American Journal of Remote Sensing
2022; 10(2): 39-49
http://www.sciencepublishinggroup.com/j/ajrs
doi: 10.11648/j.ajrs.20221002.12
ISSN: 2328-5788 (Print); ISSN: 2328-580X (Online)

Remote Sensing for Land Resources: A Review on Satellites, Data Availability and Applications

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To cite this article:
Winfred Mbinya Manetu, John Momanyi Mironga, Jackob Haywood Ondiko. Remote Sensing for Land Resources: A Review on Satellites, Data Availability and Applications. *American Journal of Remote Sensing*. Vol. 10, No. 2, 2022, pp. 39-49. doi: 10.11648/j.ajrs.20221002.12

Received: October 3, 2022; **Accepted**: December 1, 2022; **Published**: January 10, 2023

Abstract: Remote sensing is a technology that offers a unique opportunity of gathering land information by measuring and recording its emitted and reflected energy usually from a satellite or an aircraft. The capabilities of remote sensing satellite data in mapping, monitoring and managing land resources are intensifying with the rapid advancements in satellite technology. In addition, increased users demand in sustainable management of land resources has escalated the need for remote sensing technology. As a result, this article presents an overview of the remote sensing satellites that are best for mapping land resources and monitoring, focusing specifically on the necessary satellites, data availability and key land application areas. Currently, several remote sensing satellites are providing microwave, multispectral and hyperspectral data with a wide array of spatial, temporal and spectral resolutions used on land applications. Microwave remote sensing has seen the development of both active and passive remote sensing systems for remote sensing activities. Consequently, microwave data is now available with high spatial resolution and providing land information in all cloudy weather condition. On the other hand, optical remote sensing is providing space-based remote sensing data in a variety of spatial, spectral and temporal resolutions meeting the needs of many land applications. Similarly, hyperspectral remote sensing is providing digital imagery of earth resources in many narrow contiguous spectral bands. Additionally, other remote sensing techniques like Unmanned Aerial Vehicles (UAV) and Light Detection and Ranging (LiDAR) have helped in deriving detailed information of land resources to support land related studies. Besides having commercial satellites that are providing satellite data at a high cost, today several remote sensing data have been made available from open data sources and users can freely search and download areas of interest.

Keywords: Land Resources, Remote Sensing Satellites, Data Availability, Land Resource Monitoring

1. Introduction

Remote sensing is process of obtaining information about objects or areas at the Earth's surface without being in direct contact with the object or an area. It provides several techniques which infers surface parameter using reflected or emitted energy, at a given period [1]. Remote sensing has undeniably remained one of the most essential technology in research fields over the last decades because of its capability to offer a unique opportunities in obtaining information about the land resources with wide details [2]. Land resources largely include both natural and man-made features such as vegetation cover, water surface, soil, terrain, geology, land use / land cover, geomorphology etc. of the earth surface [3]. The satellite data hourly to monthly temporal resolution, wide area coverage spatial resolutions, and with a synoptic view of the Earth's surface has been used as information source for studies related to surveying, agriculture, environmental monitoring and management, urban planning as well as mapping and monitoring land resources [4-7].

Additionally, remotely sensed data have modernized the land applications to a large extent by integrating high multispectral, microwave and hyperspectral resolution features [8]. Satellite data availability and continuity has a significant impact on the use of the satellites simply because long-term data allows tracking the causes and spatial-temporal pattern of changes happening on the earth surface features. Currently, numerous satellites equipped with high resolution cameras are orbiting the Earth and majority of these are relaying data to the Earth. However, in recent past years many countries and particularly developing countries have not been able to afford satellite data due to high purchase costs and it's only available to countries that can pay for it. Luckily, nowadays much satellite data and especially medium to low spatial resolution is open for access and can be downloaded free of charge by users [9, 10]. Similarly new data policies promoting free and open access to satellite data are expanding the use of satellite data products [11]. At present, a number of commercial and non-commercial remote sensing satellites are providing vast information on land resources for the purposes of mapping, monitoring and management.

Earth Resource Technology Satellites (ERTS), later named as Landsat-1 was the first remote sensing satellite to be launched in the year 1972 and was widely used for obtaining land information [80]. Other seven satellites (Landsat 2, 3, 4, 5, 6, 7, and 8) in Landsat programs were subsequently launched over the period of years and became important sources of multispectral optical remote sensing data for many land surface applications [80]. India launched its first remote sensing satellites as Indian Remote Sensing Satellite (IRS) 1A in March, 1982 and continued as IRS series and new generation satellite series of Resourcesat for varied land applications in the country [80]. Wide range of spatiotemporal, radiometric and spectral resolution data has made Resourcesat one of the best sources of satellite data for land resource applications [12, 80].

