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# REMOTE SENSING AS INDISPENSABLE TECHNOLOGY IN ECOLOGY TO SUPPORT THE PROTECTION OF BIODIVERSITY: A REVIEW

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***Abstract***

*The most promising application of remote sensing, at present, in ecology is related to the field of biodiversity. Some of the main threats to biodiversity are the fragmentation and loss of habitat due to deforestation caused by human activities; which in turn accelerates extinction rates in the species. However, biodiversity is difficult to quantify and measure, which is why remote sensing is a valuable tool for ecological research since, given its characteristics of spatial, spectral, radiometric and temporal resolution, it is possible to try to measure certain variables of biodiversity. However, ecologists and space agencies, in a joint effort, have defined a list of essential variables with which biodiversity can be monitored from space. Thus, there is a need to implement new approaches and tools for their study and conservation, using remote sensing as a tool to support decision-making processes in biodiversity conservation efforts throughout the world.*

***Keywords**: Biodiversity; Satellite images; Variables; Conservation*

## Introduction

Habitat loss and fragmentation are some of the main threats to biodiversity [1-4]. Given the rapid decrease in biodiversity worldwide, there is a need to work with large areas. However, it is difficult to quantify and measure [5-6].

One way to measure biodiversity is through indicator species that may be threatened or in danger of extinction and that require relatively large areas in a good state of conservation [7]. Therefore, the close collaboration between experts in remote sensing and biodiversity conservation can facilitate research for the monitoring, ordering and quantification of biodiversity from space [8-12]. Experts in remote sensing are used to dealing with large areas whose spatial resolutions, in general, range from tens of meters to several kilometers and temporary resolutions between daily and every 10 days. Ecologists, on the other hand, often deal with relatively small areas in spatial resolution of a few meters and daily or annual temporal resolutions. This lack of common frames of reference makes collaborative work difficult [13]. Although, ecologists they should not expect that the indexes derived from the data obtained by remote sensing are directly equal to the data collected in the field, there is a need to strongly consider that the products obtained by remote sensing are adequate for a given analysis [14].

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This article briefly reviews the applications of remote sensing in ecology to support decision making for the conservation of biodiversity, as well as the possible use of these tools in future research.

***Use of remote sensing in ecological research***

One of the first proposals was to apply remote sensing to ecological indicators, since it can work with spatial and temporal scales to map the biotic and abiotic components of ecosystems (land cover, land use, ecological disturbance and vegetation phenology), to estimate their changes over time [7]. Subsequently, advances in spatial and spectral resolution of remote sensing increasingly feasible allowed ecologists to apply it in certain aspects of biodiversity; for example, to distinguish sets of species or even the identification of individual tree species [15-17]. Recently, remote sensing has been recognized as one of the promising approaches to estimate biodiversity, due to the difficulty of collecting field-based data. Therefore, remote sensing is used to estimate the heterogeneity of the landscape and the diversity of species, demonstrating that it is a powerful tool, since it allows working at a high spatial and temporal resolution; to map the biotic and abiotic components of ecosystems (land cover, land use, ecological disturbance and vegetation phenology) and estimate their changes over time [18]. In addition, remote sensing is used in many monitoring applications, such as fragmentation and habitat connectivity, in landscape ecology, and focus studies on individual species. This information is essential in the design of effective strategies for the conservation and management of biodiversity [19].

**Remote sensing works to support decision making for biodiversity conservation**

LiDAR is an active remote sensing technology that allows obtaining three-dimensional and continuous information on the tree structure, constituting a useful tool to complement forest inventories in field work [21]. Therefore, the variables derived from LiDAR such as the diameter of the crown, the total height and the basal area allow the characterization of tree structures [22]. Since, in the case of some species, obtaining this type of data from LiDAR technology is important for the implementation of actions that contribute to the conservation of biodiversity [23].

**Passive remote sensing to support decision making for biodiversity conservation**

Satellite images belong to passive remote sensing and are used as a tool for decision making in biodiversity conservation, since, through analysis, areas that receive support for environmental conservation can be monitored and monitored [24].

This type of passive remote sensing offers the possibility of spatially and temporally monitoring the phenomena that can be delimited in ecological units on which different measures are applied to study their spatial structure: fragmentation, shape, abundance, specificity, among others [25]. In this way, remote sensing data can play an important role in providing information on habitat change, degradation and fragmentation, as well as the spread of invasive species, which fosters compliance with monitoring objectives [13].

**Advantages of satellite images in ecological research**

Satellite images have become an important tool because, by combining information about the habitat requirements of species with land cover maps derived from remote sensing data, it is possible to estimate accurately the potential distribution of species and their richness patterns [15]. Although, to increase the use of satellite images for ecological and conservation purposes, a commitment is required from biodiversity and remote sensing experts to promote a higher level of interdisciplinary work among these communities, in order to create opportunities in the progress of both disciplines [26-27]. However, the use of remote sensing by ecologists is growing. Due to its potential, in the last decades a series of remote sensing technologies have been used in a wide variety of applications, including the identification of relationships with the habitat, the quantification of biodiversity, the modeling of the distribution of species and planning of conservation [29-30].

