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SATELLITE REMOTE SENSING IN ENVIRONMENTAL IMPACT ASSESSMENT: AN OVERVIEW

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Abstract: *Satellite remote sensing is par excellence a powerful and efficient tool to ensure acquisition of images over wide areas in short time and with great repetition that can be used in environmental impact studies. This paper proposes an overview on the role of satellite remote sensing in environmental impact assessment. The article points out how modern technology specific to remote sensing can be used in environmental impact assessment, impact caused of urban development, mining and changes that appeared due to the human factor or natural factors.*

Key words: *environmental impact assessment, satellite images, remote sensing.*

1. Introduction

Scenarios for achieving the environmental impact of various activities are an important element in securing and making correct decisions. In this way, remote sensing plays a significant role in providing geospatial information necessary for databases and monitoring the entire surface of Earth. Satellite observations over land, oceans, and atmosphere and especially during the phenomena have become very important to protect the global environment, reducing disaster losses and ensuring sustainable development.

Satellite remote sensing uses space-borne sensors and it is a modern technique that allows acquisition of data in a systematic way and comprehensive coverage. High temporary resolution between several minutes and several days, the spatial resolution and the increasingly high accuracy of information are the main criteria in choosing this type of data to carry out environmental impact studies.

Objectives of remote sensing in impact studies are: (1) monitoring and modelling of Earth surface processes and their interaction with atmosphere, (2) measurement and estimation of geographical, biological and physical variables, (3) identifying details and materials on Earth's surface and (4) analysis of spectral signature recorded with satellite sensors. Achieving these goals is possible because the details recorded in a scene absorb, emit and reflect electromagnetic radiation at different wavelengths, depending on the shape and molecular composition. Satellite remote sensing exploits the natural properties and allows the acquisition of information about the scene located at great distance from the sensor. Satellites used to take over data on Earth's surface are becoming more numerous, they are taking different types of images (Figure 1), with certain technical characteristics (Table 1).

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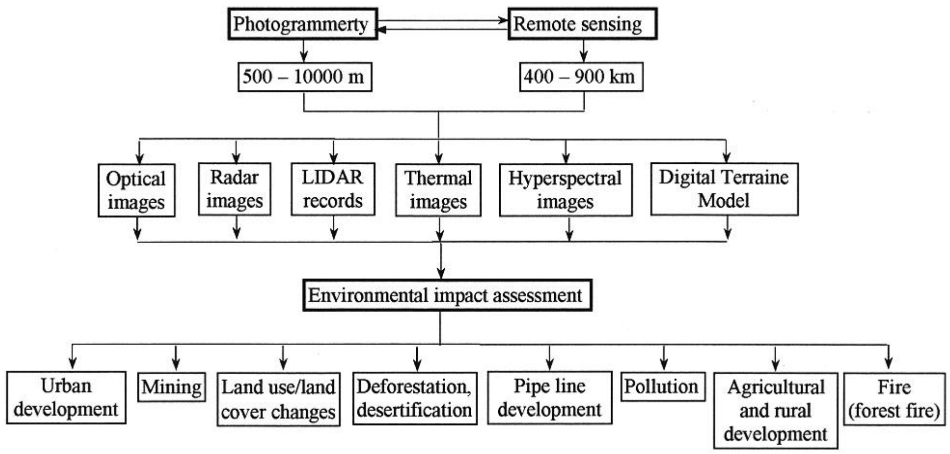

