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Multitemporal analysis of vegetation cover change in the management area "Los Números" Guisa, Granma

Análisis multitemporal del cambio de cobertura vegetal en el área de manejo "Los Números" Guisa, Granma

Análise multitemporal da mudança de cobertura vegetal na área de gestão "Los Números" Guisa, Granma

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ABSTRACT

The work was carried out in the area of "Los Números", Guisa municipality, Granma province, Cuba. This area forms one of the largest rural councils in the territory, where forestry plays a fundamental role, with an impact on more than 80 % of the area. The objective of the research was to evaluate the spatial-temporal dynamics of the change in vegetation cover that occurred between 1986 and 2016 in lands under a forest management regime. To this end, through the supervised classification of Landsat 5 and Landsat 8 satellite images, the cover was catalogued into four occupation categories (forest; shrub; grassland or crop; and naked-soil). Information from the forest management project of the Granma Agroforestry Enterprise was used, where the characteristics of the plots are presented. The result was that, during the period analyzed, 20.91 km² of shrub areas and 6.38 km² of grasslands, pastures or crops decreased, as well as 6.65 km² of naked soil, while 33.94 km² of forest clearly represented the advance of the forest cover limit. In terms of the persistence of the forest category, the Mountain Rainforest and Pine Forest formations were the most distinctive and, in relation to the persistence of the shrub category, the semi-

deciduous formation on limestone soil and mountain rainforest were the most represented. The 54 % of the total recovery was shown in the Pinar del Rio. The reforestation plans undertaken during the period analysed have a major influence on the recovery of the coverage of this formation.

Keywords: satellite image; vegetation cover; dynamics.

RESUMEN

El trabajo se desarrolló en la zona de "Los Números", municipio Guisa, provincia Granma, Cuba. Esta zona compone uno de los consejos rurales más extensos del territorio, donde la actividad forestal tiene un papel fundamental, con incidencia en más del 80 % del área. El objetivo de la investigación consistió en evaluar la dinámica espacio-temporal del cambio de cobertura vegetal acontecida entre los años 1986 y 2016 en terrenos bajo régimen de manejo forestal; para ello, mediante clasificación supervisada de imágenes satelitales Landsat 5 y Landsat 8, se catalogó la cobertura en cuatro categorías de ocupación (bosques; arbustivo; herbazales, pastos o cultivos y suelo desnudo). Se utilizó información del proyecto de ordenación forestal de la Empresa Agroforestal Granma, donde se exponen características de los lotes. Como resultado se obtuvo que, en el período analizado, disminuyeron 20,91 km² de zonas arbustivas y 6,38 km² de herbazales, pastos o cultivos; así como 6,65 km² de suelo desnudo; mientras que el 33,94 km² de los bosques representan claramente el avance del límite de cobertura boscosa. En términos de persistencia de la categoría bosques, las formaciones Pluvisilva de Montaña y Pinar fueron las más distintivas y, en relación con la persistencia de la categoría arbustivo, la formación semicaducifolio sobre suelo calizo y pluvisilva de montaña resultaron las más representadas. El 54 % del total de la recuperación se mostró en el Pinar. Influyen mayormente en la recuperación de la cobertura de esta formación los planes de reforestación acometidos durante el período analizado.

Palabras clave: imagen satelital; cobertura vegetal; dinámica.

SÍNTESE

O trabalho foi realizado na área de "Los Números", município de Guisa, província de Granma, Cuba. Esta área é um dos conselhos rurais mais extensos do território, onde a atividade florestal desempenha um papel fundamental, afetando mais de 80 % da área. O objetivo da pesquisa foi avaliar a dinâmica espaço-temporal da mudança de cobertura vegetal ocorrida entre 1986 e 2016 em terras sob manejo florestal. Para tanto, através da classificação supervisionada das imagens de satélite Landsat 5 e Landsat 8, a cobertura foi catalogada em quatro categorias de ocupação (floresta; arbustos; pastagens ou culturas; e solo descoberto). Foi utilizada informação do projeto de manejo florestal da Empresa Agroforestal Granma, onde são apresentadas as características das parcelas. O resultado foi que, no período analisado, diminuíram 20,91 km² de áreas arbustivas e 6,38 km² de pastos, pastagens ou cultivos, assim como 6,65 km² de solo descoberto; enquanto 33,94 km² de florestas representam claramente o avanço do limite de cobertura de florestas. Em termos de persistência da categoria bosques, as formações florestais de montanha e pinhal foram as mais marcantes e, em relação à persistência da categoria Arbustiva, a formação semi-decídua em solo calcário e floresta tropical de montanha foram as mais representadas. 54 % da recuperação total foi mostrada no Pine Grove. Os planos de

reflorestamento empreendidos durante o período analisado têm uma grande influência na recuperação da cobertura desta formação.

