WETLANDS ECOTOURISM PLANNING IN THE SAVANNAS OF COLOMBIA. LINKING REMOTE SENSING AND BIO-DIVERSITY

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ABSTRACT

Ecotourism has become a practice of socio-environmental interest and a conservation strategy aimed at protecting environments with high natural interest, whose lack of planning can compromise the quality of the environment. Therefore, it is necessary to explore territorial planning methods, such as remote sensing techniques, as efficient tools in predicting biodiversity - birds in this paper. In this way, the research explores using the Normalized Differential Water Index (NDWI) and biodiversity information for the design and planning of ecotourism destinations in the savannas of Colombia. Through satellite images, digital cartography, and the NDWI index, lagoon complexes were identified in a high potential region for bird watching in a key biological corridor of the Colombian savannas. This methodology made it possible to determine patterns of presence, abundance, and distribution of avifauna by classifying lagoon bodies. The results of the NDWI index facilitated the identification of 181 bodies of water in the study area and 12 visit routes for bird watching based on the recognition of potential sites whose natural wealth represents a tourist factor in the territory. This work is the first documented planning initiative for a design with technical support of birdwatching routes in the savannas of Colombia through remote sensing.

Introduction

Tourism has adopted new practices aimed at meeting the needs of the current market, promoting the exploration of “unconquered” spaces and appropriating these territories, in order to establish a relationship between the objects of the natural, social and economic environment (Vázquez Martínez & Vázquez Solís, 2017). Consequently, the concept of tourism was rethought in terms of sustainability as ecotourism, focusing on the generation of economic benefits, through the proper use of environmental and socio-cultural resources, based on the interaction of visitors with nature and creating a scenario conducive to carrying out preservation, conservation and environmental education activities (Oliveros Ocampo & Vargas, 2018). As a consequence of this, concerns have emerged around the proper management of the territories and their resources, encouraging the development of ecotourism by implementing strategies around sustainable management and aimed at

the study of different techniques that are a source of experience for those interested in adopting it as a development tool (Ospina Díaz et al., 2016). However, the development of ecotourism activities requires the delimitation of sites whose biotic and abiotic richness satisfy the needs and expectations of tourists; considering that the presence of native fauna, aesthetic landscapes, ecosystems not intervened, accessibility, and local tourist infrastructure, represent an important attribute in the search for areas with great potential for their eco touristic development (Suryabhagavan et al., 2015). Despite this trend, it has been necessary to search for alternatives and adequate methodologies that allow the execution of ecotourism projects. In this context, wetland areas have been considered a natural attraction since they represent a contact zone between aquatic and terrestrial ecosystems, in which activities of great ecotourism interest such as bird watching can be carried out (Muñoz Pedreros Andres and Quintana Jorge, 2010).

In Colombia, the development of ecotourism has been a fundamental element in the national tourism industry since the richness of its landscapes, its climatic variety, and biodiversity make it an ideal country for its development. In addition, the Colombian government developed strategies to improve the sector and generate a positive social impact via a planned development of resources that guarantee its long-term economic stability while consolidating its attractiveness to foreign investment (Santiago Escobar, 2018). Likewise, areas such as the department of Meta with biological and geographical diversity, accompanied by great tourist and ecosystem attractions, has become a favourable sector to develop tourist activities (Governacion del Meta, 2019). In turn, the municipality of Restrepo is considered a tourist centre of the department due to its strategic geographical location in the Meta-Orinoco basin and its natural attractions (Municipal Council of Restrepo Meta, 2016).

Regarding birdlife, this region is appreciated for its wide variety of habitats with the highest values of biodiversity registered in comparison with the other regions of the Colombian Orinoco basin. It is also an area of geographical importance since it is located in a transition area between the plains, the Andean mountains, and the north of the Amazon, in which 45% of the species found in Colombia can be found (Acevedo-charry et al., 2014; JI Murillo-Pacheco & Bonilla-Rojas, 2016).

The municipality of Restrepo has been the focus of study on exploration and birdwatching; where a maximum of 254 species of birds have been registered in the territory, being the Mississippi Elanio, the Chapulinero Busardo, the Sabanera Earwig, the Neck Swift, and the Great Egret, the most observed species (Alcaldía de Restrepo, 2017; Laboratorio de Cornell Ornithology, 2020).

However, inadequate surveillance, environmental control by the competent authorities, and disorganized tourism have caused contamination of rivers and areas by tourists.

