

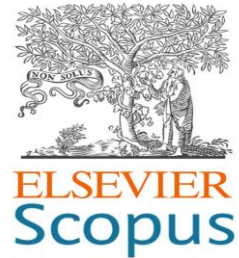
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Historical Geospatial Analysis of Socio-Environmental Conflicts in the Moor of the Duende Natural Park, Colombia

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Abstract: This study presents an innovative strategy for the use of environmental planning tools in protected areas in the context of updating land use plans in Colombia. The problem addressed is the inappropriate use of land that generates socio-environmental conflicts, threatens the integrity and exerts pressure on the main ecosystem of the Moor of the Duende National Park. The objective was to generate a zoning of appropriate land uses under a sustainability premise, integrating environmental determinants and national regulations, such as Law 2372 of 2010 and Decree 3600 of 2007. The methodology included Geographic Information Systems (GIS) analysis, geohistorical compilation of the region, social cartography, and data triangulation. Maps were generated by superimposing cartographic layers and evaluating variables such as erosion, current and potential land use, main ecological structure and use conflicts. Community participation was key to identifying local perceptions and promoting participatory governance. The results identified three levels of conflict (low, medium and high), highlighting critical areas with



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severe erosion and soil loss in the buffer zone. High-conflict areas were designated for ecological restoration, while low-impact areas were classified for sustainable uses, such as agroforestry and reforestation with native species. In conclusion, the proposed zoning balances ecological conservation and rural development, contributing to the updating of environmental planning instruments. This approach can be replicated in other protected areas, as it combines science, regulations and community participation to resolve land use conflicts, promoting a comprehensive sustainability model.

Keywords: environmental zoning, land use planning, main ecological structure, environmental planning, community participation, environmental governance, protected areas, social cartography, geographic information systems.

哥倫比亞杜安德自然公園荒原社會環境衝突的地理空間分析

摘要：本研究提出了在哥伦比亚土地使用计划更新的背景下，在保护区内使用环境规划工具的创新战略。所要解决的问题是土地使用不当，这会产生社会环境冲突，威胁到杜恩德国家公园荒原的完整性，并对主要生态系统造成压力。目标是在可持续发展的前提下，将环境决定因素和国家法规（如 2010 年第 2372 号法律和 2007 年第 3600 号法令）结合起来，对适当的土地用途进行分区。该方法包括地理信息系统（GIS）分析、该地区的地理历史汇编、社会制图和数据三角测量。地图是通过叠加地图层并评估侵蚀、当前和潜在的土地使用、主要生态结构和使用冲突等变量来生成的。社区参与是确定当地看法和促进参与式治理的关键。结果确定了三个冲突等级（低、中、高），突出了缓冲区内严重侵蚀和土壤流失的关键区域。高冲突区域被指定用于生态恢复，而低影响区域则被划分为可持续用途，例如农林业和使用本地物种重新造林。总之，拟议的分区平衡了生态保护和农村发展，有助于更新环境规划工具。这种方法可以在其他保护区复制，因为它结合了科学、法规和社区参与来解决土地使用冲突，促进了全面的可持续发展模式

关键词：環境區劃、土地利用規劃、主要生態結構、環境規劃、社區參與、環境治理、保護區、社會製圖、地理資訊系統

1. Introduction

The Moor of the Duende Regional Natural Park (RNP), located in the Andean region of Colombia, represents a strategic ecosystem due to its high biodiversity, ecosystem services and role in water regulation. However, it faces increasing pressures from intensive agricultural activities and conflicts over inappropriate land use in its buffer zone. This phenomenon, combined with vulnerable geological and climatic conditions, raises questions about the land use and conservation strategies required to mitigate the socio-environmental impacts and ensure the sustainability of the ecosystem. Although previous research has addressed the management of protected areas, gaps persist in the integration of participatory approaches and geospatial tools for the identification and resolution of land use conflicts.