Palavras-chave: imagem de satélite; cobertura vegetal; dinâmica.

INTRODUCTION

The mountain forests of the Neotropical region are among the least known and most threatened of all the forest vegetation in the tropics. In addition, they shelter water sources, are vitally important for the preservation of water quantity and quality, and provide shelter and food for wildlife (Oliveira *et al.,* 2004, cited by Rodríguez, 2015).

Analyses of changes in vegetation, landscape features or habitat properties using satellite information are relatively frequent, but they have been little addressed in Cuba. Some examples of these studies have been developed by Ponvert, (2003); Estrada *et al.,* (2013); Hernández and Cruz, (2016).

Land cover is recognized by two terms: cover and land use. The first refers to the present aspects of the land surface, regardless of its origin (natural or anthropic) and involves the physiognomy and composition of the vegetation cover. The second term applies to the types of occupation or use of a cover by man, whether temporary or permanent (Castilla, 2003).

According to the criteria of González and Romero, (2013), the knowledge of coverage constitutes one of the most important aspects within the biophysical analysis of territories, since it allows spatialization of coverage changes and makes a reading before different time scenarios (multi-temporal analysis).

According to Chuvieco, (1996), multi-temporal analysis allows the detection of changes between different reference dates, deducing the evolution of the natural environment or the repercussions of human action on that environment. These studies evaluate the speed of deforestation or reforestation, determine its geographical extension and contribute to the understanding of the natural, social or economic causes of changes on the global, regional and local scales.

Properly managed forests have enormous potential to contribute to sustainable development and a greener economy; however, there is a lack of empirical data to clearly demonstrate this (FAO, 2014).

In the context of Granma province, pine forests are the most important forest formation from an economic and productive point of view. The planted and natural forests that correspond to this formation are mainly constituted by the species *Pinus maestrensis Bisse,* an endemic taxon of the eastern region of Cuba; the Basic Business Units (UEB in Spanish) of the forestry sector manage a considerable number of hectares of these forests, on fragile mountain ecosystems.

The management area "Los Números" constitutes the most representative scenario of this situation in the municipality of Guisa and of which studies with satellite images are few. The present study was done with the objective of evaluating the spatial-temporal dynamics of the change in vegetation cover that this area has experimented during the period from 1986 to 2016.

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MATERIALS AND METHODS

Physical-geographical location of the study area

The management area "Los Números" is part of the forest heritage of the UEB Silvícola Guisa, subordinated to the Empresa Agroforestal Granma, located in the mountainous massif of the Sierra Maestra. This management area limits with the following popular councils of the municipality: to the north with Guamá, to the east with Los Horneros and Victorino, to the west with La Plata and to the south with the municipality Guamá of the province Santiago de Cuba (Figure 1).

Figure. 1 - Location of " Los Números " handling area

The topography is complex compared to the rest of Granma province, the average slope in the study area is about 19 % and reaches more than 40 % in intricate locations (Pérez, 2016). The predominant soil is leached red ferrallitic and the height above mean sea level varies from 839 to 1345 m Mogena *et al*., (2007).

According to data from the Meteorological Center of Granma province (2016), average annual rainfall is 1815.75 mm, with an average temperature of 25.2 0C and maximum and minimum temperatures of 31.7 and 20 0C, respectively.

Evaluation of the change in vegetation cover

The study area was delimited according to the surface corresponding to the management area "Los Números" (83.90 km²). Variations in vegetation were estimated with the help of satellite images, a Landsat 5 image for 1986 and Landsat 8 for 2016 with a spatial resolution (30 x 30 m, OLI sensor bands 4-3-2) and Universal Transverse Mercator map projection (WGS 84 Zone 18 N), obtained from the United States Geological Survey-USGS website and corresponding to the month of April of both years (path/row: 12/46). Remote sensing techniques and the ArcGis 10.2 Geographic Information System (GIS) were used to process the images.

