coastal region and estimating aerosol concentration in the atmosphere, whereas the main application area of the blue band will be in bathymetric studies and discriminating

Figure 2. This is a word cloud to get an overall perspective and direction of research using Landsat data in India by Indian researchers. A detailed survey of significant research from 1975 to the present (March 2013) was conducted to generate the cloud. The size of the font is directly proportional to the frequency of the corresponding term. It can be observed from the cloud that Landsat data has been used (i) across scales: city, district, state, region; (ii) for varying purposes: monitoring, mapping, assessment, analysis, detection, etc. and (iii) in different thrust areas: geology, forest, coast, groundwater, wetland, river, urban, coalfield and others.

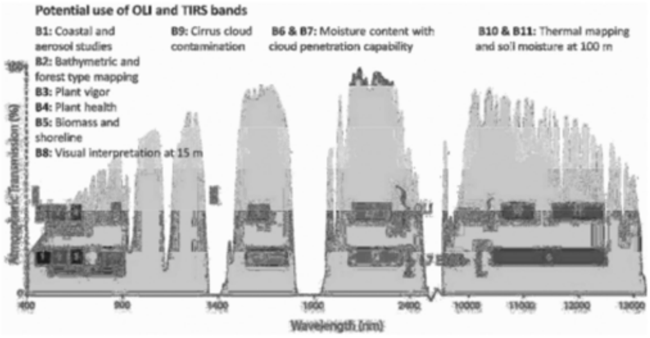

Figure 3. The potential use of each band is overlaid on the bandpass wavelengths for Landsat 8 OLI and TIRS sensor (bandpass wavelengths for Landsat 7 ETM+ sensor are shown for comparison; modified from ref. 16).

vegetation from soil, and coniferous from deciduous forests. The traditional green, red and NIR bands will have most applications in studying vegetation. NIR band can also be used for shoreline detection. Use of SWIR 1 and SWIR 2 bands, to estimate moisture content in soil and vegetation is further enhanced by their capability to penetrate thin clouds. Inclusion of cirrus band will be helpful for detecting cirrus cloud contamination. Panchromatic band will not only aid in better visual interpretation, but also to distinguish between vegetative and non-vegetative features.

PAN and TIRS bands in Landsat 8 have the highest spatial resolution among all the freely available datasets (considering the SLC error in ETM+ and absence of thermal band in EO1-ALI). Therefore, TIRS bands will be of immense importance, in fine-scale thermal mapping for urban heat island analysis, soil moisture, surface energy flux estimation and forest fire detection. The satellite is expected to return 400 scenes per day to the USGS data archive, increasing the probability of capturing more cloud-free scenes of the global land mass. Each scene dimension is 185 km cross-track by 180 km along-track. The spectral coverage and radiometric performance (accuracy, dynamic range and precision) are designed to detect and characterize multi-decadal land-cover change in concert with archived dataset captured by its predecessors[17].

Thus, Landsat 8 data will help us monitor the cultivation of food crops, quantify precious water resources, and track deforestation globally – all of which are key ingredients in decision-making for agriculture, climate research, disaster mitigation, ecosystems, forestry, human health, urban growth and water management. Such applications are possible largely because of the open data policy of the NASA and USGS partnership programme, which ensures calibration of instruments, transporting data from the satellite, rectification of datasets using information from ground stations, and to network, archive and distribute the entire dataset to the public. Like its predecessors, data from Landsat 8 can be downloaded freely[18–20]. This encourages scientists and researchers, worldwide, to fully utilize this open and free access space remote sensing data.

The open data policy can have a true sense, only when the data are available for users around the globe with least technical hurdles and also free of cost. Learning and implementing such policy by the other space organizations, would certainly steepen the learning curve and operational activities. This would certainly contribute in establishing and maintaining a national natural resources repository which will enable information services for good governance, citizenship and commerce. This is also pressingly required to be done as a part of capacity building initiatives for academic and research institutions and for the developing world.

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