Currently several classes of satellites such as PRISMA, ALOS 2 & 3, Sentinel-2a & 2b, SHALOM, GeoEye1, RapidEye, TerraSAR-X, World View-2 and 3, SPOT-6 and 7, etc. are greatly contributing in providing reliable and precise land information at large scale. Several other remote sensing satellites are planned to be launched in the world to cater for the extensive need for effective utilization of land resources to keeping the environment in sustainable manner.

Globally, remote sensing data is widely being used for various land activities such as crop inventory and crop yield estimation, [13, 14], forest types and cover mapping, [15], mapping and monitoring of water resources, [16-18], soil resource analysis, [19], waste land mapping, [20], land degradation mapping, [21], coastal mapping, [22], geological and geomorphological mapping, [23, 24], urban planning, [25], disaster management support, [26] and environmental applications, [27] amongst other land applications.

Therefore, the present paper provides a brief review of current remote sensing satellites that are being used in studying and analyzing land resources.

2. Discussion

2.1. Microwave Remote Sensing Satellites

Microwave remote sensing uses wavelength between 1 cm and 1m of electromagnetic radiation to gather information on the earth's surface. Compared to other electromagnetic bands like visible and infrared, microwave wavelengths are longer making them have unique properties that are key for remote sensing purposes. Longer wavelength microwave radiation can penetrate through fog, cloud cover, dust and all but the heaviest rainfall since longer wavelengths are not susceptible to atmospheric scattering which affects shorter optical wavelengths. Consequently, this important feature makes microwave remote sensing satellites to provide better land observation capabilities as they can work in any weather condition or environment to provide valuable information of land surface. Microwave remote sensing involves both active and passive forms of remote sensing to record land observation and provide important information on diverse land applications.

In active microwave remote sensing, radar transmits electromagnetic radiation to the earth surface. The active sensor then measures the amount of radiation scattered back at the same position as where the radiation was originally transmitted. In passive microwave sensing all objects emit microwave energy of some magnitude to the earth surface. A passive microwave sensor then detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature and moisture properties of the emitting object or surface. Passive sensors (Radiometers) are aimed at providing atmospheric and oceanographic remote sensing data from space-based platforms, whereas Active sensors (SAR, Scatterometer, Altimeter) are dedicated for land as well oceanographic applications [28].

Microwave radiation can penetrate into upper layer of soils and measure the below surface soil contents, [29]. Some of the major passive microwave radiometers includes; Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) sensor on Aqua satellite, NASA's Scanning Multichannel Microwave Radiometer (SMMR) on Nimbus-7, a series of DMSP Special Sensor Microwave/Imager (SSM/I) sensors, Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager (TMI) and Soil Moisture and Ocean Salinity (SMOS) mission by ESA [30-33],. Currently these microwave passive sensors are used largely for providing universal soil moisture products at very coarse spatial resolution to user community for various land applications [34, 35].

On the other hand, active microwave sensor like synthetic aperture radar (SAR) provide their own source of energy to record backscatter radiation through SAR system. Active microwave remote sensing includes data in wavelength region of P-band (30-100cm), L-band (15-30cm), S-band (7.5-15cm), C-band (3.8-7.5cm), X-band (2.4-3.8cm) and K-band (0.7-1.7cm) and provides data in high spatial resolution, [36]. X-band SAR data can be acquired at a spatial resolution better than 5m which allows more detailed characterization of forest canopy structure [37, 80]. Also, X-band is useful for military purposes, terrain mapping and surveillance [38, 80]. Penetration capability of C-band is limited and restricted to the top layers whereas L-band penetrates into soil, vegetation, [39]. The C- band SAR sensor onboard the RISAT-1 satellite is found to be very useful for resource monitoring and disaster monitoring, [28]. P-band (30-100 cm) not used much and being used for research and experimental applications. In addition, SAR active sensors acquires images in dual mode: 1) like-polarization and 2) cross-polarization (HH and HV; or VV and VH). The quad polarization mode gives four linear polarizations: HH, VV, HV, and VH as amplitude and phase, [40]. In Remote sensing data from SAR offers detailed information which help in mapping and monitoring of land resources. Most importantly, SAR data has applications for land use/land cover, vegetation, forest degradation, forest cover, crop type and monitoring, soil moisture and wetland mapping, etc. [37, 40]. SAR data have been used in combination with optical data for improved crop classifications and mapping land management regimes.