Therefore, is an apparent need to take immediate actions that help preserve natural habitats and the environment in general and provide efficient tools that facilitate the adoption of ecotourism as a sustainable economic activity (Alcaldía de Restrepo, 2017; Gobernación del Meta, 2016).

Due to the above, this research aims to contribute to the planning of ecotourism destinations based on the NDWI model. This technique will allow the identification of lagoon complexes in the municipality of Restrepo-Meta and establish favorable areas for the development of ecotourism in the modality of bird watching. In Colombia, the development of ecotourism has been a fundamental element in the national tourism industry since the richness of its landscapes, its climatic variety, and biodiversity make it an ideal country for its development. Besides, the Colombian government developed strategies to improve the sector and generate a positive social impact via a planned development of resources that guarantee its long-term economic stability while consolidating its attractiveness to foreign investment (Santiago Escobar, 2018). Likewise, areas such as the department of Meta with biological and geographical diversity, accompanied by great tourist and ecosystem attractions, has become a favorable sector to develop tourist activities (Gobernación del Meta, 2019). In turn, the municipality of Restrepo is considered a tourist center of the department due to its strategic geographical location in the Meta-Orinoco basin and its natural attractions (Municipal Council of Restrepo Meta, 2016).

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LITERATURE REVIEW

Avifauna in the Colombian savannah

Murillo-Pacheco et al. (2017) evaluated the influence of 36 lentic wetlands on the biodiversity of birds in the foothills of the plains, one of them in the study area, where 276 birds dependent on these ecosystems were identified, highlighting the importance of these areas for the maintenance of bird populations in Colombia.

The Corporation for the Sustainable Development of the La Macarena Special Management Area "CORMACARENA" & Ecopetrol (2015) carried out the delimitation and characterization of 55 wetlands in the municipality Restrepo-Meta, through the rapid Ecological Assessment, identifying 43 predominant bird species in these ecosystems.

Remote sensing in ecotourism planning

Remote sensing techniques have been an important technological tool proposal in ecotourism planning. For instance, Suryabhagavan K. V. et al. (2015) used multicriteria techniques and remote perception, focused on creating cartography that allowed identifying the most suitable areas for the development of ecotourism activities. Likewise, Ahmadi, M. et al. (2015) carried out the zoning of areas for ecotourism development in the province of Ilam (Iran) through the construction of cartography based on the biophysical characteristics of the area in order to study the suitability of ecotourism performance.

However, not well documented in Latin America, planning and environmental agencies in the continent are starting to implement various remote sensing techniques to provide technical support to an increasing ecotourism industry in their territories. An example of this is Vázquez & Vázquez (2017), who carried out a multicriteria analysis in the selection of 10 possible areas of tourist use in the Altiplano of San Luis de Potosí (Mexico) through the evaluation of the environmental characteristics and tangible cultural resources that allowed to study the feasibility of integrating a touristic corridor for the area.

NDWI index in species prediction

Regarding the use of remote sensing tools, the research is based on the Özelkan (2020) approach, which uses the Normalized Differential Water Index (NDWI) from the processing of satellite images to identify water masses belonging to an area. Authors such as Ferrer-Sánchez et al. (2017) used the NDWI Index in Cuba, as a spatial analysis tool to monitor areas of environmental importance. With this technique, they determined that abiotic factors (humidity, temperature, and precipitation) were associated with the presence of bird communities in which the search for water established a distribution pattern for these species (Ferrer-Sánchez et al., 2017).

Other countries such as Iran (Fallahi & Molavi Vardanjani, 2020) have used spatial information technologies to analyze the changes produced by the ecological conditions of wetlands in the bird population and thus examine migration patterns. In this case, the NDWI Model facilitated the identification of humid areas and subsequently evaluated those rest areas that attract them.

In Latin America, Álvarez et al. (2018) have studied the relationship of wetlands with bird habitats as a management strategy, protection, and management of these species. In their work, they established the role of water bodies in ecosystem structures and the presence/abundance of Flamingos Australes in Argentina through the NDWI model, which established that the hydrological regime is a factor linked to its life cycle.

REVIEW AND RESEARCH METHODOLOGY

The Normalized Differential Water Index (NDWI) is a satellite remote sensing tool focused on identifying water masses in open surface areas, which allows the delineation and extraction of information about environments in wetland areas (Li et al., 2013; McFeeters, 2013). This method is calculated from the reflectance levels of the water in the different short-wave infrared and near-infrared bands, where positive values are obtained for flooded areas and lakes (Ganaie et al., 2013; Gonzaga et al., 2011). In this context, remote sensing is considered an efficient and economical prediction technique for bird occupation, where satellite images facilitate the identification of suitable habitats, such as lakes or wetlands (Shealer & Alexander, 2013).

