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OPTICAL AND ACTIVE SATELLITE SENSORS USED IN FORESTRY

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Abstract: *Satellite images are taken with a wide variety of sensors placed on platforms at altitudes between 400 and 950 km. They are characterized by a number of elements specific to each satellite program amongst which the most important are resolution (spatial, spectral, radiometric, temporal), setting size, applications where records can be used, the image cost. This paper presents aspects of the main current satellite sensors in orbit capturing satellite images used in forestry too.*

Key words: *active sensors, optical sensors, remote sensing.*

1. Introduction

Satellite sensors used for record keeping had a spectacular evolution, especially in the last decade when satellites equipped with sensors that capture images with spatial metric and sub-metric resolutions were launched (Fig. 1). Satellite remote sensing achievements are closely related to those of satellite sensors that play a key role in taking records. Therefore, satellite remote sensing achievements by launched satellite sensors are beneficial to all sectors of national economy managing natural resources including forestry. They are especially valuable as some remote sensing techniques allow captures in stereoscopic mode. In this respect, analyses can be performed both on single satellite images and stereoscopic images for satellite sensors that have this capability (ASTER, Spot, Ikonos-2).

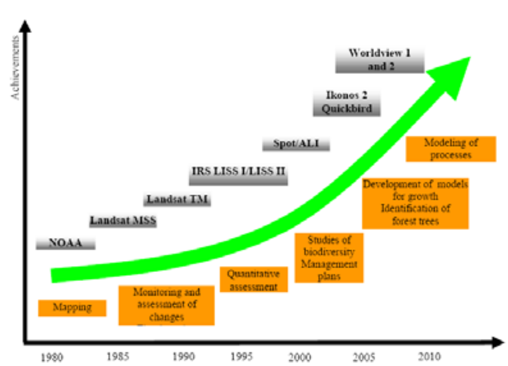

Fig. 1. *Schematic representation of the evolution of satellite sensors and of achievements in forestry and forest study*

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Images taken by optical satellites can be recorded in panchromatic mode (wide range spectral band with high spatial resolution) and in multispectral mode (several bands with narrow width and low spatial resolution). Because of technical reasons it is difficult to make very sensitive sensors with narrow spectral bands, sensors with fine spatial resolution (below 1 meter) operate in the visible range, in enlarged panchromatic mode (about 400 nm). These images allow revealing the limits of forest types, those of tree stands, of clear-cuts, of operating roads, of canopy texture etc. The multispectral mode is more adapted to characterize vegetation and allows canopy density determination, tracking photosynthesis activity, water stress, forest fires etc. The bandwidth of the satellite sensors is generally around 100 nm but some low spatial resolution sensors such as MODIS (500 and 1000 m) show narrow bands (10-30 nm) more adapted to detect biophysical characteristics. Therefore, spectral bands in visible, near infrared and short infrared are used to monitor vegetation. Thermal infrared range is used to study water flows between vegetation and atmosphere, estimation of vegetation canopy evaporation, detection of water stress.

For making correct decisions in the forestry sector based on satellite remote sensing data it is necessary to know satellite sensors and their capabilities [13]. The sensors range is wide and, as time goes on, it is diversified. Thus, the satellite sensors that are the most representative and take records used in the forestry sector too, in order to increase spatial resolution are listed as follows. They are: AVHRR (Advanced Very High Resolution Radiometer) ASTER/Advanced Spaceborne Thermal Emission and Reflection Radiometer), MODIS, ALI (Advanced Land Imager), Landsat 5 TM (Thematic Mapper), Landsat 7 ETM + (Enhanced Thematic Mapper Plus), Spot 4 and 5, Ikonos-2, Quickbird-2, Worldview - 2 and GeoEye-2. Each sensor has both advantages and disadvantages in terms of spatial, spectral, radiometric resolution and time, cost and time of capture. Data from sensors are available as raw and processed data, as corrected by atmospheric effects and other effects that cause image distortions.

2. Sensors used in forestry

2.1. Optic sensors

AVHRR-NOAA sensors have been released since June 11, 1978 (NOAA-1) and allow data capture on very large surfaces. Records have one-day time resolution, spectral resolution of 4-5 bands, and spatial resolution of 1.1 km (Local Area Coverage), respectively 4 km (Global Area Coverage). Sensors take images that are used to highlight the limits of land and water, to investigate clouds, snow and ice thickness, recording the beginning of ice or snow melting, nighttime and daytime distribution of clouds, surface temperature distribution of land and water detail. Other applications include evaluation of agricultural land, creating thematic maps of vegetation on large areas [12], mapping fires, and burned areas. Images taken by AVHRR sensors include thermal band of infrared but they lack data on temperature that can be used to estimate evapotranspiration based on energy balance. Due to the records archive that has a long history, the images are very useful to study long-term changes in vegetation. Data are supplied in limited sets and they are provided at a cost of $ 190/georeferenced setting. The disadvantage of using these data in the forestry sector is the poor spatial resolution.

