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Multi-temporal analysis of change in land use and deforestation in the Los Ilinizas Ecological Reserve, Andean Ecuador

Análisis multitemporal del cambio de uso del suelo y deforestación en la Reserva Ecológica Los Ilinizas, Ecuador andino

Analise multitemporal da mudança no uso da terra e do desmatamento na Reserva Ecológica Los Ilinizas, Equador andino

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Abstract

The Los Ilinizas Ecological Reserve, due to anthropogenic impacts and deforestation, the forest area has been drastically decreasing due to a lack of education and environmental control. Therefore, this research seeks to estimate the deforestation rate of the Los Ilinizas Ecological Reserve and describe the change in land use in the 10-year period 2013-2023, using LANDSAT 8 satellite images taken on different dates, and analyzed by remote sensing and GIS, obtaining the deforestation rate and the change in land use in a period of 10 years. The images from 2013 and 2023 were obtained from the digital repository of the United States Geological Service (USGS). Using Catalyst software, the supervised classification process was carried out for the years 2013 and 2023, through the analysis of objects including 5 categories: Forest, Agricultural Land, Clouds, Cloud Shadow, and Bare Land. The information was processed with ArcGIS and QGIS, resulting in a deforestation rate of - 2.60% in the period from 2013 to 2023, showing the decrease in forest cover in the reserve, due largely to the expansion of the agricultural frontier, poor citizen education, and the lack of environmental control by the authorities.
KEYWORDS: catalyst; deforestation; GIS; remote sensing; land use.

Resumen

En la Reserva Ecológica Los Ilinizas, debido a las afectaciones antrópicas y la deforestación, el área boscosa ha ido disminuyendo drásticamente por falta de educación y control medio-ambiental. Por ello la presente investigación buscó estimar la tasa de deforestación de la Reserva Ecológica Los Ilinizas y describir el cambio del uso del suelo en un periodo de 10 años (2013-2023), utilizando imágenes satelitales LANDSAT 8 tomadas en diferentes fechas, y analizadas mediante teledetección y SIG, obteniendo la tasa de deforestación y el cambio de uso de suelo en esos 10 años. Las imágenes del año 2013 y del 2023, se obtuvieron del repositorio digital del servicio Geológico de Estados Unidos de América (USGS). Con el software *Catalyst* se realizó el proceso de la clasificación supervisada para el año 2013 y 2023, mediante el análisis de objetos incluyendo 5 categorías: Bosque, Suelo Agrícola, Nubes, Sombra de Nube y Suelo Desnudo. El tratamiento de la información se realizó con *ArcGIS* y *QGIS*, dando como resultado una tasa de deforestación de -2,60% durante el periodo en estudio, evidenciando la disminución de la cobertura vegetal boscosa en la reserva, debido en gran parte a la expansión de la frontera agrícola, la deficiente educación de la ciudadanía y la poca falta de control medio ambiental por parte de las autoridades.
PALABRAS CLAVE: catalyst; deforestación; SIG; teledetección; uso del suelo.

Resumo

Na Reserva Ecológica Los Ilinizas, devido a afetações antrópicas e ao desmatamento, a área florestal vem diminuindo drasticamente devido à falta de educação e controle ambiental. Portanto, esta pesquisa teve como objetivo estimar a taxa de desmatamento da Reserva Ecológica Los Ilinizas e descrever a mudança no uso da terra no período de 10 anos (2013-2023), usando imagens do satélite LANDSAT 8 tiradas em datas diferentes e analisadas por sensoriamento remoto e GIS, obtendo a taxa de desmatamento e a mudança no uso da terra em esse período de 10 anos. As imagens de 2013 e 2023 foram obtidas do repositório digital do *United States Geological Survey* (USGS). O processo de classificação supervisionada para 2013 e 2023 foi realizado com o software *Catalyst*, por meio da análise de objetos incluindo 5 categorias: Floresta, Solo Agrícola, Nuvens, Sombra de Nuvem e Solo exposto. As informações foram processadas com o *ArcGIS* e o *QGIS*, resultando em uma taxa de desmatamento de -2,60% no período em estudo, mostrando a diminuição da cobertura vegetal florestal na reserva, em grande parte devido à expansão da fronteira agrícola, à baixa educação dos cidadãos e à falta de controle ambiental.
PALAVRAS-CHAVE: catalisador; desmatamento; GIS; sensoriamento remoto; uso do solo.

1. Introduction

The main purpose of creating ecological reserves is to protect a certain natural area with significant valued ecosystems from human exploitation of its natural resources (Batisse, 1982; Arcese & Sinclair, 1997b; Baker, 1992; Locke & Dearden, 2005; Halpern, 2003; Bengtsson *et al.*, 2003; Bastmeijer & Van Hengel, 2009). These protected areas may not be allowed for even limited permits of hunting or fishing, nor for timber extraction or any invasion by introduced or forced infrastructure and corresponding use of motorized vehicles (DeFries *et al.*, 2007; Batisse, 1997; Shafer, 1999; Tallis & Polasky, 2009; Arcese & Sinclair, 1997). Such shielded zones are worldwide purposed to secure and preserve endangered species and sensitive assets allowing limited access for any human interaction, excluding scientific activities (Sandwith *et al.*, 2001; Hansen & DeFries, 2007; Geneletti & van Duren, 2008; Peres & Terborgh, 1995).

Ecuador, situated in northwestern South America, within a conjunction of different tectonic plates, exhibits a varied geodynamic setting and geomorphologies which results to a great bio and geodiversity in its national territory (Jaillard *et al.*, 2000; Chunga *et al.*, 2018; Heredia-R *et al.*, 2022; García-Cox *et al.,* 2023; Herrera-Feijoo *et al.,* 2023; Lozano *et al.,* 2020; Toulkeridis *et al.,*, 2021). These circumstances are demonstrated with a variety of diverse landscapes, which include the Amazonian Lowlands, the volcanic highlands, two Andean mountain ranges, the Coastal Lowlands and the Galapagos archipelago (Pitman *et al.*, 2008; Toulkeridis & Zach, 2017; Jadán *et al.*, 2021; Toulkeridis *et al.*, 2020; Massonne & Toulkeridis, 2012; Dueñas *et al.*, 2021). Due to these realities and a consciousness of preserving many, often unique areas, several zones have been declared national parks, biospheres and ecological reserves among others (Kleemann *et al.*, 2022a; Kleemann *et al.*, 2022b; López *et al.*, 2020; Burbano *et al.*, 2020; Negru *et al.*, 2020; Valdez *et al.*, 2024).