Table 1. *Microwave Remote Sensing Satellites.*

Satellite	Sensor	Spatial Resolution	Revisit time	Launch (Date/Country)
KOMPSAT-5	X-band SAR	High Reolution-1m Standard mode-3m Swath mode- 20m	28 days	22 August 2013, South Korea
PAZ	X-band SAR	Spotlight: Imagery of size 10 km x 5 km @ 1m resolution, or 10 km x 10 km at 2 m resolution ScanSAR: Imagery on a 100 km swath @ 15 m resolution Stripmap: Imagery on a 30 km swath @ 3 m resolution (single polarization), or 15 km swath @ 6 m (dual polarization).	24 hours	22 February 2018, Spain
TanDEM-X	X-band SAR	Stripmap-1m ScanSAR-18.5m Wide ScanSAR-40m Staring Spotlight-25m HR Spotlight-1m	11 days	21 June 2010, German
TerraSAR-X	X-band SAR	1m-16m	11 days	15 June 2007, German
HJ-1C	C-band SAR	5m-20m	4 days	2006, China
SOACAM 1a, b	L band SAR	7 m-100 m	16 days	SAOCOM 1A-8 October 2018, and August 2020 (SAOCOM 1B) (planned), Argentina.
ALOS 2	L-band SAR	3m	14 days	24 May 2014, Japan
JERS	L-band (SAR), Nadir-pointing optical camera (OPS) and side-looking optical camera (AVNIR).	SAR-18 m (range) x 18 m (azimuth, 3 looks) OPS- spatial resolution = 18.3 m	44 days	11 February 1992, Japan
Radarsat 2	C-band SAR	3m-100m	24 days	14 December 2007 Canada
Radarsat 3	C-band SAR	3 m-100m	24 days	12 June 2019, Canada
Sentinel 1a & b	C-band SAR	5 m - 25m	12 days	Sentinel-1 on 3 April 2014 and Sentinel-1B on 25 April 2016, Europe
Risat	C-band SAR	1m-50m	25 days	26 November, 2008, India
Risat 2B	X-band SAR	Imaging modes of 1m × 0.5m and 0.5m × 0.3m		22 May 2019, India

Additionally, other microwave remote sensing satellites like RADARSAT-1 and RADARSAT-2, TanDEM-X, European Remote Sensing (ERS-1 and ERS-2), Sentinel-1A and 1B, Advanced Synthetic Aperture Radar (ASAR), RISAT-1 and RISAT-2, Japanese Earth Resources Satellite (JERS-1), KOMPSAT-5, TERRASAR-X and Advanced Land Observation Satellite (ALOS-1), are providing precise and valuable information for major land applications such land monitoring of forests, water, soil and agriculture, forest vegetation biomass estimation, marine monitoring of the maritime environment, sea ice observations and iceberg monitoring, forecasting ice condition, mapping oil spills, [32, 33, 40].

2.2. Optical Remote Sensing Satellites

Optical remote sensor makes use of visible, near infrared and short-wave infrared wavelengths of the electromagnetic spectrum. It obtains information about the earth's surface features by detecting and recording the solar energy reflected from targets on the ground. Multispectral optical remote sensors are providing earth information with spatial resolution ranging from coarse to fine resolution. High resolution data with 5-15 spectral bands (visible and infrared wavelength regions) has improved in generating information being used in applications for land resource mapping, monitoring and management [80]. Panchromatic sensor utilizes visible spectral band to provide very high resolution data of less than 1m resolution that helps in providing large details of land surfaces. A panchromatic band is one band that usually contains a couple of hundred nanometers bandwidth. The bandwidth enables it to hold a high signal-noise, making the panchromatic data available at a high spatial resolution. In recent years, panchromatic data has been used in urban planning and also in generating information at cadastral level. Panchromatic stereo data is being used to generate high resolution digital elevation model (DEM).

Brief details with salient features of some of the optical remote sensing satellites are given in Table 2 below.