Image pre-processing

Radiometric corrections were done using correction coefficients (Alexakis *et al.,* 2013). Standard equations were used to convert digital numbers to radiance and reflectance units (Chander *et al.,* 2009). After conversion to radiance, each image was converted to surface reflectance and then atmospheric correction was performed. To reduce the effects of atmospheric influence on the calibration process, the information in the image itself was used, using the dark object subtraction (DOS) method proposed by Chávez, (1996).

The procedure was done by supervised classification, using the maximum likelihood classifier, which is one of the most commonly used algorithms in remote sensing and considered one of the most efficient discrimination procedures (Camacho-Sanabria *et al.,* 2015 cited by Vistin, 2018).

Representative training fields of each vegetation coverage category were established in the image, through which they were differentiated. Once the point map was generated, through the Spatial Analyst Tools> Multivariate>Create Signatures tool, a GSG file was generated, which was used in the final classification through the input signature file option and carried out through the Spatial Analyst Tools>Multivariate>Maximum Likelihood Classification tool.

Chuvieco, (2010) reports that, in studies where this method is used when the area under study is known in depth, the number of categories can be reduced for better understanding. The vegetation cover was catalogued according to four categories: shrub, forest, grassland, or crop and naked soil.

For the analysis, first a table of evolution and annual rate of change of the area for each coverage category was elaborated and then a table with the transition matrix that occurred in each one of them, which is the result of crossing two maps of different date through the overlapping of vectorial lines, the use of this matrix (Pérez and Bosque, 2007).

Following this analysis, a map was drawn up showing the changes that had occurred in the vegetation cover, based on the alternatives for changes in the categories and the new proposed classification (Table 1).

Table 1.- Classification used in the dynamics of the change in coverage

Coverage 1986	Coverage 2016	Result of the change
Shrubbery	Forests	Recovery
	Grasses or crops	Lost
	Shrubbery	Persistence A
Forests	Forests	Persistence B
	Grasses or crops	Lost
	Shrubbery	Degradación
Grasses or crops	Forests	Recovery
	Grasses or crops	Persistence H-P-C
	Shrubbery	Partial recovery
Naked soil	Forests	Recovery
	Grasses or crops	Partial recovery
	Shrubbery	Partial recovery
	Suelo desnudo	Persistence Sd

In addition, in order to establish comparisons with regard to the sites where these changes occurred, information derived from the forest management project of the Empresa Agroforestal Granma, corresponding to the period 2008-2018, was used. This information shows the characteristics of the lots that form part of this management area (Table 2), as well as a shape file of their location for the work with the GIS.

Table 2. - Characteristics of the forest heritage in the AM "Los Números"

Forestry Formation	Lot Numbers	Category of Forest	Type of Soil	Area (km²)
Pluv-m	17	BPAS	PrSCarb	4,54
	28		FrRjLx	9,39
	31			7,27
	33			8,22
Pinar	22	BPAS	FrRjLx	4,65
	27			4,21
	29			4,50
	32			3,16
	35			8,68
	18	BPR	PrSCarb	8,62
	20			5,03
Scf-c	19	BPR	PrSCarb	4,46
	21	BPAS	FrRjLx	5,30
Monte Nublado	34			5,87

Source: Agroforestry Enterprise Granma, Forestry Management 2008.

Abbreviations: Pluv-m (Mountain Rainforest), Scf-c (Semi-Deciduous on Limestone Soil), BPAS (Soil and Water Protection Forests), BPR (Production Forests), PrSCarb (Non-Carbonate Brown), FrRjLx (Red Leached Ferrallitic).

The statistical package SPSS, version 21 was used for the determination of the descriptive parameters of the categories and their representation in the batches.

RESULTS

Applying the classification module, the corresponding maps were obtained with the vegetation cover of the management area in 1986 and 2016 (Figure 2).