The Los Ilinizas Ecological Reserve, located in the province of Cotopaxi in central Ecuador, is a natural treasure of great ecological value and biodiversity that faces significant challenges due to land use change and deforestation. Los Ilinizas is the name of a double-peaked, deglaciated, extinct volcano within the protected area, known for its biodiversity of plants of medical use (Brück *et al.*, 2023; Santamaria *et al.*, 2022; Sillo *et al.*, 2010; Conway *et al.*, 2023). However, to address these problems and understand their evolution over time, it is essential to employ advanced monitoring and analysis tools. Thus, remote sensing and geographic information systems (GIS) have proven to be fundamental for the study of environmental change at spatial and temporal scales (Cao & Lam, 2023; Yasir *et al.*, 2020; Bielecka, 2020; Mosquera Lopez *et al.*, 2021; Echeverría-Puertas *et al.*, 2023). With remote sensing, it is possible to obtain satellite data and images that allow to observe changes in the landscape with a broad and systematic vision (Turner *et al.* 2003; Shafique *et al.*, 2022; Zhu *et al.*, 2022; Hemati *et al.*, 2021). For its part, GIS allows to analyze and visualize geospatial information effectively, which facilitates the detection and quantification of changes in land use and vegetation cover over time (Lillesand *et al.* 2015; Simelane *et al.*, 2021; Whig *et al.*, 2024; Sun *et al.*, 2022).

One of the main objectives of the current study has been to perform a multitemporal analysis of land use change and deforestation in the Los Ilinizas reserve by integrating remote sensing and GIS. Previous work has demonstrated the potential of remote sensing to detect and quantify forest cover in tropical areas (Ferraz *et al.* 2016; Gao *et al.*, 2020; Dupuis *et al.*, 2020; Abbas *et al.*, 2020; Guascal *et al.*, 2020). Furthermore, forest carbon mapping refers to the process of quantifying the amount of carbon stored in forests using mapping and remote sensing techniques (Cook-Patton *et al.*, 2020; Mo *et al.*, 2023). This also involves the use of satellite data, aerial images, and other methods to estimate the biomass and carbon content of trees and forest soil (Asner & Mascaro, 2014; Reiersen *et al.*, 2022; Ganz *et al.*, 2020). Therefore, a corresponding analysis aims to generate accurate and up-to-date information on changes in the landscape of ecological reserve, as well as to identify critical areas that require conservation and restoration interventions. These findings will be fundamental for planning sustainable management policies and protecting the rich biodiversity that protected areas harbor (Achiso, 2020; Zhang *et al.*, 2020; Vilar *et al.*, 2020).

Based on the aforementioned, with a multitemporal analysis, we incline to contribute to scientific knowledge on the dynamics of land use change and deforestation in the Los Ilinizas Ecological Reserve and provide a solid basis for informed decision-making in the management and conservation of this valuable Ecuadorian ecosystem. Furthermore, the results of this research are expected to be useful for future studies related to the conservation of protected areas and environmental sustainability.

2. Materials and methods

2.1 Delimitation of the study area

The research has been performed in the Los Ilinizas Ecological Reserve, located in the provinces of Cotopaxi and Pichincha in central Ecuador (FIGURE 1). With an approximate area of 140,000 hectares the reserve includes the areas of the Toachi River, the western moors of the Ilinizas and Corazón hills, the Quilotoa volcanic lagoon, Zarapullo, Cerro Azul, Jaligua Alto and Tenefuerte, belonging to the cantons of Mejía, La Maná, Sigchos, Pangua and Pujilí, respectively (MAE, 2020).

For the current research, the most representative area of the reserve was taken as a basis since it has the largest forest cover to conserve and manage sustainably to mitigate damage to ecosystems and in turn reduce material damage to nearby populations due to the events that occurred in 2022-2023 caused by heavy rains. Considering that the resources may be perpetuated for future generations, since with the estimation of deforestation and the analysis of satellite images from 10 years ago, it will be possible to determine the current perspective regarding forest cover in this part of the reserve and the focal points to take into account for its correct management.