Table 2. *Optical Remote Sensing Satellites.*

Satellite	Sensor	Spatial Resolution	Revisit time	Launch (Date/Country)
Landsat 7	Enhanced Thematic Mapper (ETM+) sensor	MS (1-7 bands) - 30m PAN-15m	16 days	15 April 1999, USA
Landsat 8	Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	MS (Visible, NIR, SWIR) - 30m, Thermal-100m PAN 15m	16 days	11 February 2013, USA
Sentinel 2A & 2B	MS-VNIR MS-VNIR MS-SWIR	10m-60m	5 days	Sentinel-2A-23 June 2015 Sentinel-2B-7, March 2017, EU
Worldview 3	PAN MS MS SWIR	PAN 31 cm MS 1.24 m MS SWIR 3.7 m	Daily	13 August 2014, USA.
Terra- MODIS	MS-HIS	250m (bands 1-2) 500m (bands 3-7) 1000m (bands 8-36)	1-2 days	1999. US
Terra- ASTER	MS MS-IR	15 to 90 m	16 days	18 December 1999
SPOT 6	PAN MS	PAN - 1.5m MS-6.0m (B, G, R, NIR)	Daily	9 September 2012, India
SPOT 7	PAN MS	PAN - 1.5m MS-6.0m (B, G, R, NIR)	Daily	30 June 2014, India
GeoEYE 1	PAN MS	PAN-41cm MS- 165cm	3 days	6 September 2008, USA
RapidEye	MS	6.5m	Daily (off-nadir) and 5.5 days (at nadir)	29 August 2008, Germany
Resourcesat 2	MS – LISS 4 MS – LISS 4 MS - AWiFS	LISS-4 sensor -5.8 m LISS-3 sensor - 23.5 m AWiFS sensor - 56 m	5 days	12 April 2011, India
IKONOS	PAN MS	PAN 0.82M MS (NIR) 3.2m	3 to 4 days	24 September 1999, USA

MODIS is a key instrument on board two satellites (Terra and Aqua) which provide spatial resolution data in multispectral bands as open source which is freely available for wide land applications. Terra MODIS and Aqua MODIS views the entire Earth's surface acquiring data in 36 spectral bands ranging from visible to thermal region. MODIS spatial resolution varies from 250 m (bands 1–2) to 500 m (bands 3–7) and 1000 m (bands 8–36). Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. As a result, MODIS sensor generally obtains images in the morning (Terra) and the afternoon (Aqua) for any particular location on the Earth Surface. MODIS has significantly higher revisit frequency of 1 to 3 days and this makes it ideal in monitoring of vegetation health by means of time-series analyses with vegetation indices. MODIS imagery can also be used as a gap filler when there is limited moderate-resolution imagery coverage to derive crop acreage estimates. MODIS data are available freely for download from https://earthexplorer.usgs.gov/ and https://glovis.usgs.gov/.

The Advanced Very High Resolution Radiometer (AVHRR) is a broad multispectral band sensor carried on NOAA's Polar Orbiting Environmental Satellites (POES) sensing in the visible, near-infrared, and thermal infrared portions of the electromagnetic spectrum. The AVHRR sensor provides pole to pole on board collection of data from all spectral channels. Each pass of the satellite provides a 2399 km wide swath. The satellite orbits the Earth 14 times each day from 833 km above its surface. The resolution is 1.1 km at nadir. It provides Normalized Difference Vegetation Index (NDVI) Composites produced from multiple AVHRR daily observations that have been composited together to create a nearly cloud-free image showing maximum greenness. An NDVI ratio is produced from bands 1 and 2 of the AVHRR composite to produce a derived NDVI band composite. AVHRR data can be can be searched, previewed, and downloaded trough Earth Explorer. AVHRR data provide opportunities for studying and monitoring vegetation conditions in ecosystems including forests, tundra, and grasslands [41]. Other applications include agricultural assessment and land cover mapping [42]. AVHRR data are also used to produce image maps of large areas such as countries or continents and tracking regional and continental snow cover [43-45].

