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Land Cover in Coraza and *Montes de María* Protective Forest Reserve, Department of Sucre, Colombia

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Abstract

Objective: This research study aimed at verifying, through satellite monitoring, changes that land cover of *Serrania de Coraza* and *Montes de María* Protective Forestry Reserve has experienced from 1990 to 2017. **Methods / Analysis:** Unsupervised classification method, and Landsat and SPOT satellite images were used. **Findings:** There is a high proportion of bare soil during the first 20 years of the study, whereas in the last five years values considerably decrease. For the cover regarding the intervened areas, the opposite occurs, since during the first 20 years values are much lower than in the last five years, reaching a 43% proportion. Cover of primary forests has declined throughout the study period. **Application / Improvements:** Forced peasants' displacement in *Montes de María* during the 1990s and 2000s, due to the armed conflict Colombia has experienced for years, could be related to the results. Urgent measures are required to preserve biological diversity in the region.

Keywords: Coverage, Montes de María Protected Area, Satellite Monitoring

1. Introduction

Serranias de Coraza and *Montes de María* are geographically located in the Colombian Caribbean region, in the jurisdiction of Toluviejo, Colosó and Chalán municipalities, department of Sucre. In 1983, Colombian government declared this mountainous system as a Protected Forest Reserve Area[1]. This measure was taken to respond to intense deforestation presented in the region, and scarcity of water experienced by communities, negatively impacting biological diversity of the mountain system.

Montes de María encompasses an area of 6,297 km^2, with an approximate population of 438,119 people, who live mainly from livestock, mining and agriculture[2] 55% of the region corresponds to urban areas and 45% to rural areas. They occupy an area of 6,730 Ha and are located between 200 and 560 meters above sea level, characterized by presence of hygrotrophytic, subhigrophic and phreatophytic forests[3]. Territory is made up by mountainous belts with valleys and steep mountains. Average annual temperature ranges from 24°C to 39°C and average annual rainfall is 1,114 mm, determining two climatic periods per year[4-6].

Serrania de Coraza and *Montes de María*, have characteristic ecosystems of tropical dry forest[7,8], with great threat, mainly due to anthropic activity, such as livestock, agriculture, mining[9] and illegal species trafficking[10]. Satellite

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monitoring is effective to detect environmental impacts produced by anthropic factors such as those mentioned above[11]. Determination of changes experienced by land cover over the years is a way to contribute to initiatives of more effective conservation measures, such as those taken in other regions of the Sucre department[12, 13].

The objective of this research study was to carry out satellite monitoring of the area of the *Coraza* and *Montes de María* Protective Forest Reserve, to determine variations experienced by land cover from 1990 to 2017.

2. Materials and Methods

The Protected Forest Reserve *Serrania de Coraza* and *Montes de María*, is located at coordinates 09° 31 '48.3 "N and 075° 21' 05.2" W, in the jurisdiction of Toluviejo, Colosó and Chalán municipalities, department of Sucre (See Figure 1).

Satellite monitoring was carried out on the *Coraza* soil cover to observe prominent changes by using an unsupervised classification method which main advantage is recognition of spectral patterns in satellite images of the area under study in an autonomous way, without need of knowing the site and, thus, allowing cover interpretation[14].

Images from the United States Geological Survey (USGS) Landsat 5 TM (1990/07) were used; 7 ETM (2003/03), as the most common images in the study of vegetal cover[15] and a SPOT image, (2012/08) to quantify in hectares, the units of areas of vegetated zones, intervened zones and bare soil. With polygon in "SHP" format of the Coraza forest reserve, Landsat path 9 row 53

Figure 1. Study Area.

and SPOT images were cut out. An image processing and treatment was carried out in terms of enhancement, to improve appearance[16]. Subsequently, unsupervised classification of similar pixels was carried out in all bands, to determine types of cover and assign established names[17]. Finally, areas were quantified, and maps were prepared per year.

3. Results and Discussion

Figure 2 shows cover multitemporal analysis in the *Coraza* and *Montes de María* Protective Forest Reserve, obtained for years 1990, 2000, 2012 and 2017. As observed, land cover has undergone notable variations in that 27 years period.

Cover proportion without information and that, due to clouds and shadows, show insignificant values during the entire study period. In the first 20 years, land without cover appears in a high proportion and occupies almost half of hectares of protected area. In contrast, in the last five years of study period, values considerably decrease. In the cover related to intervened areas, the opposite occurs. In the first 20 years, values are much lower than in the last five years, where they reach proportions of up to 43%. Finally, cover by vegetation, primary forest, has declined during the period analyzed in this study.