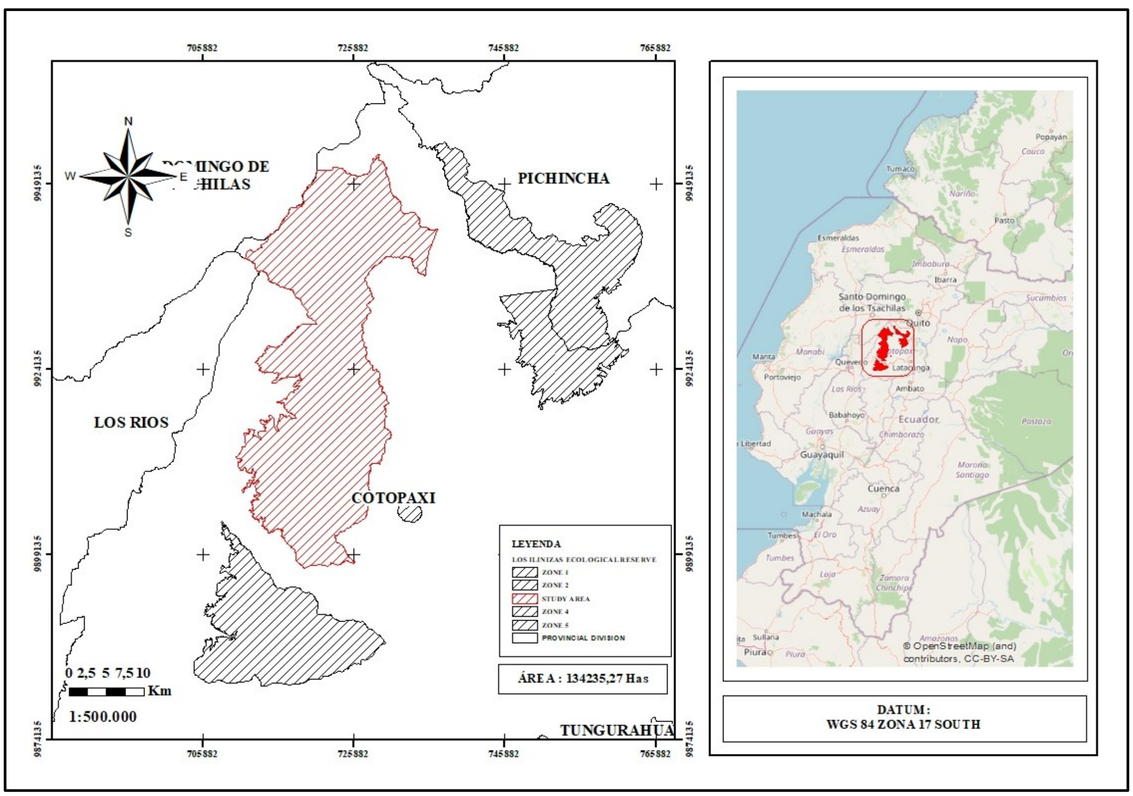

FIGURE 1. General map and setting of the Los Ilinizas Ecological Reserve. Source: the authors

2.2 Compilation and correction of satellite images

Vector cartographic information (shape) of the Los Ilinizas Ecological Reserve provided by the Ministry of Environment, Water and Ecological Transition (MAATE) was selected. In the same way, the Landsat 8 satellite image databases of the study area were obtained, from the free of use repositories of the United States Geological Survey (USGS) under https://glovis.usgs.gov/ corresponding for the years within the period of 2013 to 2023. It is fundamental to mention that it must be considered that the images have a maximum of 20% cloudiness within the study area (Chuvieco 2008).

2.3 Classification of satellite images

The Catalyst software was used to process the information by performing a supervised classification using the object analysis method. Four satellite images of the corresponding area were obtained, being two for the year 2013 (LC08_L2SP_010060_20131128_20200912_02_T1 and LC08_L2SP_010061_20131128_20200912_02_T1) and two for the year 2023 (LC09_L2SP_010060_20230913_20230915_02_T1 and LC09_L2SP_010061_20230929_20231001_02_T1).

In these images, the raster combination was performed in the QGIS program to obtain a single recombined image for each band in each time period and it was transformed into .pix format, which is the format to work with in Catalyst. Once the transformation was completed, the supervised classification was carried out. From the Catalyst menu, select 'Analysis, Object Analyst', followed by the 'Operation' option. Select 'Segmentation', where the images are loaded in .pix format and the bands with which you want to work are chosen.

For this study, bands 2, 3, 4, 5, 6 and 7 were used. The polygon of the reserve was chosen to delimit the area in which the work will be done. It is important to specify the 'segmentation parameters' options, within which Scale 25, Shape 0.5, and Compactness 0.5 were used. The result is a vector file in which polygonal files are illustrated for better identification of the areas of interest (FIGURE 2).

The next step was to choose the 'Attribute Calculation' option, where several statistical parameters can be calculated, such as area, perimeter and NDVI. Following this operation, the 'training sites editing' option was chosen, where the training sites will be created for each of the five land use categories, which are Forest, Agricultural Land, Bare Land, Clouds and Cloud Shadow. It is important that for this step the necessary combination changes are made in the bands (RGB) of the images in order to establish the different land uses clearly. When digitizing the training areas, it must be done in two options, 'Training' and "accuracy assessment" to then generate the confusion matrix.

Once the polygons of the training areas for each soil category have been entered, the 'Supervised classification' option is chosen, resulting in a polygonal file showing the previously assigned categories. The Catalyst software has the option of correcting the supervised classification with a review of the resulting polygons in which it can be checked by combining bands to ensure that the areas correspond to the assigned category.

The resulting polygonal file is then exported in Shapefile format so that it can be opened in different software. The transformed layers were uploaded to the ArcMap 10.8 program in which, using the classification already carried out, a map can be generated and the calculations of the areas for each category can be generated according to our supervised classification.