Landsat series which have been orbiting the Earth for over 45 years also provide multispectral data which is freely accessible to users. Landsat Program is a series of Earth-observing satellite missions jointly managed by U.S. Geological Survey and National Aeronautics and Space Administration (NASA). On July 23, 1972, in cooperation with NASA, the Earth Resources Technology Satellite (ERTS-1) was launched. It was later renamed Landsat 1. Additional Landsat satellites followed in the 1970s and 1980s. Landsat 7 was launched in 1999 followed by Landsat 8, launched on February 11, 2013. Both Landsat 7 and Landsat 8 are currently in orbit and both collecting multispectral and panchromatic data. Enhanced Thematic Mapper (ETM+) is the primary instrument in Landsat-7. ETM+ has a panchromatic band (band 8) with 15 m ground resolution. Landsat-7 captures visible (reflected light) bands in the spectrum of blue, green, red, near-infrared (NIR) and mid-infrared (MIR) with 30m spatial resolution (bands 1-5, 7). Landsat-7 also has a thermal infrared channel with 60m spatial resolution (band 6). In May 2003, there was a mechanical failure in the Scan Line Corrector (SLC). Landsat-7 images resulted in partially missing data because of the SLC failure. Landsat-8 was launched on February 11, 2013 from the Vandenberg Air Force Base in California. Landsat-8's primary two sensors are the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). These two instruments combine to generate 11 total spectral bands. Seven of the eleven spectral bands are basically consistent with ETM+ found on Landsat-7. Landsat-8 bands from the OLI sensor are coastal, blue, green, red, NIR, SWIR-1, SWIR-2 and cirrus. These 8 bands have a ground resolution of 30 meters. The panchromatic band spans a larger spectral range and has a resolution of 15 meters. Two new bands (band 10 & 11) from TIRS are long wavelength infrared. These bands have a coarser resolution of 100 meters.

Landsat satellites have the optimal ground resolution and spectral bands to efficiently track land use and to document land change due to climate change, urbanization, drought, wildfire, biomass changes and a host of other natural and human-caused changes, [46-49]. The Landsat Program's continuous archive (1972-present) provides essential land change data and trending information not otherwise available. Landsat represents the world's longest continuously-acquired collection of space-based moderate-resolution land remote sensing data. People around the world are using Landsat data for research, business, education, and other activities. Landsat satellites provide multispectral, moderate-resolution land imagery of the whole globe free of cost from 1972 till today with no user restrictions. In 2008, the owners of the data NASA and the US Geological Survey agreed to provide free access to Landsat's archives and Landsat's data and products can be browsed, searched, and downloaded through Earth Explorer or the USGS Global Visualization Viewer (GloVis). Even the data from newly launched Landsat 8 are also downloadable freely.

The Sentinel-2 mission consists of two satellites developed to provide multispectral data in order to support vegetation, land cover, and environmental monitoring. The Sentinel-2A satellite was launched by ESA on June 23, 2015, and operates in a sun-synchronous orbit with a 10-day repeat cycle. Sentinel 2A and 2B provide 10 multispectral bands with spatial resolution of 10-20m and 5 days' revisit for land applications. Together they cover all Earth's land surfaces, large islands, and inland and coastal waters every 5 days. It acquires images in 13 spectral bands ranging from visible and near- infrared (VNIR) to shortwave infrared (SWIR) wavelengths along a 290-km orbital swath. Out of the 13 bands, 4 bands (blue, green, red, and NIR) are having spatial resolution of 10 m. Four narrow bands in red and NIR region for vegetation characterization and two larger SWIR bands for applications such as snow/ice/cloud detection or vegetation moisture stress assessment are having resolution of 20 m. The resolution of the other three bands mainly for cloud screening and atmospheric corrections is 60 m. The data from the Sentinel-2 Multispectral Instrument (MSI) is available to free download from October, 2015. The European Commission provides free, full, and open access to environmental data gathered by Copernicus, Europe's Earth observation system. https://scihub.copernicus.eu/. Copernicus is an Earth observation program operated by a partnership of the European Commission (EC), the European Space Agency (ESA), and the European Environment Agency (EEA). Sentinel-2 provide a wide range of applications related to Earth's land and coastal water. The mission provides information for agricultural and forestry practices and for helping manage food security. Satellite images also provides information used to determine various plant indices such as leaf area chlorophyll and water content indexes. This is particularly important for effective yield prediction and applications related to Earth's vegetation as well as monitoring plant growth. Sentinel-2 data is also used to map changes in land cover and to monitor the world's forests.

The ASTER instrument was built in Japan for the Ministry of Economy, Trade and Industry (METI). ASTER is the only high spatial resolution instrument on the Terra platform. The natural resource management researchers are increasingly aware of the importance of DEMs in their applications. ASTER's ability to serve as a zoom lens for the other Terra instruments is particularly important for change detection, calibration/validation and land surface studies. Unlike the other instruments aboard Terra, ASTER doesn't collect data continuously; rather, it collects an average of 8 minutes of data per orbit. All three ASTER telescopes (VNIR, SWIR, and TIR) are pointable in the crosstrack direction. Given its high resolution and its ability to change viewing angles, ASTER produces stereoscopic images and detailed terrain height models. ASTER Global Digital Elevation Model (GDEM) at 30 m spatial resolution was developed jointly by the NASA and Japan's Ministry of Economy, Trade, and Industry (METI) and is available freely downloadable by users from a number of different sources including http://earthexplorer.usgs.gov/, http://glovis.usgs.gov and http:// reverb.echo.nasa.gov/reverb.