**Spectral vegetation indexes applied for the conservation of biodiversity**

The essential variables of biodiversity propose to take advantage of spectral vegetation indexes to measure certain characteristics of vegetation phenology continuously through space; for example, the structure and function of ecosystems [30]. Therefore, 10 variables are proposed to measure biodiversity from space [12].

There is a need for closer collaboration between experts in biodiversity conservation and remote sensing today [12-59], [31]. Investigations such as those of [32] and [59] describe that there is a significantly positive relationship between high values of the normalized vegetation difference index (NDVI) and the presence of species such as ostrich (Struthio camelus) and wildebeest (Connochaetes taurinus). In the case of primates, [33] used the NDVI to model the habitat of the vervet monkey (Cercopithecus aethiops) in Africa, in the study it was identified that the monkeys preferred areas with high values of NDVI, which acted as an indicator of food availability (green vegetation). In addition, there are investigations in which certain species have been studied from space through satellite images. For example, populations of flamingos off Nalabana Island at Chilika Lake of the India [34], emperor penguins on the continental coast of Antarctica [35], whale pathways through the New Gulf of the Valdes Peninsula in Argentina [36], ñus, zebras and gazelles in the East of the African Savannah [37-38], polar bears in the Canadian Arctic [39], elephant seals in the southern Pacific Ocean [40] and albatrosses in the Bird Island to the west of mainland South Georgia [41]. Some of the most important investigations are presented in Table 1.

Table 1. Outstanding research on remote sensing, ecology and biodiversity conservation

| **Research** | **Authors and year** |
|---|---|
| Close collaboration between experts in ecology and remote sensing for research on climate change, biodiversity conservation and ecosystem dynamics. | [7-8], [15-16]. |
| NDVI recommendation as an indicator of food availability associated with the presence of species such as ostrich, wildebeest and vervet monkey. | [32-33]. |
| Use of satellite images in relation to the dynamics of ecosystems to observe changes in land cover due to fragmentation and loss of habitat. | [10], [42-43], [18]. |
| Identification of populations in environments without vegetation of species such as flamingos, penguins, whales, wildebeest, zebras, gazelles, polar bears, elephant seals and albatrosses through the use of hyperspectral satellite images. | [34-41] |
| Proposition of variables to monitor biodiversity from space. In which, through the spectral vegetation indexes, certain phenological characteristics related to the movement patterns of the species can be measured. | [12], [19], [63], [14], [31]. |

**Types of satellite images used in ecological research**

There are two types of satellite images: multispectral (Modis, Landsat, Sentinel, among others); and hyperspectral such as QuickBird (figure 1), GeoEye (figure 2) and WorldView (figure 3), in which certain populations of species have been identified. Multispectral satellite images have been useful for the classification of different types of soil cover, usually based on vegetation [15]. In addition, with this type of images can be done ecological monitoring, in terms of habitat structures and the associated effects on wildlife; what makes it a common tool for exploration in the composition of biodiversity, that is, the richness of species [32]. On the other hand, the hyperspectral images describe in a fine scale the occupation of the soil of each species, such as vegetation categories or soil types, making the contribution to the study remarkable, in relation to the biodiversity patterns [44]. In addition, they have been used to generate information, regarding the phenological properties of the plants (for example, leaf pigment, water content and chemical composition), achieving tree species differences in landscapes and making the identification quite accurate between Different species, which allows the distinction of tree types based on reflectance in response to pigment, nutrients, and structural differences between species [45]. For example, the spectral signature of a plant shows the characteristics of the electromagnetic radiation behavior with its structure; there are also vegetation indices, which are combinations of the spectral bands recorded by satellite images, the NDVI being the best known and used to estimate the quantity, quality and development of vegetation based on the measurement of the intensity of the radiation [46].