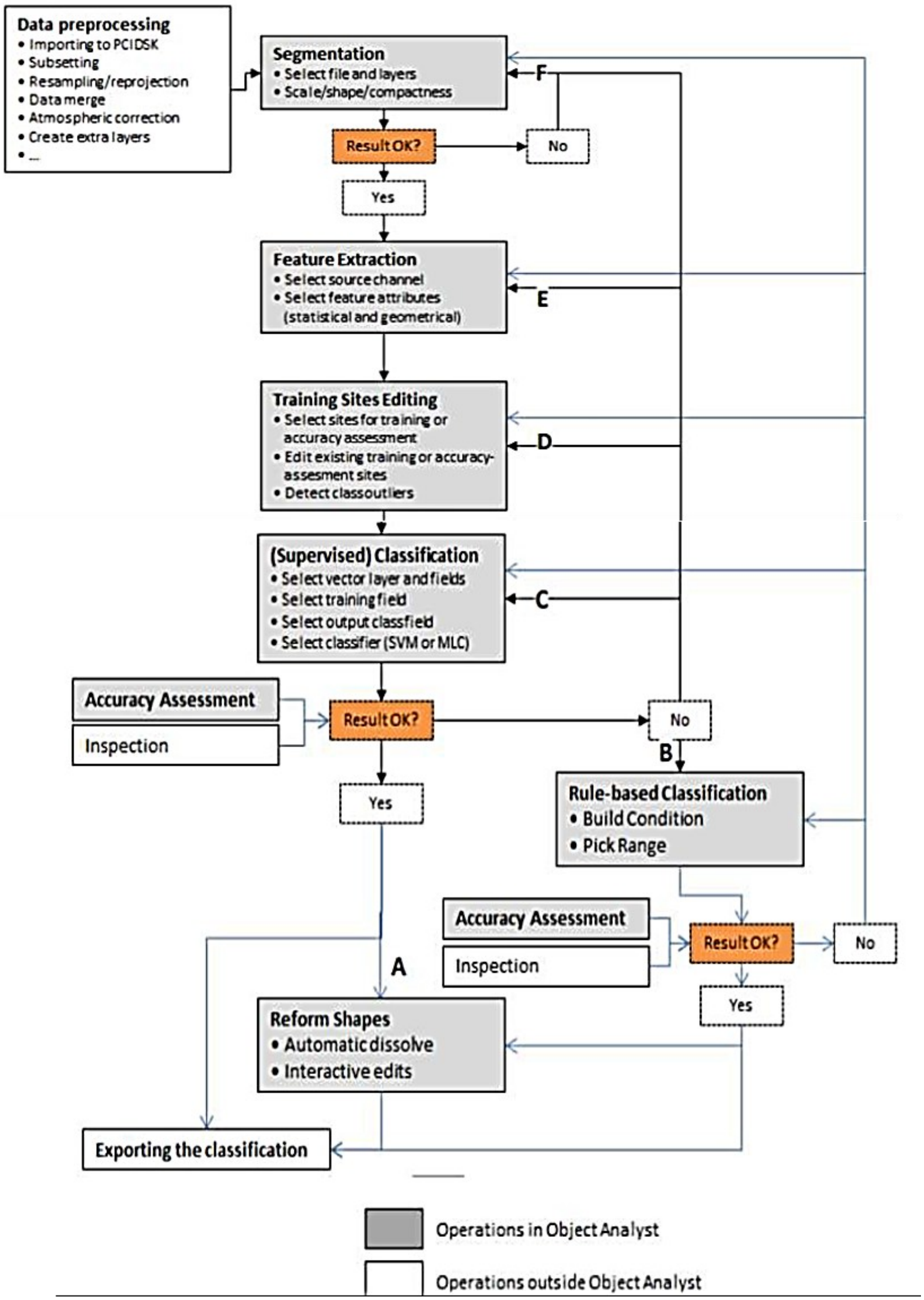

FIGURE 2. Process flowchart for supervised classification in Catalyst. Source: the authors

2.4 Deforestation rate

Using the map algebra tool, the forest cover and anthropogenic cover (agricultural land) of the working level will be added, where the percentage change of the surfaces corresponding to each period was calculated, using the following equation 1 (Mas *et al.*, 2004).

$$dn = \left(\sqrt[n]{\frac{S_2}{S_1}} - 1\right) * 100 \qquad \text{Eq. 1}$$

Where: dn = Change rate
S1 = Area at date 1
S2 = Area at date 2
n = Number of years between the two dates

2.5 Change rate in vegetation and land use

The geometric superposition of land use and vegetation coverage was used to determine the rate of change by plant category where vegetation cover maps were obtained for the periods from 2013 to 2023, using the following equation (Mas *et al.*, 2004).

$$C = \left(\left(\sqrt[n]{\frac{T_2}{T_1}}\right) - 1\right) * 100 \qquad \text{Eq. 2}$$

Where: C= Change rate
T1= Starting year
T2= Current or most recent year
n= Number of years between T1 and T2

2.6 Verification of results obtained in the field

By selecting 50 random points, the results obtained from the multitemporal analysis of land use changes and deforestation in the Los Ilinizas Ecological Reserve were verified (TABLE 1).

TABLE 1. Matrix for verification of points in the field

Point	**Coordinates**		**Detail**		**Coincidence**	
	X	**Y**	**Unsupervised**	**Supervised**	**YES**	**NO**
1...						
...50						
					Σ	**Σ**
					%	**%**

3. Results and discussion

3.1 Land use for the years 2013 to 2023

As a result of the supervised classification, the resulting area of the land use categories for the years 2013 and 2023 respectively was obtained. For the year 2013, the category forests resulted to an area of some 39,703.50 ha, which represents 54.11% of the total area, the agricultural land with an area of 14,322.10 ha (19.52%), cloud with an area of 13,231.80 ha (18.23%), cloud shadow with an area of 1,277.45 ha (1.74%) and bare ground with an area of 4,696.05 ha (6.40%) in the Los Ilinizas Ecological Reserve. For the year 2023 the forests area comprised some 30,503.10 ha (41.57%), agricultural land some15,564.00 ha (21.21%), cloud appeared with an area of 16,065.40 ha (21.89%), cloud shadow comprised an area of 3,323.94 ha (4.53%) and bare ground covered an area of 7,921.06 ha (10.79%) of the total research area. Yielding a greater increase in the percentages of land use change in the central and northern part of the studied area, which is where most of the towns in the area are located (TABLE 2; FIGURE 3 and 4).

TABLE 2. Land uses in the Los Ilinizas Ecological Reserve. Source: the authors

#	Category	2013		2023		Change
		ha	%	ha	%	(%)
1	Forests	39 703.50	54.11	30 503.10	41.57	-12,54
2	Agricultural land	14 322.10	19.52	15 564.00	21.21	1,69
3	Cloud	13 378.10	18.23	16 065.40	21.89	3,66
4	Cloud shadow	1 277.45	1.74	3 323.94	4.53	2,79
5	Bare ground	4 696.05	6.40	7 921.06	10.79	4,40
Total		73 377.20	100	73 377.50	100	0