Resourcesat is also a multispectral high resolution remote sensing satellite launched in India. Resourcesat-1 satellite was launched by the Indian Space Research Organization (ISRO) on October 17, 2003, followed by Resourcesat-2 on April 20, 2011 to ensure systematic and repetitive coverage of the earth's surface. The instruments on the Resourcesat-1 and Resourcesat-2 satellites acquire four spectral bands ranging from Visible and Near-Infrared (VNIR) to Shortwave Infrared (SWIR) wavelengths. In addition, these satellite operates in a sun-synchronous orbit at an altitude of 817 km. The satellites take 101.35 minutes to complete one revolution around the earth and complete about 14 orbits per day. The entire earth is covered by 341 orbits during a 24-day cycle. The LISS-3 sensor covers a 140-km orbital swath at a spatial resolution of 24 meters with a 24-day repeat cycle. AWiFS covers a 740-km orbital swath at a resolution of 56 meters with a 5-day repeat cycle. A collaborative effort between ISRO and the U.S. Geological Survey (USGS) provides open access to Linear Imaging Self Scanning (LISS-3) sensor and Advanced Wide Field Sensor (AWiFS) data products through Earth Explorer and USGS Global Visualization Viewer (GloVis).

WorldView-3 is the first super-spectral and high-resolution commercial satellite sensor operating at an altitude of 617 km. WorldView-3 satellite gives 31 cm panchromatic band, 1.24 m multispectral band and 3.7 m short wave infrared resolution (SWIR). The satellite has an average revisit time of less than 1 day and is capable of collecting up to 680,000 km^2 per day. US Digital Globe satellite systems are the world- leading providers of high resolution multispectral satellite data of 30cm spatial resolution from WorldView-3. Because of its high resolution imageries, worldview-3 is ideal for many new and enhanced applications, including mapping, urban planning, oil and gas, disaster preparedness and response, etc [50-52].

The SPOT imagery products offer high resolution over broad areas using the SPOT satellites: SPOT 1, 2, 3, 4, 5 (archive only) and 6/7. The SPOT 6 and SPOT 7 satellites were designed to continue SPOT-5 mission in obtaining wide-swath high-resolution imagery. SPOT 6 was successfully launched on September 9, 2012 by India's Polar Satellite Launch Vehicle and was followed by SPOT 7 on June 30, 2014. The SPOT-6 & -7 satellites addresses the SPOT 5 market with improved characteristics by having swath of 60-km to maintain high level of coverage capability, have a better resolution with 1.5 m ortho image products, addition of a blue band to get native natural color images, ultimate satellite agility, enabling to achieve efficiently both collection of large coverage and collection of individual targets: more than 3 million km^2 per day for each satellite with daily revisit. SPOT-7 provided 1.5m panchromatic and 6m multispectral data on daily revisit. Obtained high-resolution data can be applied in: Forest surveyance and management, control over deforestation, logging and woodworking activities, Agricultural land use observation, land inventory, yields control, crop diseases exposure and pest management, land productivity forecasting, weed infestation definition. Monitoring, forecasting and prevention of desertification, bog formation, salification and soil erosion.

The GeoEye-1 satellite sensor was launched at Vanderberg Air Force Base, California on September 6, 2008. The satellite sensor provides a resolution of 0.46 m. GeoEye-1 is capable of acquiring image data at 0.46 m panchromatic band and 1.84 m multispectral resolution. It also features a revisit time of less than three days, as well as the ability to locate an object within three meters of its physical location. The GeoEye-1 satellite sensor features the most sophisticated technology ever used in a commercial remote sensing system. This sensor is optimized for large projects, as it can produce over 350,000 square kilometers of pan-sharpened multispectral satellite imagery every day. GeoEye-1 has been flying at an altitude of about 681 kilometers and is capable of producing imagery with a ground sampling distance of 46 centimeters, meaning it can detect objects of that diameter or greater. During late summer of 2013 the orbit altitude of the GeoEye-1 satellite sensor was raised to 770 Km/ 478 Miles. GeoEye-1 new nadir ground sample distance (GSD) is 46cm compared to the previous GSD of 41cm. Can provide spatial resolution of up to 30cm for better analysis, assessment and monitoring natural resources.