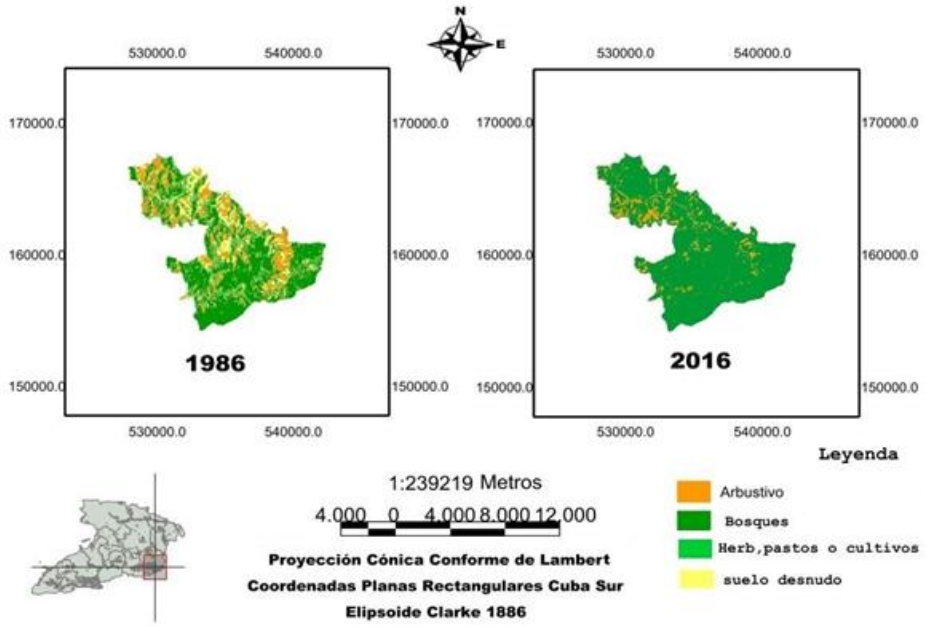

Figure 2. - Vegetation cover of the management area "Los Números" in the years 1986 and 2016

The Table 3 shows, for both years, the total values in area and percentage, as well as the annual rate of change of the analysed categories (Table 3).

Table 3. - Evolution in surface area and percentage of vegetation cover between 1986 and 2016.

CATEGORIES	Year 1986		Year 2016		* Area and rate annual change	
	km²	%	km²	%	km²	TAC
Shrubbery (A)	26,70	31,82	5,80	6,90	20,91	0,69
Forests (B)	44,04	52,49	77,98	92,95	-33,94	-1,13
Grasses or crops (HPC)	6,51	7,75	0,12	0,15	6,38	0,21
Naked Soil (SD)	6,65	7,93	0,0015	0,002	6,65	0,22
Total	**83,90**	**100**	**83,90**	**100**		

* S= (category in 1986 - category in 2016), TAC = S/ number of years difference Negative values indicate category gain and positive values indicate loss.

The prepared transition matrix shows the persistencies, losses and gains for each coverage category (Table 4).

Table 4.- Transition matrix obtained from the cross tabulation of the 1986 and 2016 vegetation cover maps (area in km²)

Stable 45,36		YEAR 2016				Total 1986	Losses
		A	B	HPC	SD		
year 1986	A	**2,25**	24,39	5,94	0	26,70	24,45
	B	0,93	**43,08**	2,70	0	44,04	0,96
	HPC	0,97	5,51	**2,73**	0	6,51	6,48
	SD	1,63	5,01	1,20	**0,0015**	6,65	6,65
Total 2016		5,80	77,98	0,12	0,0015	**83,90**	38,54
Profits		3,54	34,90	0,10	0,0000	38,54	

Area of the coverage categories in the plots in the management area

The classification made with the 1986 images showed that the four categories were present in each of the 15 plots in the study area: the bush category presented a minimum value of 0.57 km² (lot 29), a maximum of 4.13 km² (28) and an average of 1.91 km²; in the forest category the average was 3.15 km² with a minimum value of 1.13 km² (lot 20) and a maximum of 7.0 km² (plot 33). The fields, pastures or crops presented an average value of 0.47 km² with a minimum area of 0.26 km² (lot 17) and a maximum of 0.69 km² (plot 18). Finally, the soils without vegetation had an average of 0.48 km², minimum of 0.05 (plot 32) and maximum of 1.36 km² (plot 20).

For the year 2016 it was determined that the naked soil category was only present in two of the plots (28 and 31) and with a despicable surface area; grasses, pastures or crops were not represented in four units (plots 29, 32, 34 and 35), for the rest presented an average area of 0.01 km ² with a maximum value of 0.03 km ² (lot 31).

The shrub and forest categories presented area values of 0.41 km² on average, minimum of 0.04 km² (plot 33) and maximum of 1.22 km² (plot 19) for the first and for the second average of 5.57 km²; minimum 3.02 km² (plot 32) and maximum of 8.72 km² (plot 28).

The alternatives for changes in the categories according to the forest formations represented in the study area are shown in Figure 3 (Figure 3).

