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Spatiotemporality in studies of vegetation and land use change

La espaciotemporalidad en los estudios de vegetación y cambio de uso de suelos

Espaçotemporalidade em estudos de vegetação e mudanças no uso do solo

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ABSTRACT

Spatiotemporal studies hold great importance in the Characterization of land Cover, particularly on studies of vegetation and land use change in different periods. The objective of this bibliographic review has been to investigate aspects related to the implementation of knowledge from spatiotemporal studies of vegetation Cover and land use change. The state of spatiotemporality or multitemporality, the use of remote sensing and Geographic Information Systems in them, as well as aspects of the state of the art of spatiotemporality have been characterized.

Keyword: vegetal cover; state of the art; change detection.

RESUMEN

Los estudios espaciotemporales ostentan una gran importancia en la

caracterización de las coberturas terrestres, en particular sobre los estudios de vegetación y cambios de uso de suelos en distintos periodos. El objetivo investigar aspectos relacionados con la implementación de conocimientos en estudios espaciotemporales de cobertura de vegetación y cambios de uso de suelo. En consecuencia se ha realizado una caracterización sobre el estado de la espaciotemporalidad o multitemporalidad, la aplicación de la percepción remota y los sistemas de información geográfica en los mismos, así como aspectos relacionados con el estado del arte de la espaciotemporalidad.
Palabras clave: cobertura vegetal; estado del arte; detección de cambios.

RESUMO
Os estudos espaço-temporais são de grande importância na caracterização da cobertura do solo, particularmente nos estudos da vegetação e das mudanças no uso do solo em diferentes períodos. O objetivo é investigar aspectos relacionados à implementação do conhecimento em estudos espaço-temporais de cobertura vegetal e mudanças no uso do solo. Consequentemente, foi realizada uma caracterização sobre o estado da espaçotemporalidade ou multitemporalidade, a aplicação da percepção remota e dos sistemas de informação geográfica no mesmo, bem como aspectos relacionados com o estado da arte da espaçotemporalidade.
Palavras-chave: cobertura vegetal; estado da arte; detecção de alterações

INTRODUCTION

With the emergence, first, of aerial photography on the surface of the earth, the first steps of remote sensing begin, which reaches its greatest peak secondly with the launch of the satellite.

From here on, the first studies by researchers from different countries on the objects present on the Earth's surface begin, highlighting those of an environmental nature.

The use of photographs and images with different dates on the land cover allows, through the use of different methods and techniques, the detection of spatial changes such as changes in land use, the distribution and composition of vegetation, monitoring of the natural regeneration, monitoring recovery from the impact of a fire, hydrometeorological event or other.

Spatiotemporal or multitemporal monitoring, as it is also known, of extensive geographical areas, has made it possible to estimate patterns of cover deterioration, changes in the composition and distribution of species at latitudinal and altitudinal levels, as well as the determination of priority areas for conservation (Evangelista et al., 2010); These changes are defined by environmental causes, as well as by social and economic behavior interpreted on a global, regional or local scale (Ruíz et al., 2013; Evangelista et al., 2010).

Change detection is defined as the temporal effect identified from variations in a spectral response (any type of radiant energy depending on its wavelength or frequency); That is, it involves a situation where the spectral characteristics of the vegetation or other type of cover in a certain location changes over time (Gil & Morales, 2016).

Gil and Morales (2016) and Ruíz et al. (2013) report that mapping and monitoring land cover is one of the largest applications of Earth observation, based on data from satellite sensors; this monitoring has been essential to estimate coverage changes. The digital detection of change allows determining modifications associated with land use and cover properties (Land-Use and Land-Cover).

Among the main limitations that affect land cover monitoring studies and mapping has been the acquisition of inputs (photographs and satellite images). The photographs have been developed in the first instance by governments and their access has been limited only to military uses, and in the case of satellite images from platforms such as Landsat they had not been made available to the international community.