RapidEye, a German geospatial information provider focused on assisting in management through decision-making services based on their own Earth observation imagery. The constellation consists of satellites named RapidEye 1 RapidEye 2, RapidEye 3, RapidEye 4 and RapidEye 5. All the satellites were launched simultaneously by a Dnepr rocket on 29 August, 2018. All the satellites have a common orbit; they are separated by 19 minutes' orbit interval. Each of RapidEye's five satellites contain identical sensors, are equally calibrated and travel on the same orbital plane (at an altitude of 630 km). Together, the 5 satellites are capable of collecting over 4 million km^2 of 5 m resolution, 5-band color imagery every day. RapidEye's satellites are the first commercial satellites to include the Red-Edge band, which is sensitive to changes in chlorophyll content. Studies show that this band can assist in monitoring vegetation health, improve species separation and help in measuring protein and nitrogen content in biomass.

2.3. Hyperspectral Remote Sensing

Hyperspectral Remote Sensing is the future of remote sensing, providing continuous data along the electromagnetic spectrum (spectral signatures of objects) rather than few data points averaged over broad wavelengths, [53]. According to Filchev., hyper spectral Remote sensing satellites acquire very narrow, adjacent spectral bands throughout the visible, near-infrared, mid-infrared, and thermal infrared portions of the electromagnetic spectrum. Hyperspectral remote sensing leverages information in many (often more than 100) narrow (smaller than 20 nm) spectrally contiguous bands, in contrast to multispectral remote sensing of few (up to 15) non-contiguous wider (greater than 20 nm) bands, [55]. The detailed reflectance spectrum acquired by hyperspectral remote sensing makes it possible to identify and distinguish material and conditions on the ground in ways that are impossible even with very high-resolution multispectral imagery. According to Inomata et al., intensive image pre-processing including corrections for atmospheric, radiometric and spatial distortions, data normalizations and quantitative analysis require for effective use of this data for quantitative estimates of biophysical and chemical properties of land surface features Hyperspectral images have found many applications in, soil, geology, vegetation, water resource, agriculture and environmental monitoring. It provides ample opportunity to study biophysical and biochemical parameters of crop and vegetation [53, 56, 57]. Several studies have used hyperspectral data for analysis of soil type and their mineralogical and chemical compositions [58, 59] as well as in environmental monitoring [60]. The hyperspectral data has also been useful for water resource identification and management at different levels [61]. Hyperion is a hyperspectral instrument on board the EO-1 spacecraft that collects 220 unique spectral channels ranging from 0.357 to

2.576 micrometers with a 10-nm bandwidth resolution of 30 meters for all bands. Hyperion provides large number of hyperspectral data and have used globally for various land applications. PRISMA is a medium-resolution hyperspectral imaging mission of the Italian Space Agency ASI under development as of 2008. The hyperspectral sensors can determine the chemical-physical composition of objects present on the scene. This offers the scientific community and users many applications in the field of environmental monitoring, crop classification pollution control and resource management. Other coarse spatial resolution (30m) include HISUI, EnMAP and HyspIRI. However, according to [62], high resolution hyperspectral sensors like HypXIM and SHALOM (10 and 8m) have become helpful to improve the applicability of hyperspectral data. Where, for instance, SHALOM provides high quality hyperspectral data of 10 m spatial resolution with a 2.5 m panchromatic sharp channel, 240 spectral channels across the visible, near infrared and shortwave infrared (VIS ‑ NIR ‑ SWIR) region with 10nm spectral resolution and revisit time of <4 days [63]. Currently, only two satellite-based hyperspectral data are available, namely, Hyperion (30 m resolution) onboard EO-1 satellite of NASA and HySi (500 m resolution) onboard IMS-1 of ISRO. The Hyperion data are available for download freely from http://earthexplorer.usgs. gov/ and http://glovis.usgs.gov. The HySI data are available to download freely from http://bhuvan-noeda.nrsc.gov.in/download/download/download.php for India. Table 3 below shows some of the existing space-borne hyperspectral satellites.