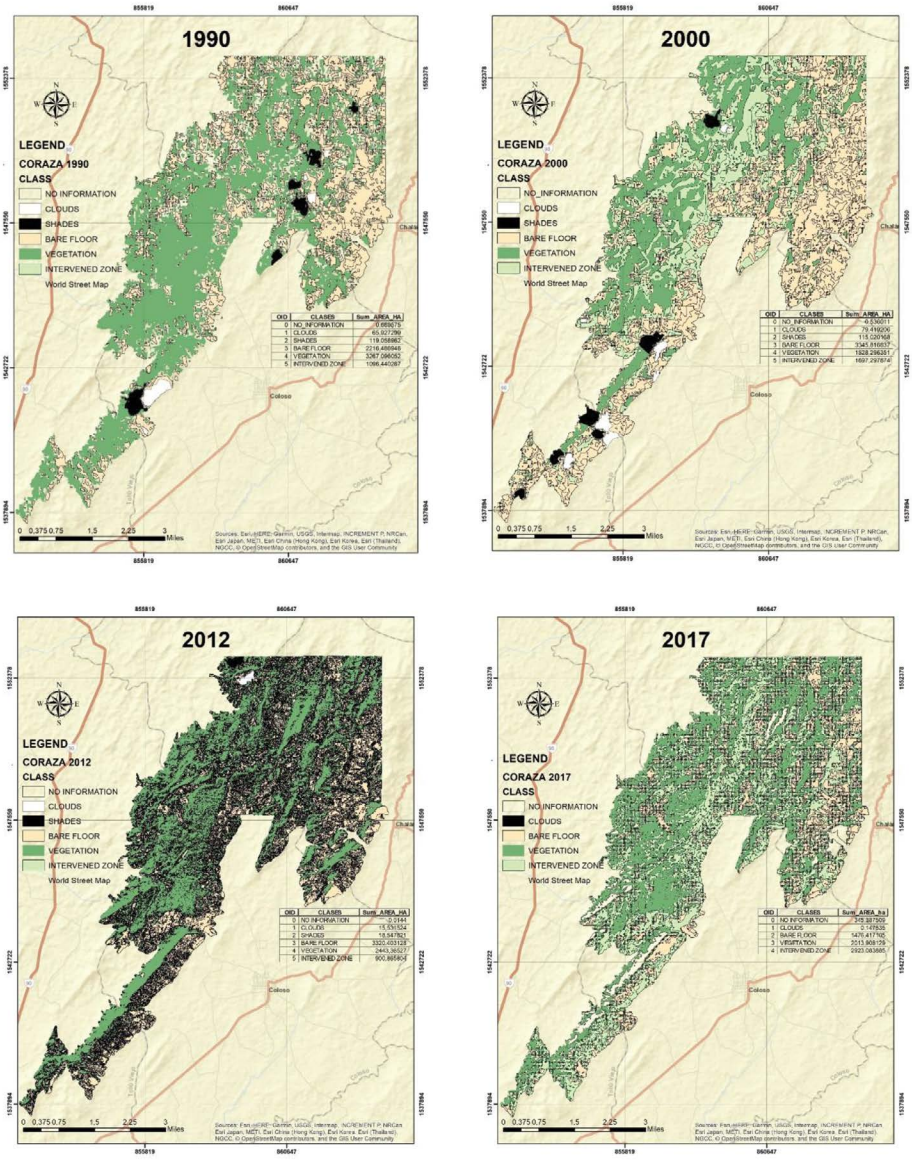

Figure 2. Multitemporal analysis of the cover in the *Coraza* and *Montes de María* Protective Forest Reserve.

In (Figure 3), a graphic summary of these results can be seen.

Forced peasants' displacement in Montes de María in the 1990s and 2000s, due to the armed conflict in the country[18], could be related to the results shown in Figure 3. That is, when they would work the land, it appears without cover. After abandonment, a greater proportion of hectares with cover are observed, especially of secondary forest and fragmented forest with pastures and crops[19], as shown in Figure 4 something similar was reported

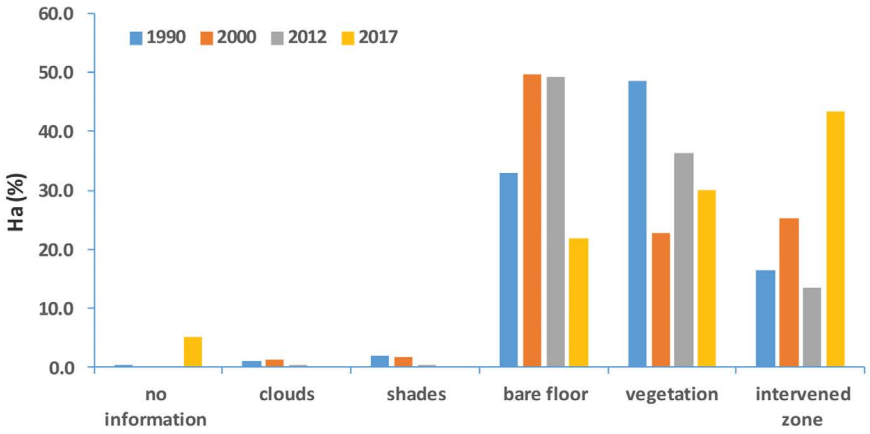

Figure 3. Graphical summary of cover hectares (percentage) observed in the multi-temporal maps in the different years analyzed.