The change detection methods implemented in spatiotemporal studies in Cuba have not been widely used. This has been due to the access to aerial photographs and satellite images as well as the appropriation of these techniques by universities and research centers substantially. Among the studies that have ventured into its use are those on terrestrial vegetation coverage, among them those on mangrove monitoring stand out from the years 2012-2013, where the first steps in the use of these techniques are beginning to be taken.

All these land cover studies are developed and integrated thanks to geographic information systems Galeana et al. (2009) cited in Vera (2018) mention that the most used tools to evaluate changes in vegetation cover and land use come from Geographic Information Systems (GIS), these were developed between the 70s together with computers.

Nowadays there is a multitude of Geographic Information Systems software for working with raster and vector data such as Qgis, ArcGis, Erdas, Mapinfo, Envi, MultiSpec, OpenEv, Image 2000, Grass, Ossim, TNTmips among others.

The use of Geographic Information Systems is very useful for monitoring natural resources (Olaya, 2009) cited in (Vera, 2018), highlighting the potential they have for environmental analyzes such as the fragmentation of forests, the change in land use and the decrease in vegetative quality (Gigorro and Martínez, 2005) cited in (Vera, 2018).

Remote sensing techniques are now regularly employed for the study and monitoring of mangroves (Thomas et al., 2018). The most generalized methods for the study and monitoring of Cuban mangroves have focused more on the use of field data although the goal of using satellite images is recognized (Guzmán & Menéndez, 2013; Menéndez, Guzmán and Capote, 2002 cited in Denis *et al.,* 2020).

The use of satellite information for the study of Cuban mangroves has been limited. Generalized methods that obtain field data provide local perspectives and a restricted temporal amplitude, insufficient to generalize, they are distributed over hundreds of kilometers of coastal areas with high spatiotemporal variability (Dennis et al., 2020).

Based on what was stated above, the objective is to investigate aspects related to the implementation of knowledge in spatiotemporal studies of vegetation cover and land use changes based on a systematic review of the topic in question.

DEVELOPMENT

State of spatiotemporality or multitemporality

Changes at any scale and type have been present throughout time, before the emergence of man and with greater intensity and significant frequency with him. It has modified the landscape on a global scale of land cover, highlighting studies on changes in vegetation patterns.

This criterion is considered by Gil and Morales (2016); Molina and Albarran (2013), who report that historically, the socioeconomic changes that occurred in the decades of the 20th and first decades of the 21st century have produced environmental alterations worldwide at different time scales, which is currently reflected in significant changes in the structure and functioning of ecosystems, in addition to the accelerated loss of biodiversity.

According to FAO (2015), scientific monitoring recently carried out from space on forest cover has revealed that deforestation has registered an increase, particularly in the tropics.

In the tropical region during the 1980s, drastic changes in forest cover were identified. This negative effect is due to changes in land use, wild plant cover, climate change, and increased CO2 concentration, the world economy based on fossil fuels, inadequate wastewater management and the excessive exploitation of soil and subsoil (Gil & Morales, 2016; Sepulveda et al., 2015; Prieto et al., 2013; Bodart et al., 2011).

Spatiotemporal analyzes of land use and land cover become fundamental, since they allow the identification of the changes that occur in a certain geographic area on a time scale (reference dates), this deducing the evolution of the natural environment and the repercussions humanities on this environment (Chuvieco, 1996 cited in (Gil & Morales, 2016).

Spatiotemporality allows defining representative modifications of objects, their versions (plant covers), also establishing spatial relationships between different graphic elements (geospatial topology) and their position on the map (close, adjacent, and in the middle of) based on management. of temporal data (Gil & Morales, 2016).

Gil & Morales (2016) state that an importance of spatiotemporal analyzes lies in identifying the balance between natural habitat and urban-rural landscape, since it can determine the future of biological diversity in any area of the planet.

This methodological procedure of visual interpretation, which allows evaluating the changes that occur in the situation of forest or non-forest cover between different periods, deducing gain or loss of the mangrove forest, as a consequence of a natural phenomenon or of anthropic origin and in the Satellite images identify the changes demonstrated to compare with the data obtained from the satellite (Cabreras, 2022).