Fig. 1. *Type of satellite images used in environmental impact assessment*

Description of current imaging earth observation satellites [13] Table 1

Country/organisation	Satellite	Sensors	Technical characteristics
Canada/CSA	Radarsat-1	SAR	C-band SAR, HH polarization and multi-imaging modes
China/CAST	CBERS-2	CCD IR-MSS WFI	20 m, Pan + 4XS (VNIR) 78 m (VNIR/SWIR), 156 m (TIR), 4 SX (Vis-TIR) 258 m, 2 XS (VNIR)
EU/ESA	Envisat	ASAR MERIS	C band, multi-polarization, multi-imaging mode SAR 260-1200 m, 15 bands (VNIR)
France/CNES	SPOT-5	HRG HRS	2.5 m (Pan), 10 m (MS), Pan + 4XS (VNIS/SWIR) High resolution (10 m, pan), stereo 1.15 km, 3 XS (VNIS/SWIR)
India/ISRO	Cartosat-1	IRS P5	2.5 Pan, 6 bit
Japan/JAXA	ALOS	AVENIR-2 PALSAR PRISM	10 m, 4 SX (VNIR) Multi-imaging mode L band radar 2.5 m panchromatic
USA/NASA	Terra Terra/Aqua NMP EO-1	ASTER MODIS ALI	15 m (VNIR), 30 m (SWIR), 90 m (TIR), 14 XS (VNIR, SWIR, TIR) 250-1000 m, 36 bands (VIS-TIR) 10 m (Pan), 30 m (VNIR/SWIR), Pan + 9 XS (SNIR/SWIR)
USA/USGS	Landsat-7	ETM+	15 m (Pan), 30 m (Vis-SWIR), 60 m (TIR), Pan + 8 XS (VIS-TIR)
USA/Digital Globe	-	WORLDVIEW 1	0.5 m (Pan), 2.6 (VNIR), 11 bit
USA/Space Imaging	-	IKONOS-2	1 m (Pan), 4 (VNIR), 11 bit
USA/Geoeye	-	(Q2) GEOEYE-1	0.41 m (Pan), 1.65 m (VNIR), 11 bit
VNIR - Visible and near infrared, SWIR-short-wave infrared, TIR-Thermal infrared, XS-Multispectral bands For detailed list the readers are referred to CEOS (2005)			

The most used applications of remote sensing in environmental impact assessment are the inventory and monitoring studies. Thus satellite imagery are valuable sources of data on landscape topography, land use and land cover, quantification of regional and global change that lead to habitat destruction. Records of remote sensing plays an important role in classification, mapping and detecting changes in ecosystems, thereby achieving homogeneous maps with predictable characteristics [17].

In most studies of environmental impact assessment there are used time series satellite images, taken from the same area at different times [19]. The use of time series satellite images requires specific procedures for processing of remote sensing by satellite (Figure 2). Within these procedures the application of atmospheric and radiometric corrections are essential to ensure a single base of comparison [22].

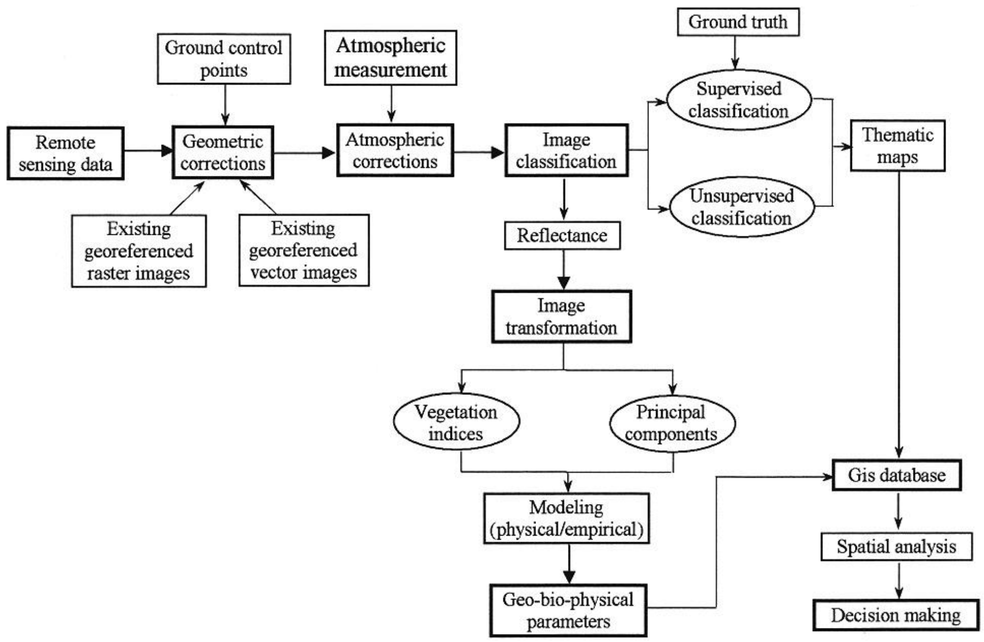

Fig. 2. *A schematic diagram of general image processing procedures in remote sensing*

2. Environmental Impact Assessment Using Remote Sensing Records

2.1. Evaluation of urban development

High, explosive and uncontrolled dynamic of the urban development leads to the increase of the built surfaces and to the appearance of bulk settlements. Negative action on the environment results from the lack of information on establishing a correct systematization and selection of areas for cities expansion. Using records of remote sensing with high spatial resolution has the advantage of using updated information on district and allows the estimation of systematic socio-economic parameters. Thus, remote sensing records provide tracking the extension of constructed surfaces; they can be used in conducting the general, urban and regional plans, in systematic planning of settlements and in any extension of localities [23].