The convenience of models such as the Normalized Differential Water Index (NDWI) in selecting potential sites for the development of ecotourism activities, as it identifies areas with the presence of water, is suggested by Ferrer-Sánchez et al. (2017). These authors highlight that these wet areas define the migration patterns of birds. Therefore, and are of vital importance in improving the tourist attraction in the study area, given the ecological

value of wetlands in having the ability to provide multiple ecosystem services, including providing key resting, feeding, and breeding sites for a wide variety of bird species (Igl et al., 2017; Samraoui & Samraoui, 2008).

RESEARCH METHOD

For the study, a multispectral Landsat-8 OLI-TIRS satellite image dated February 12, 2020, was used, with a resolution of 30 m; retrieved from the U.S Geological Survey of the USGS Earth Explorer portal; selected according to a low percentage of cloudiness (Özelkan, 2020). Additionally, layers related to the delimitation of the municipality of Restrepo (Meta), sidewalks, roads, and municipal seat were extracted. They were provided by the Department of Administrative Statistics (DANE) and the OpenStreetMap website to locate the study area.

Subsequently, the information collected was combined by superimposing the layers using the ArcGis 10.8 Software. The Normalized Differential Water Index (NDWI) was calculated for the municipality's total area using the near-infrared band and the short wave infrared band as follows:

$$NDWI = \frac{NIR-SWIR}{NIR+SWIR}$$

where:

NIR = Near Infrared band.
SWIR = Short Wave Infrared band.

In this case, band 5 was taken as NIR and band 3 for SWIR, and the index was calculated using the ArcGis 10.8 Raster calculator in order to differentiate the aquatic and non-aquatic areas, whose values greater than zero allowed identifying those areas with a moisture content (McFeeters, 2013; Md. Sofi Ullah, 2017).

Subsequently, a characterization of the population structure of the birds was carried out in some key areas of the municipality. Within this area, 3 observation points were selected to carry out a field visit; taking into account its proximity to the municipal seat and ease of access, in order to collect relevant information on the distribution of birds in the municipality of Restrepo and monitor them (Poudel & Adhikari, 2020).