The reliability of an analysis of changes at the landscape level depends on visual field verifications through transects, that is, records of observations or surveys of control points, such information complements the spatial information in a precise, clear and objective way to obtain, through remote sensing tools or geographic information systems (Gil & Morales, 2016; Pérez & García, 2013).

The reliability of the results obtained from a spatiotemporal analysis greatly affects the resolution of the satellite image or aerial photography used. Satellite images can be classified as low, medium and high resolution. Studies today have generally been based on the use of the first two, since they are freely accessible, but not the high resolution ones, which you have to pay to access them.

Spatiotemporal studies focused on the dynamics of vegetation cover contribute to the delimitation, specialization and analysis of imbalances between natural vs. artificial landscapes (Gil & Morales, 2016).

Spatiotemporal studies based on image preprocessing, metadata, metrics that quantify the composition and configuration of the landscape and Geographic Information Systems are a valuable input to determine processes of fragmentation, deforestation, loss or gain of connectivity between vegetation remnants (Gil & Morales, 2016). They have been widely used by researchers worldwide.

According to González and Romero (2013) criteria cited by Figueredo et al. (2020), knowledge of coverage constitutes one of the most important aspects within the biophysical analyzes of the territories, since it allows the changes in coverage to be specialized and a reading to be made in different time scenarios (multi-temporal analysis).

Spatiotemporality can cover large and/or small time periods, depending on the interests that are intended to be evaluated. The selection of photographs and materials would be in accordance with the availability, quality and scale at which the information is intended to be provided, as well as the objective to be pursued by the researcher.

Remote sensing and geographic information systems in spatiotemporal studies.

The history of remote sensing dates back to the first aerial observation platforms: hot air balloons and the invention of photography in the 19th century. Modern remote sensing was born with aerial photography in the 20th century. The year that symbolizes the entry of remote sensing into the modern era is 1957 with the launch of the satellite (Emanuelli et al., 2016).

Remote Sensing is the science that is responsible for obtaining information about objects or areas at a distance, generally from aircraft or satellites" (NOAA, 2018).

Canadian Center for Remote Sensing, CCRS (2018) states that it is the group of techniques to obtain images or other forms of data about measurements made at a distance of an object, the processing and analysis of the data.

A satellite image is a visual representation of data reflected by the Earth's surface captured by a sensor mounted on an artificial satellite. The data are sent to an earth station where they are processed and converted into images, enriching our knowledge of the characteristics of the Earth at different spatial scales (Cabreras, 2022; Salas et al., 2019).

Armenteras *et al.* (2013) and Brovkin *et al.* (2004) emphasize the importance of using remote sensors to identify modifications and effects on land cover, because today climate change caused by the concentration of CO2 and greenhouse gases, together with the inadequate use of natural resources, threaten the biological Diversity.

Automatic change detection in images of a scene acquired at different times is one of the most interesting topics in the field of remote sensing (Huang *et al.,* 2009).

From the computer processing of satellite images, soil conditions, types of vegetation and their state can be discriminated. Being possible to obtain the cultivated or wooded area and even identify the plant species. Through multi-temporal analysis of satellite images, it is possible to monitor the evolution of different plant communities and agricultural crops (Aullo, 2013).

Palacios (2015) states that a multi-temporal analysis involves a digital crossing of two satellite images that have previously been classified and that necessarily have similarity in the classes and their legend, area, scale and cartographic projection used, in this way by digitally crossing them it allows detecting the coverages that have changed and quantify the coverages that gain or lose area. This is known as change dynamics, since it assumes that the loss of area for a certain class corresponds to its replacement by another coverage whose class is recognized at the time of classification.

Coppin *et al.* (2014) cited in Emanuelli et al. (2016) state that the detection of changes from a multi-temporal sequence of satellite images is one of the most important applications in remote sensing and geographic information systems. The analysis of this sequence allows the monitoring of dynamic processes on earth; since the images are obtained from sensors from a stable orbit, allowing access to repetitive images of the same area.