One of the direct major impacts of uncontrolled urban development over environment is degradation and the quality of water resources [25]. Transformation of agricultural land, forests, grasslands and wetlands in the fields of construction generally leads to an alteration of natural hydrological conditions of rivers. Such phenomena are reflected in the increased frequency of landslides and in the decreases of base flow [4], [2], [11]. All these lead to the generation of floods, rising sea levels in lakes and wetlands, changing water balance and increase erosion of rivers, decrease in channel flow during the dry season [21]. These environmental impacts can be analyzed and quantified using remote sensing records.

Many studies have used remote sensing to quantify the urban heat island appeared from the urbanization process. Quantification was based on parameters and indices such as land surface temperature (LST), vegetation fraction (VF) and Normalized Difference Vegetation Index (NDVI). Depending on the relations between them there were made predictions on the impact of urban development on the environment.

2.2. Assessment in mining

Excessive industrialization without environmental impact prediction, leads to ecosystem degradation. Surface mining causes extensive damage to flora, fauna, hydrography and soil. Mining operations involving the extraction of minerals from the area tend to have a notable impact on the environment, landscape and biological communities of the ecosystem [3]. Unscientific mining environment pose serious problems, reducing the area covered by forests, soil erosion and pollution, air pollution, water and biodiversity loss.

The conflict between mining activities and environmental protection has increased in recent years and it requires improving information on the dynamics of local and regional scale impacts [9]. Mapping and assessing impacts of mining are difficult problems because of the size and extent of areas affected by mines. Monitoring and controlling these activities through traditional methods is quite difficult due to high costs and lengthy time in obtaining accurate and updated maps. In addition, achieving a successful follow-on evaluation of surface mining processes and their dynamics on a regional scale requires observations with high temporary coverage for a long time. In order to solve such problems policy makers must have accurate and updated information. Thus, for mapping changes in mining activities since 1970 there have been used analogical photograms and satellite remote sensing techniques are used today to collect large scale information more efficiently and with a lower cost.

Satellite remote sensing together with geographic information systems are recognized as a powerful and efficient technology in assessing impacts on the environment caused by mining activities. Integrating these technologies allows taking decisions to monitor and determine the environmental impact in a fast and efficient way. On the other hand, views of processed remote sensing data deliver significant benefits to researchers from all disciplines related to environmental sciences. In many specialist publications [15], [24] there is indicated the usefulness of these techniques in detecting contamination and in determining the way in which the recovery of areas affected by surface mining is made.

From the remote sensing techniques, the DInSAR (Differential Interferometric Synthetic Aperture Radar) is cost effective and is the only one which can map the land surface deformation and it can assess the impact of mining on the environment.

2.3. Assessment of changes in land use/cover

The changes in land use/cover lead to high social and economic benefits but bear in mind that they cost quite high on the natural environment. Studies on land use/cover using remote sensing data have got a huge attention from countries around the world due to its importance in the overall analysis of change [5]. The actions produced by natural and human factors may lead to changes in terrestrial ecosystems [8], in biodiversity [18] and landscape ecology [16], [20]. In addition, studies reflect environmental impacts at different spatial and temporary scales [10]. Accurate and updated information on land use/cover is essential for environmental monitoring, impact providing terrestrial ecosystem [12] and sustainable development [1]. More, reliable and updated data on and use/cover can ease the training resource management policies.

Studies have shown that the transformation of land use/cover both in the natural and human activities can have profound impact on the hydrological cycle by accelerating flood risk areas in mountain [14], degradation of water quality and increasing the causes that produce erosion [24], [6]. In general, from the results that were obtained, it was found that for monitoring changes of land use/cover there is needed temporal resolution of at least 3-4 years.

Even among the most developed countries possessing advanced equipment and detailed information on land use/cover, the lack of geospatial databases for land use/cover can prevent the achievement of good planning practice. Therefore, satellite data are useful for both developed countries and developing ones where recent and reliable data on spatial information are lacking [7].

Remote sensing data available today and used in assessing the environmental impact caused by changes range from recordings of very high resolution such as Ikonos and Ouickbird images, to records retrieved from medium spatial resolution such as Landsat (MSS, TM and ETM +) and SPOT images to coarse resolution such as MODIS (Figure 3).

Using remote sensing for environmental impact studies related to land use/land cover assumes three types of analysis: (1) spatial assessments by mapping and classification of vegetation, (2) evaluation of productivity of vegetation by vegetation indices, (3) studying the processes using the parameters obtained from satellite data. The analysis of changes in ecosystems and biomass requires information about crown such as leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR).