RESULTS

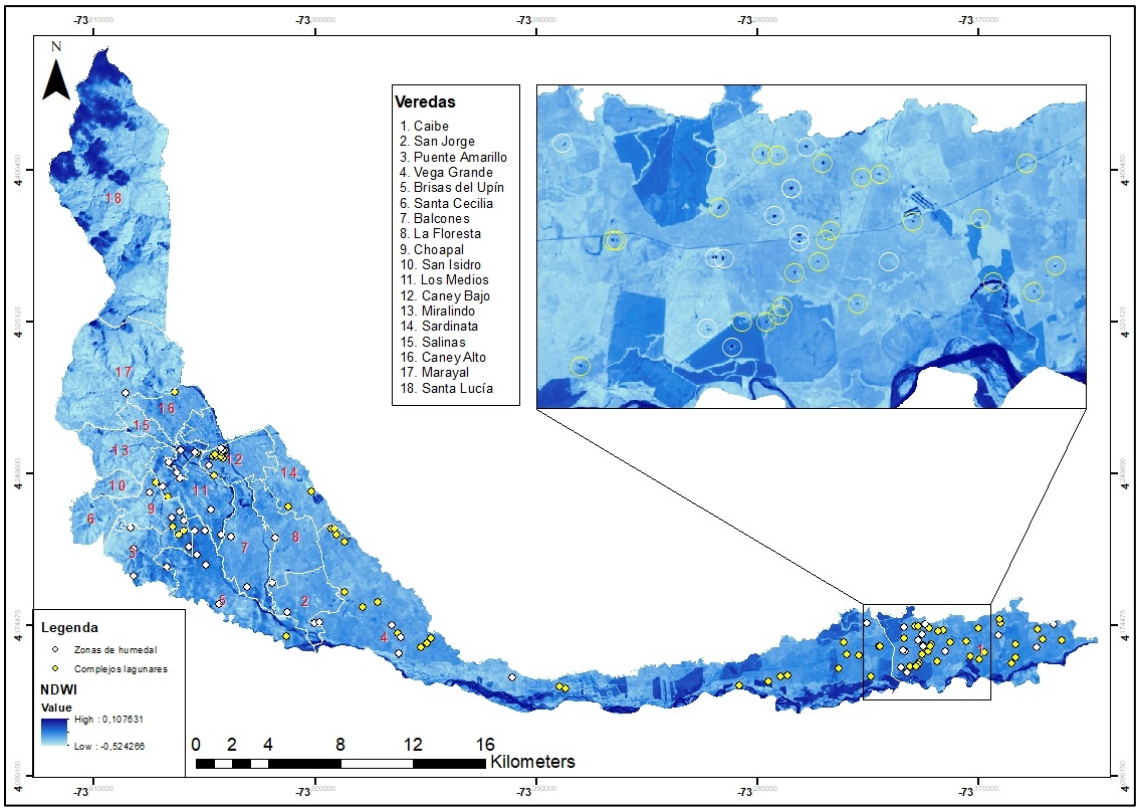
NDWI

The NWDI was calculated for each of the satellite image pixels belonging to the municipality of Restrepo-Meta, whose values are between 0.107631 and -0.524266. These were calculated from the subtraction between the near-infrared and short wave infrared bands to obtain a cartographic representation of the areas of wetlands and complexes lagoons in the studied territory.

Figure 1 shows the delimitation of water bodies in a range between 0.107631 to -0.2083175, represented in a dark blue color and values lower than these (-0.2083175 to -

0.524266), identified in a lighter color; it is indicated that they correspond to pastures and seasonal agriculture.

Figura 1: NDWI municipality of Restrepo-Meta



The enlargement of the previous figure represents the different selected points that correspond to the lagoon complexes located in the municipality. In this graphic, the NDWI index allowed to identify - from darker tones - the water content present in the soil, distinguish in 30-meter resolution bodies of water, in addition to giving an approximate visual of their shape and size.

As a result of the NDWI model, 181 points were identified in the municipality, of which 126 were related as lagoon complexes in which natural, artificial, and mixed bodies of water stand out without categorization. The remaining 55 are wetlands that are part of the lentic bodies of ecological importance delimited by the Corporation for the Sustainable Development of the La Macarena Special Management Area (Cormacarena & Ecopetrol, 2015).

Fieldwork

Seventeen species of birds belonging to 16 genera and 15 families were recorded in the three lagoon complexes studied. Complementary information was collected to analyze the current state of some areas and establish in more detail the incidence of these ecosystems in the number of birds found for each area.

The first place analyzed during the fieldwork was an artificial wetland located in a fish farm dedicated to the breeding of *Colossoma macropomum* and *Oreochromis mossambicus*. It was possible to identify eight species of birds in this location, such as *Ardea Alba*, *Ardea cocoi, Pilhero Pileatus, Mimus gilvus, Sturnella Militaris*, among others. It was possible to identify a conserved habitat with a large number of arboreal individuals that serve as a habitat for this species.

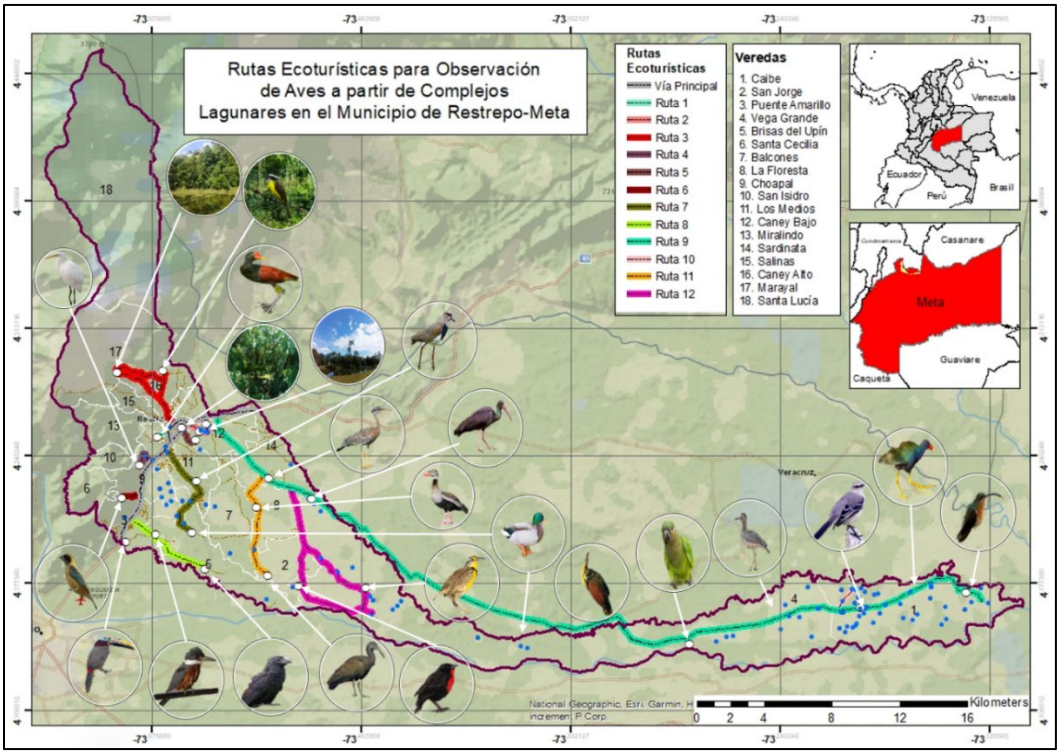
La Dueña Wetland was visited as the second location. Eight species of birds were identified, including *Tachybaptus dominicus, Phimosus Infuscatus, Tringa Solitaria, Aramides Cajaneus, Vanellus Chilensis, Phaethornis Augusti*, as the most representative species. This location was defined as a little intervened ecosystem with signage that informed visitors about its great potential to host birds.