Changes can be due to various factors, from natural disasters or extreme weather events to public or economic policies. Identifying these changes is a process that requires adequate manipulation of the images and management of image processing and classification algorithms, so that the detected changes are only attributable to true landscape modifications (Emanuelli et al., 2016).

Chuvieco (1998), cited in Gil and Morales (2016), states that an important contribution of remote sensing to the environment is the ability to follow dynamic processes in a temporal dimension, since it allows collecting and integrating data from satellite sources. This dynamic can be analyzed from sporadic events (eruptions and fires) or continuous processes (deforestation) in varied cycles (hours, months or years).

The dynamics at the level of coverage or potential land use are evaluated based on the detection of changes in a landscape mosaic, with the application of classification techniques (category discrimination). The identification of differences in time and space with satellite images (digital representation of the types of coverage) can indicate whether the landscape is more or less homogeneous, a product of fragmentation processes or heterogeneous according to the spatial cohesion of the elements of the Chuvieco landscape (1998 and 2007) cited in (Gil & Morales, 2016).

The observation of land cover from space has taken on a strong environmental role, due to its usefulness, which lies in the periodicity and consistency of the information acquired. Initially, analyzes with satellite images focused on obtaining inventories of specific phenomena; That is, the visualized objects are used to sectorize the space and thus obtain thematic cartography (Gónima, 2001; Chuvieco 1996) cited in (Gil & Morales, 2016).

Currently, analyzes with satellite tracking are still implemented, although systematic measurements of variables of interest are already incorporated into these, that is, sensors are used as means to obtain quantitative information, which allows an approach to the interpretation of phenomena that are difficult to understand. Analyzable, with conventional means (sea temperature modeling, precipitation behavior, spatial variations of plant formations) and that lead to projecting future scenarios of change according to a pattern determined for the past and present (Chuvieco, 2002, 1996 cited in Gil & Morales, 2016).

The combination of remote sensors in the environmental area and GIS, which have been widely used for the generation of thematic maps of land use and land cover, also focus on guiding biodiversity conservation strategies (ecosystem services and capital) natural and environmental planning (Chuvieco, 1995 cited in Gil & Morales, 2016).

The uses of images generated by satellites provide us with immediate and precise information to be used in different aspects, including: monitoring the vegetation cover of a previously selected geographic area (Salas et al., 2019).

Artificial satellites that allow remote sensors to be placed to obtain satellite images that, by capturing electromagnetic radiation, generate periodic information, giving the possibility of monitoring different changes in land use, as well as natural and anthropogenic phenomena (Salas et al., 2019).

Remote sensing is a technique used to acquire information through spatial images, in which different techniques will subsequently be applied for the digital and visual processing of satellite images (multispectral Landsat type), and in this way the changes can be determined. That exist in the soil vegetation cover over various periods of time (Condori et al., 2018). It represents a mechanism that allows the analysis of large areas of land and inaccessible places at a low economic value (de León et al., 2014 cited in Narváez, 2019).

Remote sensing offers a set of historical data on extensive forested areas such as mangroves, in addition to providing high spatial, spectral and temporal resolution, which is why many multispectral and/or spatiotemporal studies, particularly on mangrove forests, have been carried out. by different authors (Castillo et al., 2021; Elmahdy et al., 2020; Pham *et al.*, 2019; Islam et al., 2019; Hong et al., 2019; Selvam et al., 2019). In particular, monitoring the structure of mangrove forests based on their distribution (Onesmus, 2020; Pham & Nguyen, 2019).

Nowadays, the use of Unmanned Aerial Vehicles known as (UAV) has begun to be implemented based on the use of active sensors, which are responsible for emitting active sensors that are responsible for emitting energy towards the object of study which it backscatter and towards the sensor (Gupta, 2018). According to Hsu et al. (2020) and Cao et al. (2019) provides an opportunity to obtain images with higher resolutions and therefore generate more accurate data, which helps us adjust the estimates in vegetation classifications produced by satellite images.

One of the most important applications related to Earth observation and access policies to satellite image inputs is the temporal detection of changes because we can have precise and quality multi-temporal information on the global coverage of the Earth land in a short period of time, in a sustainable way (Granja, 2020).