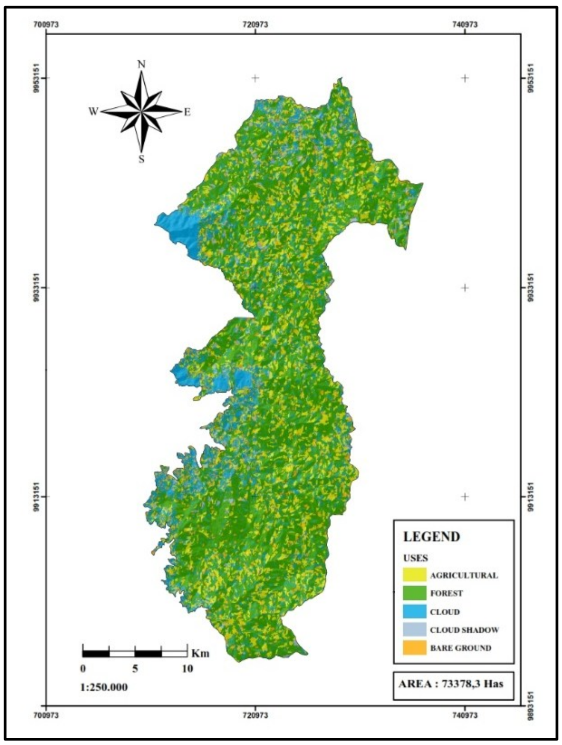

FIGURE 3. Los Ilinizas Ecological Reserve land uses

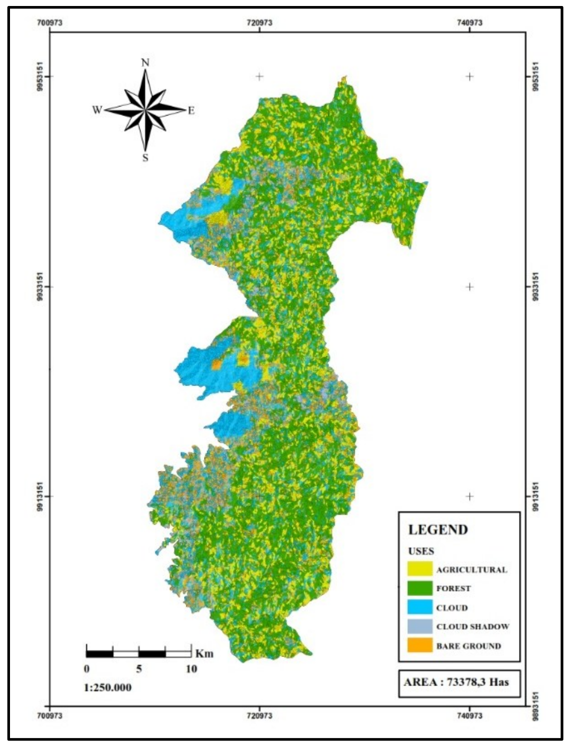

FIGURE 4. Los Ilinizas Ecological Reserve land uses

3.2 Deforestation rate

After applying equation 1 [Eq. 1] to calculate the deforestation rate using the area of the category 'Forest' in the different years proposed in this study (2013 and 2023). In 2013, 39,703.50 ha were obtained and for 2023, 30,503.10 ha were obtained, as a result the deforestation rate is -2.60% which represents a gradual reduction in forest cover over the 10-year period (2013-2023). Using the script used and the map algebra tool, the total areas can be quantified as it represents deforestation and natural regeneration in the period 2013-2023. In the case of 'Deforestation' an area of 12,236.70 ha was obtained, which represents 16.68% of the total study area and 'Natural Regeneration' with an area of 7,174.70 ha, which represents 9.78% of the total area. Considering that the unanalyzed area 'No Data' has an area of 53,966.90 ha, which represents 73.55% of the total study area within the Los Ilinizas Ecological Reserve (TABLE 3; FIGURE 5).

TABLE 3. Deforestation rate of the Ilinizas ecological reserve period 2013 – 2023. Source: the authors

Change of land use	ha	%	Deforestation rate %
Deforestation	12 236.70	16.68	
Regeneration	7 174.70	9.78	**-2,60**
No data	53 966.90	73.55	
Total, general	73 378.30	100.00	

3.3 Land use change rate

From equation 2 [Eq 2] applied to calculate the land use change rate by categories (TABLE 4 and FIGURE 6), the following results were obtained for the categories 'Forest' the change rate is -2.96%, 'Agricultural Land' the change rate is 0.84% and 'Bare Ground' the change rate is 5.37%. Thus, we obtain that the category that suffered the greatest change corresponds to the 'Bare Ground' category, which indicates the increase in deforestation for the use of pastures for livestock, followed by the 'Forest' category, in which a gradual reduction in forest cover is evident in the period (2013-2023) and the 'Agricultural Land' category, which is the one that suffered the least changes in the period (2013-2023). It is worth mentioning that the cloud and cloud shadow categories were not considered (FIGURE 7, 8 and 9).

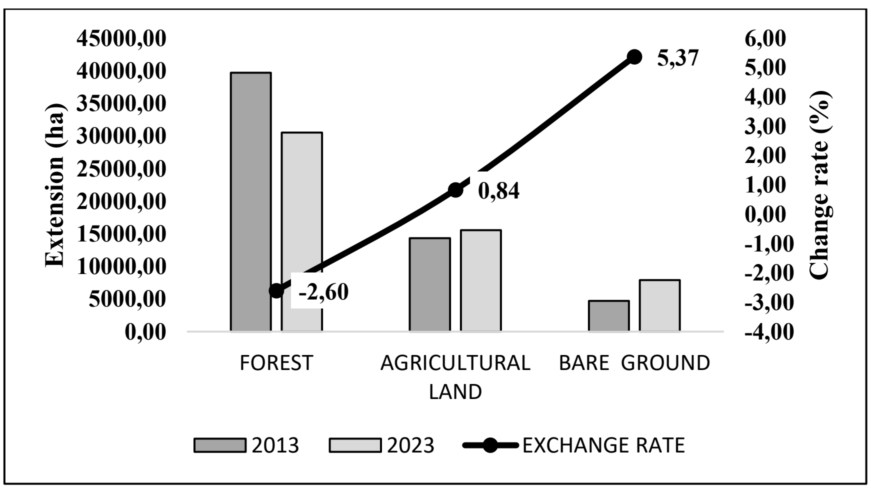

FIGURE 6. Land use change rate trend line. Source: the authors

TABLE 4. Land use change rate. Source: the authors

Category	2013 (ha)	2023 (ha)	Change rate (%)
Forest	39 703.50	30.503.10	-2.60
Agricultural land	14 322.10	15.564.00	0.84
Bare ground	4 696.05	7.921.06	5.37