Besides the impact assessment due to important environmental changes there is the need to quantify them. Thus vegetation indices provide quantitative information on vegetation productivity based on spectral information that can be extracted from satellite imagery. Generally, vegetation indices are used for continental and global scale modelling, which assumes low resolution images. Thus, the AVHRR data with daily global coverage are used to calculate vegetation indices for monitoring land cover and vegetation phenology.

Most widely used index of vegetation, NDVI index (Normalized Difference Vegetation Index), is linked to vegetation reflectance in red and near infrared bands and the factors affecting its values are vegetation cover density and the leaf chlorophyll of content. NDVI index, as well as other vegetation indices, expresses a measure of the amount of greenery that is indirectly linked to vegetation structure through variables LAI, vegetal cover, land surface biomass, photosynthetic efficiency and FAPAR. These variables, in turn, may be related to net primary production of the ecosystem to a large scale using an effective model. In addition to NDVI index there are other indices that can be used to assess the impact on vegetation cover due to various natural or human actions. Of these, the SAVI index is similar to NDVI index but incorporates the formula for calculating an adjustment factor to determine

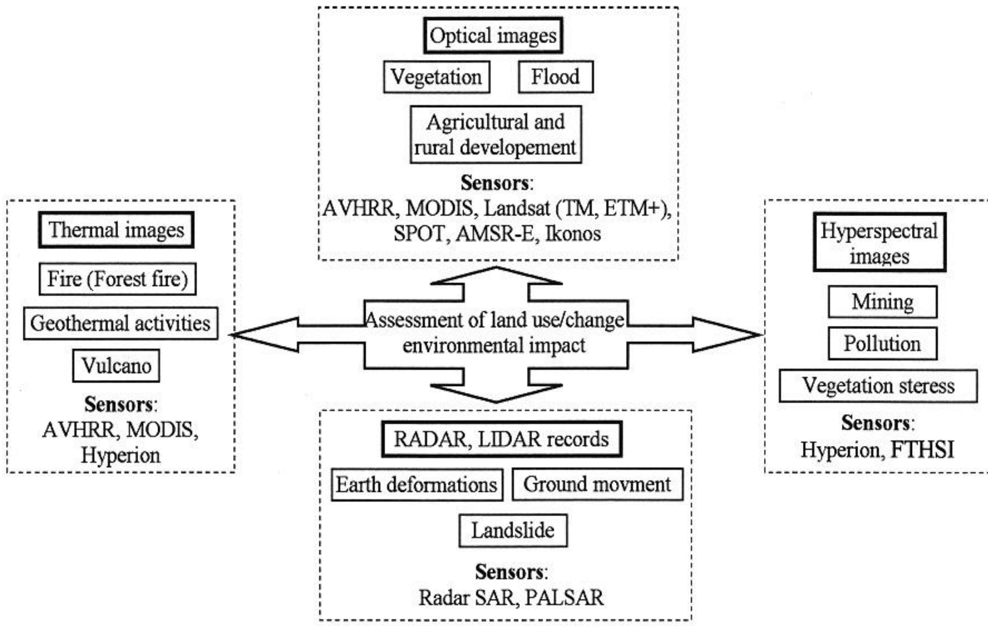

Fig. 3. *Sensors used in assessment of land use/change environmental impact*

reflection's details given that soil reflectance strongly affects NDVI index values.

Other indices such as OSAVI (Optimized Soil-Adjusted Vegetation Index), MSAVI (Modified Soil-Adjusted Vegetation Index) and TSAVI (Transformed Soil-Adjusted Vegetation Index) use different adjustment factors that SAVI index. Besides these indices based on ratios using orthogonal indices which depend on the soil line in spectral space most use are GI (Greenness Index) and GVI (Green Vegetation Index).

3. Conclusion

To understand the consequences of human actions and natural phenomena on the environment there are needed data acquired in real-time that are the basis of modelling various environmental impacts. Satellite remote sensing is an excellent tool for this purpose using images with different spatial, spectral and radiometric resolution depending on purpose.

Using satellite images in environmental impact assessment has the following advantages: recorded area is large, they capture the overall characteristics, they can be retrieved at any time of day (radar records), they cover areas inaccessible or hostile to humans, they highlight the unusual features of phenomena or registered details, information obtained is uniform throughout the area, data are obtained with high repetitivity and there can be identified the phenomena rapidly evolving in time, data are obtained in real time, there can be made thematic selections and classifications, records are made as needed in different parts of the electromagnetic spectrum in various forms (analogue, digital, radar, lidar).

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