Among the images most used in land cover and land use change research, the following stand out: Landsat, which is a program of the National Aeronautics and Space Administration (NASA); and Sentinel-2 (S-2) which is developed by the European Space Agency (ESA) which belongs to the Copernicus program; Both products are available on digital platforms with updated versions of sensors, OLI (Operational Land Imager) for Landsat 8 and MSI (MultiSpectral Instrument) for S-2 (Claverie et al*.,* 2018 cited in Castro *et al.,* 2021), being used by multiple authors such as Wang et al. (2020), Valderrama *et al.* (2021).

Analyzes of changes in vegetation, landscape characteristics or habitat properties through satellite information are relatively frequent, but in Cuba they have been little addressed. Some examples of these studies have been those developed by (Figueredo et al., 2020).

As the population continues to grow and commercial and development activities intensify, coastal zone management is of increasing importance to generate and use information to design, monitor and manage conservation or development sites (Adade et al*.,* 2021).

These techniques are mainly based on digital image processing through electromagnetic radiation from an emission source, thus collecting data from the Earth's surface to interpret it through visual and digital analysis. The use of remote sensing products helps us to carry out much more specific analyzes such as the evaluation of the condition of vegetation that is in some risk status, such as the mangrove forest (Torres, 2022).

Methods for detecting land cover changes

In a multitemporal or spatiotemporal analysis, the selection of the classification method is important depending on the monitoring system that you want to implement based on the inputs, processing times and results that you want to obtain. Change detection allows us to obtain direct results in the process of identifying differences in an object observed in satellite images of different dates (Granja, 2020).

The three necessary steps prior to the implementation of a change detection technique are the preprocessing of satellite images including geometric, radiometric and atmospheric correction; selection of appropriate techniques to implement the change detection analysis and finally the evaluation of accuracy (Lu et al., 2003 cited in Granja, 2020).

Classification of change detection techniques:

One of the most complete studies related to the different change detection techniques, allows us to analyze the review of the different techniques (Lu *et al.,* 2003) cited in (Granja, 2020). But it also shows us that the search for new techniques is still an active topic and with the additional issue that the new techniques seek to incorporate the remote sensors currently available (Granja, 2020).

No classification method is better than another, they all have their advantages and disadvantages, their use depends largely on the time, inputs and knowledge available to the user about the area to be classified (Table 1).

Table 1. Classification of land cover change detection methods.

Classification Method	Techniques	Advantages	Disadvantages
Algebraic operations (Smola & Schoelkopf, 1998) citados en (Granja, 2020)	Image difference, vegetation index difference, image quotient, image regression and change vectors.	Simplicity. They are based on the differentiation of images.	Does not provide change matrices. Selection of thresholds is necessary.
Transformaciones (Granja, 2020)	Principal component analysis, Tasseled cap transformation, Gramm-Shmidt transformation and Chi-square.	They work directly with the components.	Does not provide change matrices. Selection of thresholds is necessary and makes interpretation of the change difficult.
Clasificación supervisada (Hai *et al.*, 2022); (Onesmus, 2020); (Salas *et al.*, 2019); (Tso & Mather, 2009, Cutler *et al.*, 2007, Chuvieco 2006, Huang & Jensen, 1997, Rumelhart *et al.*, 1986 citados en Granja, 2020).	Maximum likelihood classifier, post-classification comparison, combined spectral time series analysis, unsupervised change detection, hybrid change detection, artificial neural networks, decision tree-based classification, random forest-based classification an improvement of decision trees.	Ability to provide change matrices. These techniques rely on the experience of the performer to select training samples of the changes.	Need to precisely define the quality and quantity of samples to produce reliable results.
Modelos avanzados (Granja, 2022)	Li-Strahler reflectivity model, spectral mixing model and biophysical parameters method.	They use linear or non-linear models to convert image reflectivity values to biophysical parameters.	The complexity makes it a disadvantage due to the time it demands. It is necessary to associate them with measurements in the field.
Analisis visual (Granja, 2022)	Direct photointerpretation of spatiotemporal data in satellite images.	Experience of the interpreter and knowledge of the area of study.	Time.