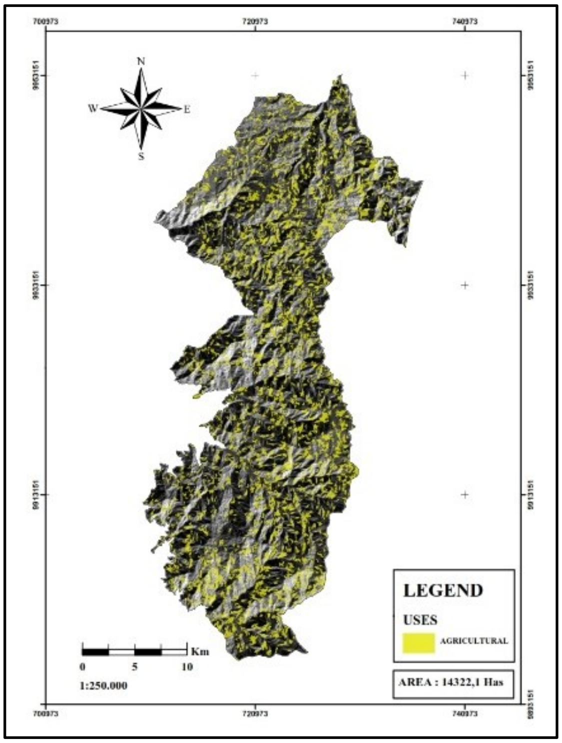

FIGURE 7. Comparison of land use changes in the ‘Agricultural land” category in 2013. Source: the authors

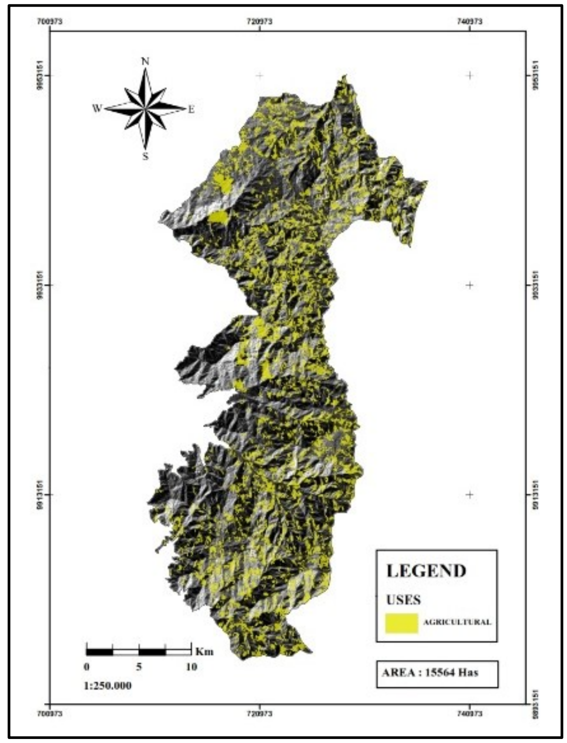

FIGURE 8. Comparison of land use changes in the ‘Agricultural land’ category, 2023. Source: the authors

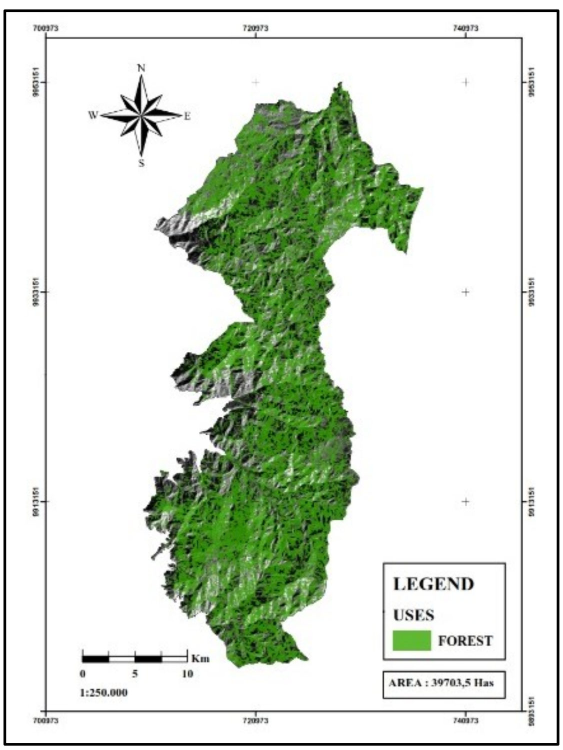

FIGURE 9. Comparison of land use change in the ‘forest’ category, 2013. Source: the authors

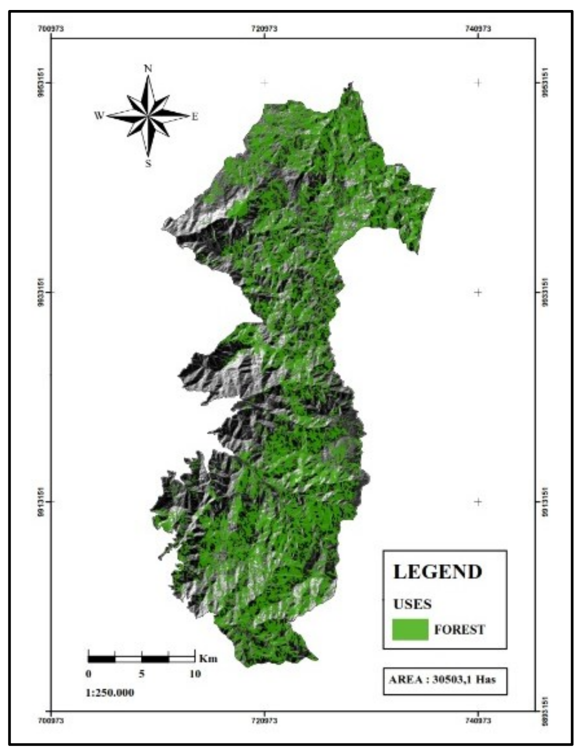

FIGURE 10. Comparison of land use change in the ‘forest’ category, 2023. Source: the authors

There is a gradual decrease in forest cover over the 10-year period and in the places where deforestation and natural regeneration were concentrated as illustrated in FIGURES 9 and 10. An evident and somewhat significant increase in bare land over the 10-year period and in the places where deforestation was concentrated, since this area is suitable for livestock farming, as demonstrated in FIGURES 11 and 12.