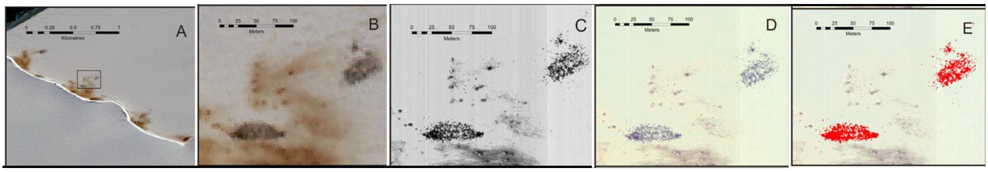


**Fig. 1.** Penguin populations [35]

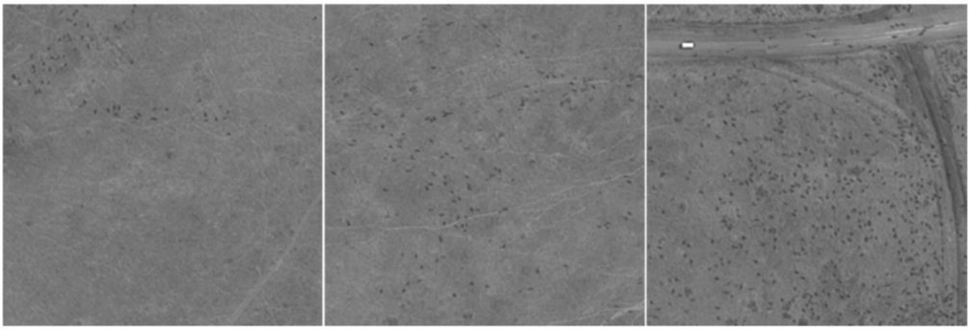

**Fig. 2.** Populations of wildebeest, zebra and gazelles [38].

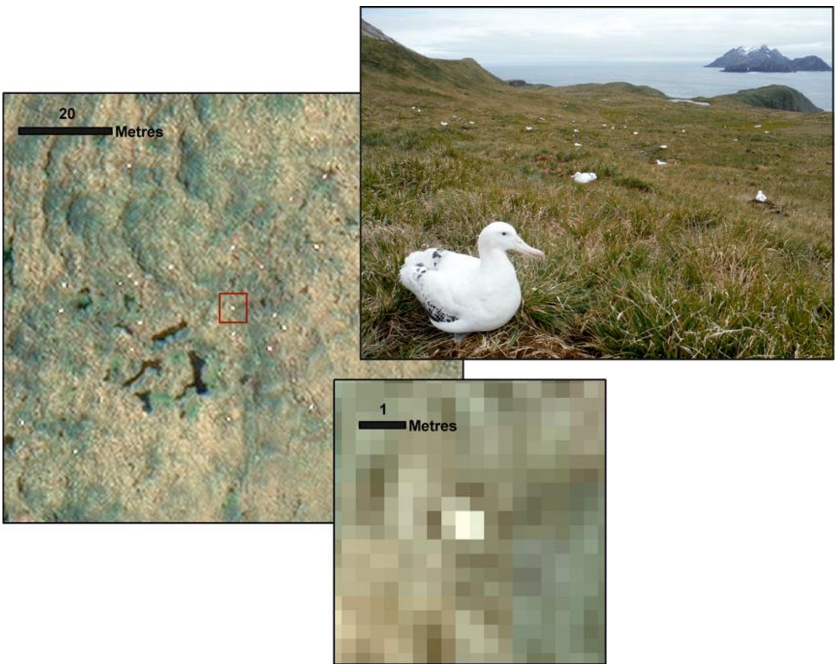


**Fig. 3.** Albatrosses populations [41]

**Spatial models to support decision-making for the conservation of biodiversity**

The models are tools of increasing use that combine literature review, field work, geographic information systems and remote sensors for biogeographic, ecological and conservation studies [47-51]. Such is the case of species distribution models that, based on a geographic information system, indicate by means of a cartographic representation derived from remote sensors the environmental suitability of the habitat for the development of a specific species, and thus, help make conservation decisions [52-56]. Spatial modeling is an important tool for the evaluation of the potential distribution of terrestrial species [57], so recently models have been made in which spectral indices of vegetation have been introduced as variables. the NDVI, derived from satellite images [58].

**Final considerations**

It is necessary to increase the use of satellite images for ecological purposes and for the conservation of biodiversity, in order to promote a higher level of interdisciplinary work between ecology and remote sensing and thus stimulate the creation of opportunities and the advancement of both disciplines [13], [26-27]. However, the results obtained from the synergy of these two sciences have to be collated with data collected in the field [14].

The potential for synergies between science and remote sensing is the key to improving interpretations and uses of satellite data to support future research in decision-making process management for biodiversity conservation [60-61]. Remote sensing experts should seek a deeper understanding of ecological concepts and requirements to minimize semantic confusion and to ensure that data processing is most appropriate and useful [62], [12].

## Conclusions

Remote sensing is one of the main tools available for the assignment and monitoring of biodiversity patterns through large spatial scales. The data derived from remote sensing provide information on the characteristics of the environment that influence biodiversity, the structural and functional properties of ecosystems, the spatial distribution of the different components of biodiversity, the patterns of natural vegetation changes induced by the human and impacts of various disturbances and ecological interactions. In addition, it is an important tool to monitor and monitor the state of biodiversity and associated environmental parameters relevant to conservation; among them, certain elements of the habitats.

It is useful in generating records for the monitoring of changes in biodiversity (land cover, land use, ecological disturbance and vegetation phenology) locally and globally. In addition, it is widely used as a source of environmental information for ecological research. For example, in relation to ecology, studies have often sought information on variables such as species richness and facilitating biodiversity monitoring activities, since spatial models allow the use of both data derived from passive remote sensing as variables. To measure certain phenological characteristics of the vegetation through satellite images, such as vegetation height from active remote sensing derived from LiDAR technology.

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