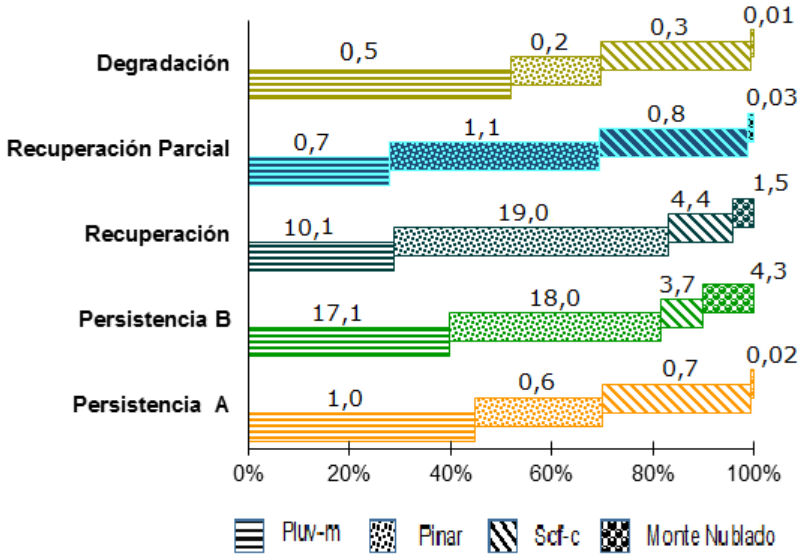

Figure 3. - Vegetation cover dynamics by forest formation (area in km²)

The Figure 4 shows the mapping of the changes that occurred in the study area, where the persistence of naked soil and grasses or crops were despicable for the scale used, which is why they were not represented on the map (Figure 4).

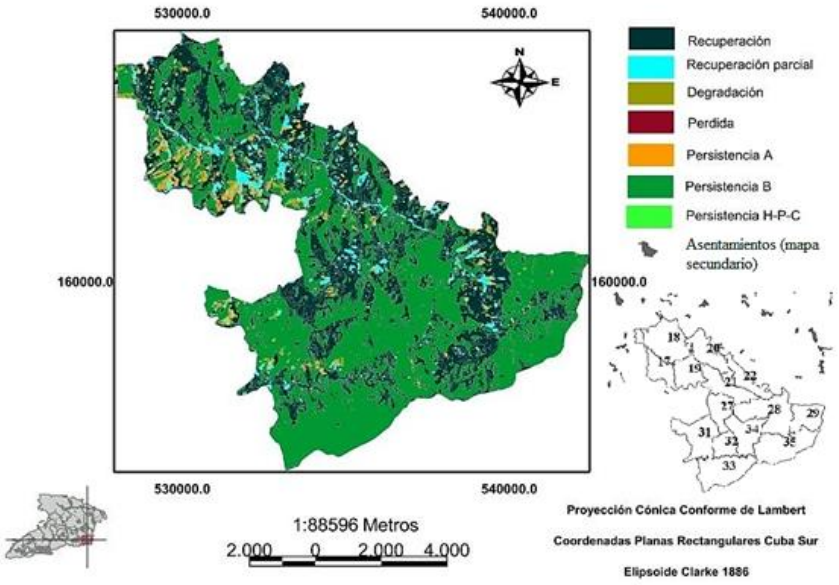

Figure 4. - Map of vegetation cover dynamics between 1986 and 2016

DISCUSSION

The Figure 2 clearly shows an increase in the forest category for the time interval analyzed, coinciding with Ramón, (2012), who reported similar results for this area in a study estimating the forest potential of the municipality of Guisa. Forest management is one of the activities that generates drastic changes in vegetation cover, which can result in an increase or decrease in forest cover depending on the way in which they are undertaken; for example, afforestation and/or reforestation actions, sustainable forest management, and exhaustive and indiscriminate logging and failure to observe current forest regulations for the use of wood in the area according to the relief, forest category and forest formation would be positive for this purpose. Therefore, the forest management carried out in this management area, at least in the aspect of cover, has been positive.

In the evolution of the area shown in Table 3, it can be seen that in 1986 the percentage distribution shows a greater forest cover, occupying more than half of the area, followed by shrub vegetation. On the whole, these two categories occupy 84.3 % of the surface, in the rest the herbaceous areas, pastures or crops and the naked soil presented the same percentage of occupation. In 2016, unlike 1986, grassland or crops and naked soil are practically not represented and the percentage contribution of the categories shows an almost total conversion to forest.