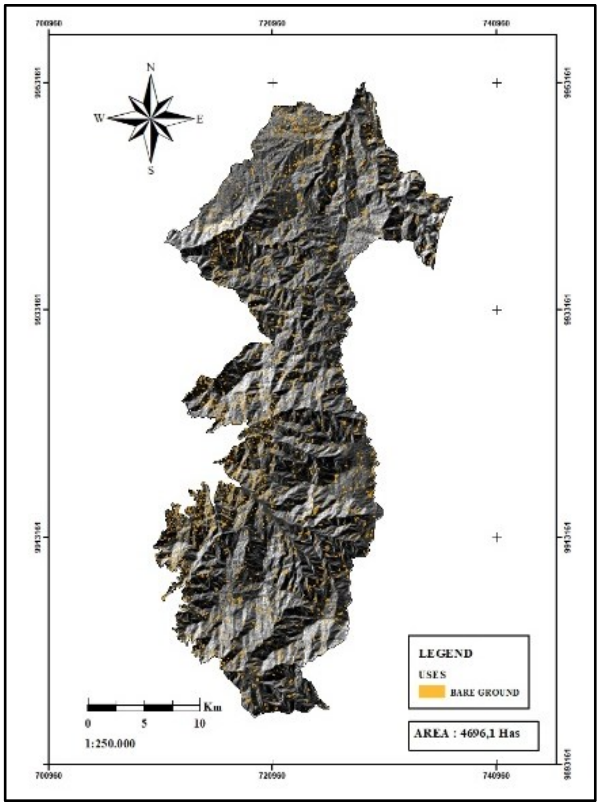

FIGURE 11. Comparison of land use change in the 'Bare ground' category in the years 2013. Source: the authors

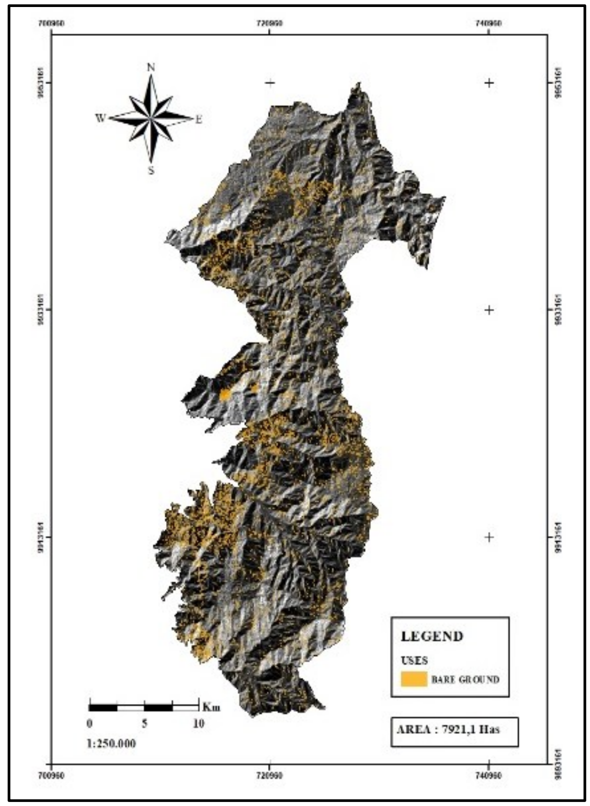

FIGURE 12. Comparison of land use change in the 'Bare ground' category in the years 2023. Source: the authors

3.4 Verification of multi-temporal analysis

A total of 50 random points were taken where a face-to-face verification of the results was carried out where there was some type of transition (deforestation and natural regeneration) in the research area. For this, a matrix was used to calculate the percentage of veracity of the multi-temporal analysis, of which 45 points equivalent to 90% coincided with the results of the multi-temporal analysis while the remaining 10 points equivalent to 10% did not correspond to the results of the multi-temporal analysis of land use change in the Los Ilinizas Ecological Reserve (FIGURE 13).