Fuente: elaboración propia.

State of the art of spatiotemporality in vegetation studies

Gil and Morales (2016) distinguish that the implementation of remote perception tools, processing and interpretation of satellite images and Geographic Information

Systems are widely studied and applied in environmental and landscape problems, given that they have allowed the provision of spatial data with adequate spatio-temporal resolutions; The implementation of images in environmental or climatic services allows us to analyze the dynamics of plant coverage and how natural and human factors operate on them.

In Colombia, in 1998 the Universidad del Valle carried out a demonstrative study on land cover and land use changes in the Buenaventura region, through a "Multi-temporal analysis with Landsat TM images from 1986 and 1997", the project made it possible to identify intervention dynamics of vegetation cover and urban expansion patterns in the area (Fonseca & Gómez, 2013).

In 1999, the Ministry of Public Works and Services of the province of Buenos Aires in Argentina, carried out a multi-temporal analysis of floods in the province of Buenos Aires as a result of the incidence of the El Niño event 1978-1998 and the Francisco José District University of Caldas carried out a multi-temporal evaluation and analysis of deforestation in the Colombian Amazon in which deforestation was quantified for the region (Fonseca & Gómez, 2013).

Particular cases are the studies carried out by Gil and Morales (2016); Veraverbeke *et al.* (2012); Armenteras et al. (2011a); Merino et al. (2011); Pezzola and Winschel (2004); Heredia *et al.* (2003) and Recondo et al. (2002) where they evaluated at a spatio-temporal level with infrared bands, the sectors affected by forest fires (before and after the event). These investigations address a comprehensive approach to rural development, the implementation of strategies aimed at improving management, land use, and natural resources; Likewise, they support the implementation of satellite images, because their use provides reliable and truthful information on data on fire outbreaks and expansion.

Ordoñez and Figueroa (2009) carry out a spatiotemporal study of the fragmentation process of forest cover in the Palacé River basin, using an aerial photograph from 1983, Landsat images from 1989-2000 and a QuickBird from 2007, based on Through the photointerpretation of the images, two types of forests were defined (Dense and Open), a loss of vegetation cover was observed, somewhat increasing the degree of fragmentation of the landscape.

Armenteras et al. (2011) analyzed the deterioration of montane and lowland forests in the Colombian Andes (1985-2005), using remote sensors, Geographic Information Systems and Generalized Linear Models; The results determined that these forests show a positive deforestation rate influenced by economic activities, protected areas and broken reliefs, while it is negative, due to parceled lands, road density, water scarcity and minimum temperatures. The authors relate for lowland forests, a deforestation rate closely related to the rural population, the percentage of grazing, crops and protected areas.

Similarly, Bodart et al. (2011) evaluated areas with changes in forest cover with multi-data and multi-scene analysis, in the periods of 1990-2000-2005 for tropical regions. Processing more than 12,000 Landsat TM and ETM+ data involved atmospheric reflectance conversion, cloud shadow detection, haze correction, and radiometric normalization of the images. Such results showed a significant improvement in the visual appearance of the image, specifically with the infrared bands, when implementing algorithms for haze correction. They conclude that image preprocessing provides a consistent multitemporal data set for the tropics and constitutes an objective basis for supervised classification.

The change in slope area of the Tumaradó swamp “Los Katíos Natural Park” in Colombia (1991 and 2000) was studied by Fonseca and Gómez (2013) where they performed combinations of landsat image bands, two classifications, one unsupervised and one supervised with the ERDAS software, and ArcGis for graphic output, resulting in few changes between the two dates analyzed.

Palacios (2015) carries out a multi-temporal analysis of the forest cover in the northern area of the department of Chocó, Colombia, between 1990-2014, demonstrating that there has been a tendency to decrease forest areas based on the use of high-resolution RapidEye images. and the use of supervised classification.