MODIS sensors are placed on the Terra satellite, which also carries the sensor ASTER, and on the Aqua satellite. Terra MODIS and ASTER satellites were launched by NASA in 1999. Although Terra ASTER and MODIS sensors are on the same satellite, the temporal resolution of MODIS images is much better than the ASTER images (one day versus 16 days) because the MODIS sensor field of view is larger than the sensor ASTER's (2300 km^2 versus 60 km^2). MODIS images have low spatial resolution (250 m), a spectral resolution in 36 bands and they are free. Because the first seven bands of MODIS sensor were designed to simulate Landsat records, except spatial resolution, users can view MODIS images in the same way as Landsat images.

MODIS records are used to classify global vegetation, for biomass estimation, assessment of land degradation, in forest fire monitoring and mapping of areas after fires [8]. MODIS also provides surface temperature and reflectance products enabling energy modeling based on energy balance. The disadvantage of these records is the poor spatial resolution even for analyses on fires [2].

Landsat sensors ave been launched aboard satellite platforms since 1972 then in 1975, 1978, 1982, each being part of a certain generation (Landsat 1-4). Landsat 4 TM has the same bands as Landsat 5 TM and data are now free by USGS EROS (Earth Resources Observation and Science) center. Landsat 5 TM and 7 ETM + sensors have a high spatial resolution in visible, near infrared and short bands and Landsat 7 ETM + has the highest resolution thermal bands of all current satellite sensors. Because Landsat 7 ETM + sensor has had problems with the scanner since 2003, currently only 20 km from the middle of the image can be used. Landsat does not allow high-level products creation such as those recording surface temperature and reflectance of vegetation, which are important variables to model water stress based on energetic balance [15].

Landsat products are used in mapping vegetation, mainly at regional level. The fact that Landsat has a long history of data is an advantage for thematic mapping on vegetation for a long time and for studying the spatial and temporal changes of vegetation [5]. Temporal resolution of 16 days is problematic for their use in emergency such as forest fires.

ASTER sensor was launched in 1999 as the Landsat 7 ETM + with a tool kit on board changed to allow records in several wavelengths. It includes a telescope used to take back view pictures, in near infrared (band 3B), thus allowing for stereoscopic view. After Landsat 7 ETM + images, ASTER data have thermal band with the highest resolution of all current satellite sensors and the resolution in visible and near infrared bands is great. As ASTER data have the same bands and resolution as Landsat sensor, they can be used in similar applications. Before March 2006, all ASTER data were free and now every setting, regardless of processing level, costs about $ 80.

ASTER products with high processing level provide data on temperature and vegetation reflectance that are used as inputs in models based on energy balance to estimate evapotranspiration. As with Landsat sensors, temporal resolution is 16 days, which raises problems in applications on the health of forests. ASTER data are used to obtain thematic maps of land use categories, of reflectance and drawing digital terrain model [3].

Spot 4 sensor was launched in 1998 and Spot 5 in 2002, the satellites being owned by the private company Space Imaging of France. The instruments package on board of the two satellites is different from ASTER and Landsat. The spectral resolution and the spectral bandwidth of the two sensors are limited compared to Landsat and ASTER, but the spatial resolution is much higher. Thus, the sensor Spot 4 takes records with spatial resolution of 10 m in panchromatic and 20 m in multispectral and Spot 5 captures images with 5 m spatial resolution in panchromatic and 10 m in multispectral. Spot 4 and 5 satellites have on board as well a Spot Vegetation sensor that captures images with a spatial resolution of 1 km. Spot sensors have no thermal bands in the infrared and they cannot provide products on the surface temperature but they have the ability to take stereoscopic images.

The main disadvantage of using Spot images is the high price of delivered data. Thus, a stage Spot 4 costs $ 1,200 - $ 1,900 and there are additional fees for faster delivery in emergency (forest fires). A Spot 5 scene costs $ 3300 and, just as with Spot 4 image, there are additional charges for urgent delivery. To ensure prompt delivery of emergency imaging, researchers can order Spot images with no correction on the ground.

Spot data are used for thematic mapping of vegetation, forest fire monitoring, mapping fire severity, detecting invasive vegetation etc. and stereoscopic images allow creation of the terrain digital model. In the specialty literature [6] one shows that Spot VGT images are very useful for detecting large-scale dynamics of changes in the environment due to the wide band they cover and to the sensitivity of records to vegetation growth. Moreover, Spot images can be used even for modeling biochemical processes [4].