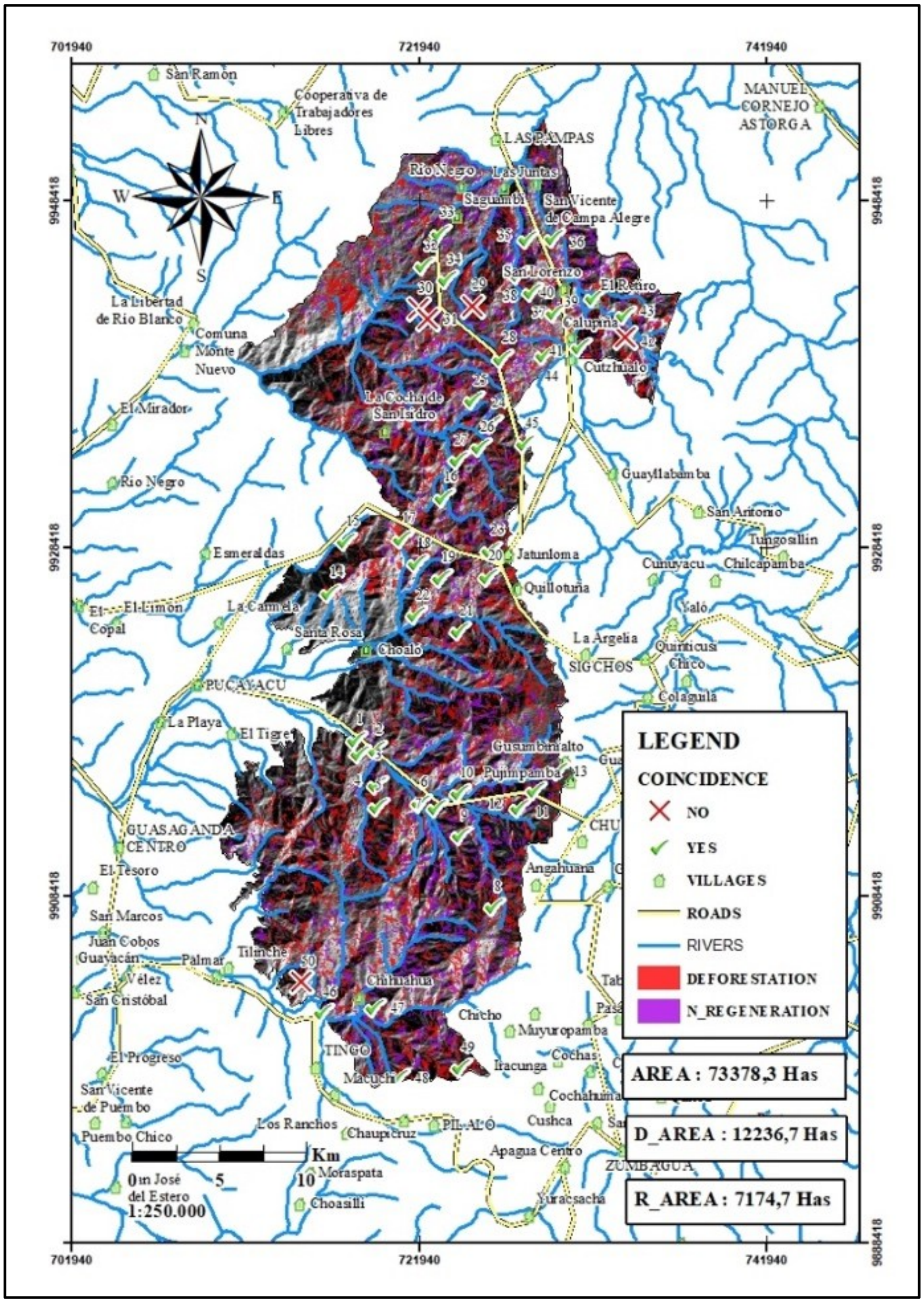

FIGURE 13. Verification points of the multitemporal analysis in the Los Ilinizas Ecological Reserve. It can be observed that from the results obtained where there was an alteration, whether deforestation or natural regeneration, we proceeded to verify it using 50 random points with the GPS, giving us a success rate of 45 points corresponding to what the results indicate, where the errors are marked with an X and the successes with a check. Source: the authors

The Ecuadorian Andes have experienced significant deforestation due to agricultural expansion, livestock farming, urbanization, and natural resource extraction (MAATE, 2020). Thus, between 2000 and 2018, it is estimated that around 530,000 hectares of forest were lost in the Ecuadorian Andes region due to human activities. Deforestation in the Ecuadorian Andes has had significant impacts on biodiversity, ecosystem services, and the local climate. Deforestation was noted to have contributed to habitat loss for endemic species and soil erosion, affecting agricultural productivity and food security in the Andean region (INIAP, 2019).

Due to the increasing deforestation in Ecuador, new multitemporal analysis techniques have been implemented using geographic information system software and it has been possible to identify strategic points to focus on conservation and reforestation. In the case of the Los Ilinizas Ecological Reserve, it allows in a general summary of the state of vegetation and change in land use in the reserve, to make government decisions regarding the well-being of the reserve and its conservation. A multitemporal analysis study between the years 1990 - 2018 in the province of Morona Santiago, deforested areas represented 0.73% of the total protective forests and 0.27% of the protected area of the province, indicating that the growth of agriculture in an uncontrolled and disorganized manner violates sensitive areas with high biological diversity, making it necessary to generate and execute public policies aimed at the protection of protected areas at the national level (Camacho *et al.*, 2022).

In the Mache-Chindul ecological reserve, through multitemporal analysis, it was found that the deforestation rate within the ecological reserve was 1,512,125 ha/year, 917,167 ha/year and 1,292 ha/year, for the periods 2000-2008, 2008-2014 and 2014-2016, respectively (Mendoza & Román, 2021). It is evident that deforestation has been decreasing over the years within the Mache-Chindul Ecological Reserve. Total deforestation from 2000 to 2016 has been 20,184 ha, which means that 16.94% of the reserve has been lost (Mendoza & Román 2021).

In another multitemporal analysis of deforestation in the province of Manu in Peru, tools such as GIS were used, they maximize the possibilities of using the data obtained in satellite images, as well as optimize the quality of the results in the processing of the information (Gonzales, 2018). Thus obtaining a conclusion from our study performed that for the year 2000 we have an approximate of 230.79 km^2 increasing for 2008 to 317.64 km^2 and so consecutively for the year 2016 we have an accelerated deforestation of 570.57 km^2 which gives us a difference since the year 2000 a total of 339.78 km^2 was deforested.

Having as the main factor of deforestation the increase in the price of gold and the construction of the interoceanic highway.

In the south of the country, it shows us the specific effectiveness of working with Catalyst software through object analysis, since with this we simplify the work a little and we can obtain effective results in less time and thus make decisions about soil management in the different areas, in this case in protected areas, since over the years they have been degraded until there are only remnants of what they once were in the past (Muñoz *et al.*, 2023). It is important to carry out more similar research to have a clear vision of the forests today in Ecuador.

This demonstrates that the results obtained within the given research in Los Ilinizas, that they have experienced a demographic increase and needs of the inhabitants, the percentage of forests has decreased in the period of 10 years (2013-2023) and the agro-pastoral frontier has increased significantly. Losing a total of 9,200.40 ha of forests in the period (2013 -2023) and the agro-pastoral frontier increased 4,466.91 ha. This research is of great ecological importance since it indicates the current state of the ecological reserve and will help to make the right decisions for the corresponding authorities since this area is of great importance as it is located in a transition zone between the coast-mountains and is home to a large number of species of wild flora and fauna, native to the country, including species that are in danger of extinction.

4. Conclusions

Based on our research, it is estimated that in the period from 2013 to 2023 the deforestation rate was -2.60%, being a negative rate which indicates the gradual decrease in forest cover, referencing poor political administration and population education in the area. This deforestation rate is an example that if it continues to affect this protected area, in the next 33 years we would lose all the forest cover in the study area belonging to the Los Ilinizas Ecological Reserve.

The land change rate for the hunting reserve based on the adopted categories is, for 'Forest' -2.60%, 'Agricultural Land' 0.84% and 'Bare ground' 5.37% in the period studied from 2013 to 2023, which in the case of 'Forest' has decreased coverage, while 'Agricultural Land' has increased and 'Bare Land' has increased, this is partly due to anthropic activities that still exert pressure on these ecosystems.

New technological tools and good or adequate management of GIS are able to support increase the precision of the analyses, obtaining reliable results based on field verification with a 90% accuracy in the multitemporal analysis of land use change and deforestation in the Ilinizas ecological reserve.

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