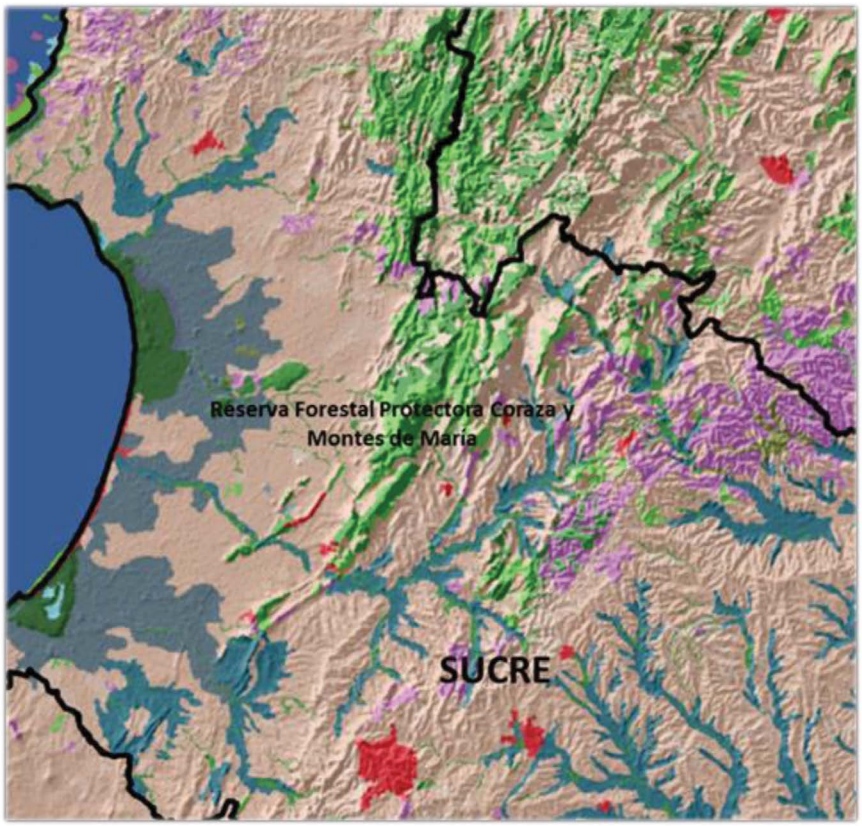

Figure 4. Plant elements within the *Coraza* and *Montes de María* Protected Forest Reserve.
Source: Continental, Coastal and Marine Ecosystems Map of Colombia, 2017[19]

by[12], in localities of *Montes de María*. This situation could explain why a reduced number of intervened hectares appear for 20 years and, that, in the last years of observation period, with return of peasants to their lands because of the end of conflict, the intervened areas have increased. The situation of primary forests seems to be very compromised, since their proportion remains very low throughout the observation period.

Despite the situation, the Coraza and Montes de María Protective Reserve maintains an appreciable biological diversity, as pointed out by several authors[12, 20-23], giving it scientific relevance. Furthermore, there are endemic species in the area, such as the Titi (*Saguinus oedippus*), the arrow frog (*Dendrobates truncatus*), the Caracolí (*Anacardium excelsum*), the Guayacan (*Bulnesia arborea*) and others. There are also very important species for ecotourism in the region, which still cannot be adequately exploited[22]. However, flora and fauna situation in the Forest Reserve is not good and it faces numerous threats, standing out, due to their negative impact, deterioration and fragmentation of habitat, overexploitation of species and illegal species trafficking. Currently, many endemic species of the Coraza and Montes de María Forest Protector Reserve threatened with extinction or are in a vulnerability state.

For the reasons previously stated, the need to take urgent measures to stop deterioration of the Forest Reserve is evident[12]. It is necessary to achieve a reasonable balance between the necessary agricultural, livestock and mining production with the conservation of biological diversity of the region.

4. Conclusión

Abandonment of lands belonging to the *Coraza* and *Montes de María* Protective Forest Reserve, due to the armed conflicts and anthropic impact on natural resources the region has experienced for many years, have considerably altered land cover; resulting in loss of biological diversity. To mitigate effects of such environmental threats, political, economic, social and ecological measures must be applied throughout the affected area.

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