2.4. Unmanned Aerial Vehicle (UAV) Based Remote Sensing

According to Patterson and Brescia, UAVs are typically used for data collection in the forms of video and images on areas on interest. Technological advancement in the contemporary society has catalyzed rapid global growth in the number of Unmanned Aerial Vehicle (UAV) platforms. Improved sensors as well as enhanced image processing techniques have confirmed UAVs as the technology of choice. The UAV platform sensors are available in visible, multispectral, thermal infrared and microwave regions, [65]. Unmanned aerial vehicle (UAV)-based glaciological studies are gaining pace in recent years due to their advantages over conventional remote sensing platforms. The high spatial resolution remote sensing data obtained from these UAV-borne sensors are a significant improvement over the data obtained by traditional remote sensing. The cost involved in UAV data acquisition is minimal and researchers can with ease acquire imagery according to their schedule and convenience, [65]. The UAVs are establishing as crucial tool for crop disease damage assessment, mineral identification and mapping, crop mapping for monitoring and m, disaster management and forest fire monitoring amongst other land applications, [66-68]. However, despite its broad land applications, UAV technology has been associated with various constraints such as less capability and the strict airspace regulations, and lack of suitable methods and techniques for fast data processing and limited models for estimations and predictions of complex environmental parameters [69, 70].

Table 3. *Hyperspectral Remote Sensing Satellites.*

Satellite	Spectral bands	Spatial Resolution	Revisit time	Launch (Date/Country)
SHALOM	275	10m	4	2017, Italy/Israel
TianGong-1	120	10m-(VNIR) 20-(SWIR)	-	September 2011, China
Hyperion (EO-1)	220	30m	16-30	2000, China
PRISMA	249	30m	7-14	22 March 2019, Italy
ALOS-3	57 (SWIR) 128 (SWIR)	30m	35	2019, Japan
HJ-1A/B	128	100m	4	2008, China
HySI on IMS-1	64	550m	-	2018, India
HISUI	185	30m	2 to 60	2019, Japan
PROBA-1/2/V	15 (VIS) 4 (NIR)	100-300M	1 to 2	(2001, 2009 and 2013), Belgium
HypXIM	210	8m	3 to 5	2011, France

2.5. LiDAR (Light Detection and Ranging)

LiDAR is an active remote imaging system that uses light in the form of a pulsed laser to measure ranges on the Earth surface. It uses a very narrow band of electromagnetic spectrums. Lidar instrument principally consists of a scanner, a laser and a specialized GPS receiver. Airplanes and helicopters are the most commonly used platforms for acquiring lidar data over broad areas. LiDAR laser systems are mostly used to measure height of the target and land surface, measurement of cloud and aerosol content of the atmosphere sea ice thickness ice sheet elevations, or high biomass vegetation assessment, [71 -74]. Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) is a space-borne LiDAR jointly managed by U.S. (NASA) and French (Centre National d'Etudes Spatiales/CNES) and was launched on April 28, 2006. CALIPSO combines an active lidar instrument with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols over the globe. GLAS-LiDAR sensor is another Lidar system. GLAS (the Geoscience Laser Altimeter System) was successfully launched aboard the ICESat, from Vandenberg Air Force Base, California on Sunday, January 12, 2003. GLAS is the first laser-ranging (LiDAR) instrument designed for continuous global observations of Earth. It makes unique atmospheric observations, including measuring ice-sheet topography, cloud and atmospheric properties, and the height and thickness of radioactively important cloud layers needed for accurate short term climate and weather prediction. LiDAR data classically have been used to derive high resolution elevation data, [75, 76] LiDAR data have also been used to derive information about vegetation structure including canopy height, canopy cover, leaf area index and vertical forest structure [77-79]. Lidar data sets for many coastal areas can be downloaded from the Office for Coastal Management Digital Coast web portal.

3. Conclusion

Remote sensing technology has made it possible to characterize, assess, and monitor land resources most effectively, reliably and in a cost-effective manner. It has emerged as an effective tool in generating spatial information of natural and man-made resources. Application of remote sensing satellites for mapping, monitoring and management of land resources has been advanced from local to global in order to cater the needs of various users. Additionally, remote sensing technique has been proven very useful for numerous applications of water resources mapping and management, land use / land cover mapping, soil resource mapping and analysis, terrain mapping, land degradation, agricultural applications, watershed planning, wetland mapping, flooding, urban planning, etc.

4. Recommendation

Future of remote sensing satellite for land application is exciting in mapping and monitoring of land resources in very effective manner. As a result this paper recommends detailed comparison of different remote sensing satellites in mapping land resources in order to identify suitable satellites for every land resource on the earth's surface.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgements

Thanks to my lecturer Dr. John Momanyi Mironga for his advice and improvements he made on this paper. His useful comments are highly appreciated.

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