ALI sensor was launched by NASA in November 2000 to take pictures in addition to data captured by Landsat sensor. Because ALI sensor will track the same orbit as Landsat 7 ETM + images captured by this satellite, compared to Landsat 7, have better time resolution. ALI sensor is an experimental one; it takes images in panchromatic and multispectral bands and, as such, applications where they can be used are similar to Landsat sensors. The bands were designed to simulate Landsat MSS records having in addition three bands covering wavelengths in the ranges from 0.433 to 0.453 μm, 0.845 to 0.890 mm, and 1.20 to 1.30 μm. Theoretically, this sensor can be considered a replacer of Landsat 7 ETM + sensor, but without thermal bands. ALI images archived and corrected from radiometric perspective cost $ 250/setting and those corrected from radiometric and geometric perspective are $ 500/setting. ALI records are narrower than typical Landsat settings, with width of 37 km and 185 km (Fig. 2).

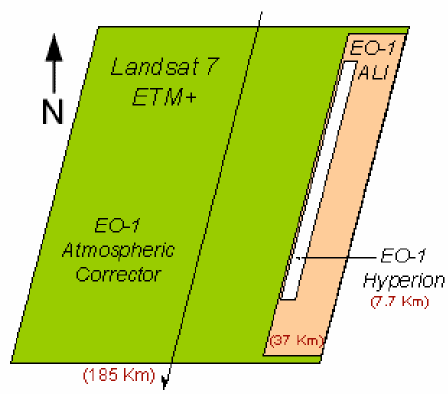

Fig. 2. *The size of satellite images taken with the ALI sensor*

Ikonos-2 sensor was launched in 1999 by Space Imaging and retrieves records whose spatial resolution is 1 m in panchromatic and 4 m in multispectral. Registrations cost amounts to $ 7/km^2 for archived data, the minimum order being of 49 km^2 and for current data, depending on the level of processing, from $ 15 to 22.5 $/km^2. The sensor does not capture data in thermal infrared so that they cannot be used to estimate land surface temperature and vegetation details [17].

The images are used for classification of vegetation and landscapes, to estimate the volume of tree stands, to identify insect attacks, for mapping and monitoring them, for mapping burned surfaces, etc. (Fig. 3) [9]. In addition, comments made on the Ikonos-2 images can serve as a "virtual" source of measurement of land for low spatial resolution images and for global observations. These images can be also used to validate the vegetation area classification based on other satellite images [5].

Fig. 3. *Ikonos-2 satellite images*

Quickbird-2 sensor was launched by DigitalGlobe Corporate United States of America in 2001 and it captures remote sensing images for profit. Spatial resolution of Quickbird-2 records is 0.61 m in panchromatic and 2.65 m in multispectral and temporal resolution is high. Archived data cost 22.5 $ / km^2 and the minimum order is of 25 km^2.

Images are used for vegetation classification, detection, mapping and monitoring insect attacks, landscape classification, mapping forest fires, invasive species detection, ecological modeling [16]. Quickbird-2 records are usually used in different studies of small areas or at local level and it is not indicated for use on large areas due to high cost and rigid technical parameters. Since this sensor has no thermal bands, recordings cannot be used to estimate surface temperature. As for Ikonos images, Quickbird-2 recordings can be used to validate classifications of the vegetation area made on other satellite images. Given the high cost of the records, it confines their use in monitoring the health of the forests.

Worldview-1 and 2 sensors are part of the new generation of sensors launched by DigitalGlobe Corporate that capture very high spatial resolution images. Worldview-1 sensor was launched in 2007 and it records only in panchromatic with a spatial resolution of 0.5 meters, and it has a temporal resolution of 1.7 days. Worldview-2 sensor was launched in 2009. It allows capture of images with a spatial resolution of 0.46 m in panchromatic and 1.84 m in multispectral. It works in 8 bands, it has a temporal resolution of 1.1 days and it is able to capture images of over 975,000 km^2 in one day.