Based on the analysis of changes in forest cover and land use using high spatial resolution satellite images “RapidEye”, in the period 2010-2015 in the area of influence of the Diquis Socio-Environmental Mechanism, Republic of Costa Rica, stability was observed in vegetation cover (Emanuelli et al., 2016).

Changes in vegetation in a context of open pit mining exploitation between the years 1991-2015 in Spain from Landsat images and using the Normalized Difference Vegetation Index (NDVI) demonstrated an increase in vegetation cover (Miller, 2017).

Vera (2018) identifies changes in vegetation cover (mangroves) related to human settlements according to the multi-temporal analysis of satellite images of the Manglares Estuario Río Esmeraldas Wildlife Refuge in Ecuador, based on supervised classification and the use of Landsat images (1991-2000-2006-2018), reporting deforestation in the period 2000-2006 with a TAC of – 2.4%.

The multi-temporal analysis of forest behavior in the mangrove ecosystem through remote sensing in the period 1986-2021 in Tumbes, Peru; using the supervised classification method based on the use of Landsat 5, 7 and 8 images, where an annual deforestation rate of – 2.4 % was reported in 2006 (Cabreras, 2018).

Narváez (2019) carries out a spatio-temporal analysis of the vegetation cover of the Yasuní National Park and its buffer zone, Cononaco sector in Ecuador, using Landsat images over a period of 30 years (1987-2017), from of the supervised classification demonstrated the existence of landscape fragmentation by reducing plant cover.

Mazuera and Martínez (2019) studied the spatiotemporal dynamics of spectral indices such as the Normalized Difference

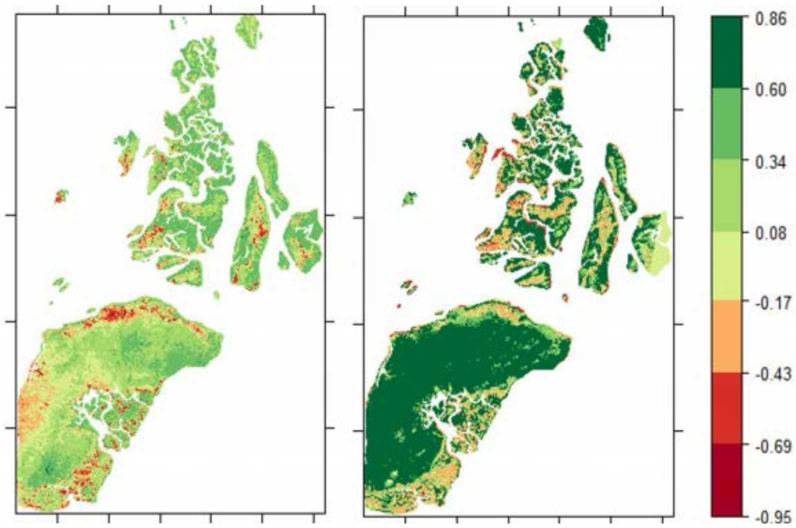
Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) and their relationship with hydrological parameters in the southern area of the Department of Tolima. Colombia, based on the use of Landsat 5 and 8 images between the years 1989, 1997, 2007, 2018.

Vélez (2019) performs a multi-temporal analysis of a series of sentinel-1 images and the detection of changes in land use for the evaluation of the Manglares Churute Ecological Reserve and its surroundings in Guayas-Ecuador in 2019, determining that between the years In 2015 and 2018 there was an increase in the area occupied by shrimp farms and sugar cane 1 km away from the perimeter, land uses that replaced rice crops and other uses such as grass and scrub.

A spatiotemporal analysis of the mangrove cover in the Cayos Miskitosn Reserve in Nicaragua, based on the impact of Hurricane Félix category 5 in 2007, using Landsat 7 images with dates 2006, 2012 and 2017 and using the supervised method, is observed an increase in fragmentation processes (Salas *et al.,* 2019).