The analysis also revealed that, between 1986 and 2016, 20.91 km² of shrubbery and 6.38 km² of grassland, pasture or crops, as well as 6.65 km² of naked soil, have decreased, indicating that these categories of coverage over 30 years were gradually losing space. While 33.94 km² belonging to the forest category in 2016 clearly represents a notable increase in the limits of the forest category with respect to 1986.

Some of the causes for which these categories ceded surface area could have been the establishment of plantations, the growth of bushes towards a higher stratum and, to some extent, the exodus of mountain dwellers (an aspect that is evident today) which would reduce other anthropic uses of the soil, such as temporary agriculture.

The category transition matrix shown in Table 4 shows the gains and losses for each of the categories individually. It shows how the shrub vegetation gained 3.54 km²; but yielded 24.45 km², which were mostly transformed into forest (24.39 km²), so the gain in this particular category is considerable, which also occupied 5.51 km² of grassland or crops and 5.01 km² of naked soil for a total gain of 34.90 km² with only 0.96 km² lost.

Summation of the persistence values (indicated in the diagonal) establishes that, of the total surface area of the management area, 54.1 % maintained its occupation category, that is, 45.36 km²; of these, again the forest category is the most representative with 95 % of the surface area remaining stable. However, this percentage of vegetation cover should not be appreciated as an indicator of the structural quality of these forests if it is taken into account that authors such as Rosabal, (2011) and Pérez, (2016) describe a situation of deficient forestry in this forested area.

The alternative changes visible in Figure 3 show that, in terms of the persistence of the forest category, the mountain rainforest and pine forest formations are the most distinctive; which is logical as they are the most extensive within this management area. Overall, they represent about 81 % of the forest mass that remained unchanged; the cloud forest formation present in the study area only in one of the lots represented 10 % and was somewhat higher than the semi-deciduous formation on limestone soil (9 %), which is almost double its extension, so the incidence of the anthropic factor and/or climatic phenomena seem to have had less impact on this formation than on the previous one.

The persistence of the shrub category was mostly shared in the mountain rainforest (45 %) and semi-deciduous formations on limestone soil (29 %); the latter, even though it is represented in only two of the 15 plots that compose the management area, was superior to the pine formation (25 %), which is present in seven of these dasocratic forest management areas.

When analysing the recovery, it is pine forest, with 54 %, that has the greatest influence in this respect, followed by mountain rainforest (29 %), semi-deciduous on limestone soil (13 %) and cloud forest (4 %). The fact that the pine forest is the most recovered formation, as well as with relatively low degradation and persistence values of the shrub category compared to its extension, infers the appearance of a catalyst factor in the practically homogeneous growth of the shrub category towards a higher stratum, as it results, for example, in the establishment of forest plantations.

The results for this category of change are consistent with the reports in the literature, which refer to the undertaking of an extensive reforestation program in the early 1980s, reaching the country in 2016 the figure of 12.48 thousand km² covered by forest in the areas of the Plan Turquino (National Forestry Directorate, 2017).

This suggests that the recovery was mostly influenced by reforestation plans, since the plantations that have traditionally been made in this area have been with species of the genus *Pinus,* according to reports from the state service of the province of Granma; in 2015 there were 31.46 km² planted with *Pinus maestrensis Bisse* in the municipality of Guisa with three or more years.

The Figure 4 provides an objective visual representation of the sites where these changes occurred. In general, the recovery was evident throughout the entire management area, but it was more representative of the northeast, where the existing population settlements are more distant from the area; the sites with partial recovery are often shown to coincide with the area's road network, suggesting the abandonment of timber extraction trails and access roads and/or the narrowing of existing rural roads. Degradation and persistence of shrubs is grouped in the northwest of the area and with a greater relationship in terms of proximity and number of settlements, which without being conclusive may have influenced the concentration of these two classifications in this part of the management area, because it presents characteristics such as greater accessibility and less rugged topography that make them more vulnerable to land use for mountain agriculture. The following conclusions can be drawn from the research results:

The changes associated with vegetation cover dynamics in the years between 1986 and 2016 show a considerable increase in the forest category.

In terms of the persistence of the forest category, mountain rainforest and pine forest formations were the most distinctive and, in relation to the persistence of the shrub category, mountain rainforest and semi-deciduous formation on limestone soil were the most represented.

The 54 % of the total recovery was shown in the pine forest and the greatest influence on the recovery of the cover in this formation was given by the reforestation plans undertaken during the period analysed.

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