Finally, a tour was made in the Brisas del Llano Wetland, located in a residential sector. In this location, the invasion of its roundabout has greatly affected its ability to provide food and water to fauna in general. In this area, it was not possible to identify birds due to exposure to noise and pollution.

Ecotourism route for bird watching

Ecotourism routes are considered indispensable to promote the culture of tourism in any of its forms. They provide updated information on the different destinations and tourist attractions that a specific area has (Valle Díaz et al., 2020). In this study, its creation was essential to analyze the importance of lagoon complexes as strategic areas for the conservation of birds and how they can generate added value to the touristic offer of the municipality and its community.

Figura 2: Ecotourism route for bird watching.



Due to this, 12 types of ecotourism routes were drawn in the municipality of Restrepo-Meta, based on the lagoon complexes previously identified. A bird characterization was carried out from the Atlas de Humedales de Cormacarena & Ecopetrol (2015) - as presented in Figure 2 - to establish the type of bird fauna present throughout the studied area.

DISCUSION

The use of tools such as remote sensing and the applicability of the NDWI in the planning of ecotourism attractions could be established as a remote technique that facilitates the identification of favorable areas to carry out ecotourism activities such as bird watching through the association of lagoon complexes with the abundance in the variety of bird species (McIntyre et al., 2019).

The avifauna biodiversity increases tourism due to its natural attraction. Furthermore, in concordance with Muñoz Pedreros Andres and Quintana Jorge (2010), the natural complexes present contact zones between the aquatic and terrestrial systems, allowing the development of great ecotourism activities like bird watching. Therefore, ecotourism and the planning of avitourism corridors in a municipality such as Restrepo-Meta can positively impact its natural attraction. In this context, aviturism represents the development of new economic tourism-related activities, whose environmental wealth is based on sighting areas for eight species of great national importance.

When considering the results of the NDWI Index and the biodiversity of the avifauna in the study area, the environmental conditions of the lagoon complexes identified in the municipality of Restrepo-Meta indicate that these can influence the variation of bird

populations. For instance, the scarce vegetation heterogeneity negatively affects the bird species, where deforestation influences the habitat, reproduction, and food services they need to survive (J. Murillo-Pacheco et al., 2017). Thus, the development of ecotourism projects requires coordination with the regional environmental authority (Cormacarena), as this organization can ensure protection and conservation, taking into account the potential of the study area and the socio-economic impact in the regions/municipalities involved in such touristic developments.

CONCLUSION

Implementing a new birdwatching route will encompass the many forms of local involvement in the development of ecotourism activities. Their design based on information from this study can provide necessary technical information that can be used for the strategic planning by the stakeholders who manage, control, and benefit by the creation of tourism products and services. In this context, the use of remote sensing to clearly identify not just the areas but communities who could benefit from new eco-tourism projects enhances the sense of awareness and the potential for effective participation of these communities. The use of this data (regions, biodiversity, communities) provides an opportunity to improve the collective dialog and appropriation of the territory, becoming a platform for participatory collective design of rural preservation and regeneration initiatives around the design and provision of ecotourism services as previously documented by (e Vos et al. (2016) and Velasteguí López, (2020).

Regarding the applied methodology, the study contributes to recognizing the NDWI in territorial planning, whose long-term projection may facilitate the development of new ecotourism routes by allowing the recognition of natural areas under conservation as potential scenarios for the promotion of the local economy (Mirsanjari, 2012).

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