Multitemporal analysis of the change in vegetation cover in the management area "Los Numeros" Guisa, Granma, Cuba was carried out by Figueredo et al. (2020) where the spatiotemporal dynamics of the change in vegetation cover that occurred between the years 1986-2016 in lands under forest management regime is evaluated; To do this, through supervised classification of Landsat 5 and Landsat 8 satellite images, cataloging the coverage into four occupation categories (forests; shrubs; grasslands, pastures or crops and bare soil).

Zhiminaicela et al. (2020) carry out a multispectral mapping of the impact of shrimp ponds on the mangrove ecosystem of the Gulf of Guayaquil, Ecuador, using Landsat 5 (1985) and 8 (2017) images based on NDVI analysis; Marked deforestation was detected due to the impact of the pools (Figure 1).



Source: Zhiminaicela et al. (2020)

The multi-temporal analysis from landsat 7 and 8 satellite images using the Normalized Difference Vegetation Index (NDVI) where a study is made on the state of the vegetation after the disturbance caused by four hurricanes on the Guanahacabibes peninsula in Cuba between the years 2002, 2003, 2004, 2018, 2019 (Muñoz et al*.,* 2021).

Izabal (2021) suggests that it is relevant to know the spatial distribution and behavioral dynamics over periods of time, this allows obtaining information on the state and current distribution of mangroves in the Guatemalan Caribbean, which is why he carries out a pilot plan for the study. multi-temporal analysis of the mangrove ecosystem 2012-2019 in the protected areas of the Sarstun River, Punta de Manabique and Rio Dulce using Landsat, Rapideye, and Sentinel -2 A images.

Castro et al. (2021) carry out a multi-temporal analysis of sentinel-2 images for the vegetation cover of the Andean zone of the El Oro province, in Ecuador, based on a supervised classification, they obtain an annual rate of change of 43.90 % for forests.

Likewise Jaramillo et al. (2021) carry out an analysis of the spatio-temporal change in the vegetation cover of Cerro de Hojas Jaboncillo, during the period (2015-2020) they present an analysis of the loss of vegetation cover, based on Landsat 8 satellite images from the Earth platform. Explorer, with the combination of bands 5, 4 and 3 known as infrared for the aforementioned time, in turn, a classification was carried out that allowed deducing the Annual Cover Change Rate for bare soil, healthy and well-developed vegetation, highly variable bush and less dense vegetation areas or with less developed vegetation, the qualitative and descriptive methodology was also used and the subsequent calculation of the NDVI.

A recent study in which three images Spot 4 (1995, 2004) and 5 (2015) are used is the study of mangrove cover in Mui Ca Mau, province of Vietnam, using the Random Forest method, determining decrease in coverage and fragmentation (Hai et al*.,* 2022).

Another multi-temporal analysis of deforestation by satellite images in the district of Pangoa, Junín from the year 2000-2020 is carried out by Janampa and Ponce (2022) using supervised classification using Landsat images and the ENVI 5.3 and ArcGIS software. The study showed deforestation for the 20 years of about 3,240.03 ha.

The National Autonomous University of Mexico carries out a temporal and spatial analysis of the mangrove forest canopy (*Avicennia germinans* (L.), *Laguncularia racemosa* (L.), *Rhizophora mangle* (L.)) in a semi-arid coastal lagoon using emerging tools remote sensing and machine learning algorithms (Torres, 2022).

CONCLUSIONS

The implementation of studies of vegetation cover and soil change are largely accompanied by the use of Landsat images starting in 1985, reaching a marked boom since 2010, together with the use of remote sensors, which allow us to have a global vision of the geographical space, facilitate work and reduce research time.

The application of multi-temporal studies using satellite images, reinforced with the more recent use of drones, has made it possible to monitor all types of vegetation cover in real time.

The use of these new applied geomatics techniques is required in present and future studies of work to be carried out. Therefore, it is currently impossible to practically conceive a study of land surface coverage where the use of remote sensors is not present in the face of a changing climate change scenario.

One of the limitations that prevent better development and application of these techniques on a global scale is access to high resolution images, which would improve the reliability of the results obtained.

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AUTHORS' CONTRIBUTION

MLYJ and MCI de la C: literature review and analysis, manuscript writing and comments on the cited literature

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.