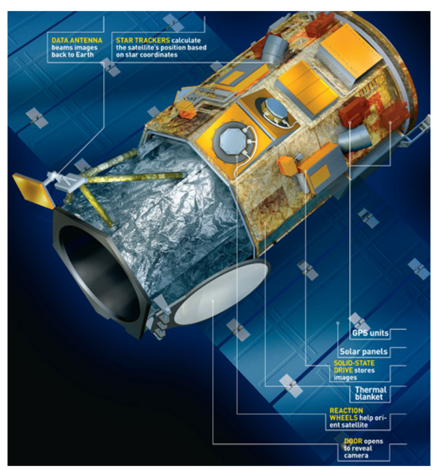

Fig. 4. *The GeoEye-1 satellite*

GeoEye-1 sensor is the most advanced sensor in the civil sector being able to take images with spatial resolution of 0.41 m in panchromatic and 1.65 m in multispectral

(Fig. 4). Records are made in four spectral bands (visible and near infrared) and are ideal for forestry administration problems concerning forest mapping and monitoring [10] and obtain measurements of trees and tree stands. The satellite is able to record images in a day covering an area of 700000 km^2.

Along these optical sensors of the multitude of sensors there can be listed the following that take records that can be used in the study of forests and forestry: IRS (India), CBERS (China-Brazil), Orbview-2 (USA) , ADEOS-II GLI (Japan), Formosa-2 (Taiwan), Alosa Avnir-2 (Japan), Kompsat-2 (Korea), Cartosat 1 and 2 (India) etc.

Hyperspectral satellite sensors, compared to those placed on airplanes, are fewer in number, and they take records on a large number of narrow spectral bands, which describe them.

EO-1 Hyperion sensor was launched by the United States in 2000 and uses for data acquisition 220 spectral bands in visible and infrared regions. Data spatial resolution is 30 m and temporal resolution is 16 days. It is an experimental sensor and records are free.

CHRIS sample sensor is in orbit since 2001 and collects data in 63 spectral bands (visible and near infrared). As EO-1 Hyperion, it is an experimental sensor whose images have a spatial resolution of 34 m and are free for research.

In addition to the two sensors mentioned, in 2008, China launched HJ-1A/1B hyperspectral sensor working in 110 bands but whose data are not available to the public. In addition, India also launched in 2008 IMS-1 HySI, an experimental hyperspectral sensor operating only over this country.

Hyperspectral images are suitable for detailed analysis so that one can be separated materials with a spectral behavior, related or similar and one can obtain information at sub-pixel level. Applications where hyperspectral images can be used are multiple because of their ability to separate recorded data. Thus, hyperspectral records can be used successfully in forestry and forest study to detect vegetation stress, mapping expansion of different species of trees and shrubs, to determine the chemical concentration in leaves etc. [14]. Compared to multispectral images, which can be used in mapping areas covered with forest, hyperspectral images can be used for mapping species within tree stands [1].

2.2. Active sensors

Active sensors that take records used in forestry too are less diversified than the optical ones, but gradually they are supplemented by new sensors. Generally, they are represented by radar sensors, which allow the use of their own source of energy for record keeping. These systems do not require sunlight as in optical systems, they can take records both by day and by night, and they can penetrate the clouds texture between limits given the working wavelength with no effect on the records [1].

The SAR System (Synthetic Aperture Radar) is a technique that allows capture of high-resolution records that depend on the surface properties, which are registered, as tilt, roughness, moisture, texture, and dielectric constant. The use of these records in the forestry sector can be made to obtain topographic maps and for monitoring land use [11].

Satellites ERS-1/2 (European Remote Sensing Satellite 1 and 2) were launched in June 1991, respectively in April 1995, and take data from an average altitude of 785 km. Records are retrieved in band C, with vertical polarization and have a resolution of 30 x 26 m. The size of a record is 100 x 100 km.

Satellites RADARSAT-1 and RADARSAT-2 were launched by Canada in 1995, respectively in 2006. Records are made in band C and have a resolution of 8-100 x 8-100 m for RADARSAT-1 and 3-100 x 2.4 to 100 m for RADARSAT-2.

The satellite IGESAT GLAS is a LIDAR type and it was launched by the United States of America in 2004 and the data are free. Records have a footprint of 70 meters and a revisiting period of 183 days.

In addition to the above satellites, considered significant for the forestry sector there can be mentioned the satellites JERS-1 (Japan) whose mission was completed in 1997 and the SRTM shuttle [7]. It was launched in 2000 and for 11 days, it collected data. Based on them, there was performed the digital terrain model with a resolution of 30 m (90 m outside the U.S.). Along these sensors Envisat ASAR (EU), TerraSAR-X (Germany), Alosa PALSAR (Japan), COSMO SkyMed (Italy), and Ibuka (Japan) can be mentioned.

3. Conclusions

The wide range and variety of satellite sensors allow images taken by them to be used in forestry. Many of them were launched to capture images even for vegetation mapping, for its study and the monitoring of its health. From this point of view, the forest sector highlights a rich palette of satellite records with different spatial resolutions, spectral, radiometric, and temporal. As such, analyses and interpretations based on satellite images can be carried out both at forest and tree stand study level.

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