In response to this problem, the present study is based on the theoretical foundations of environmental management and territorial planning, as well as on

participatory methodologies such as social cartography and multi-criteria analysis using geographic information systems (GIS). These tools have proven effective in assessing the interaction between human and ecological dynamics, providing a framework for decision-making in territories of high environmental complexity.

The results of this research are expected to contribute to the identification of appropriate land uses and the proposal of zoning strategies that harmonize environmental conservation with sustainable rural development. By consolidating an integrative and multidimensional approach, this study seeks not only to contribute to strengthening territorial governance but also to lay the foundations for replicating these methodologies in other strategic ecosystems in Colombia.

2. Methods

2.1. Methodological Approach

This research corresponds to the use of a qualitative methodological strategy: *a case study*. The study was carried out in the following districts: La Sonora, Venecia and Andinópolis located in the main zone and buffer zone of the Moor of the Duende Regional Natural Park in the Municipality of Trujillo. Four study methods were used corresponding to the four research phases, as illustrated in Figure 1.

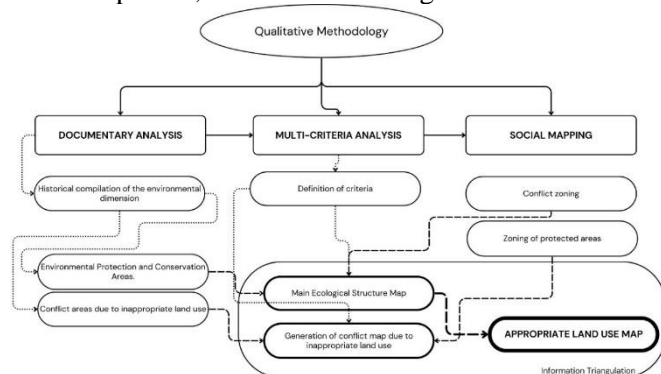


Figure 1. Methodological design of the research (elaborated by the authors)

The *Documentary Analysis* consisted of the collection of information from studies and cartography of protection areas, environmental conservation and inappropriate land use. The period covered for this analysis was between 2001 and 2022, using the timeline tool as a diachronic analysis of the environmental dimension. *Multicriteria Analysis* using GIS tools for generating cartography concerning the current main ecological structure and areas with conflict due to inappropriate land use. The use of *Social Cartography* as a graphic input for the collective and participatory analysis of interested parties. These methodologies allow us to comprehensively construct a territory and visualize its histories, situations, and socio-environmental conflicts [1]. Finally, the *Information Triangulation* method is used as a validation strategy for different types and sources of information collected. The study focuses on the collection, analysis and understanding of the biophysical and socio-environmental characteristics of the study area.

2.2. Study Area

The biodiversity and great variety of ecosystems that Colombia has allowed progress in the research and study of different ecosystems such as the moors. Currently, there are 36 moorland complexes registered in Colombia and in the case of the Department of Valle del Cauca, 6 of these with a total area of 82.101 ha [2]. The Duende moor ecosystem is located inside the Regional Natural Park (RNP), (Figure 2). It is an intriguing wasteland due to its geographical conditions, making entry difficult. The above has contributed to the preservation of species and the provision of ecosystem services to nearby communities [3].

The area comprising the Moor of the Duende Complex is located on the eastern flank of the western mountain range between the departments of Choco and Valle del Cauca [2].



Figure 2. Location of the Moor of the Duende National Park (CVC, 2022)

The area comprising the Moor of the Duende Complex is on the eastern flank of the western mountain range between the departments of Choco and Valle del Cauca. This research focuses on the study of the Moor of the Duende RNP area shared by 4 Municipalities of the Department of Valle del Cauca according to Tables 1 and 2.

The Moor of the Duende RNP is made up of 3 zones distributed as follows: Sub-Andean Forest between 1,200 and 2,500 m.a.s.l, Andean Forest between 2,500 and 3,400 m.a.s.l, and Moor between 3,400 and 3,800 m.a.s.l. It is characterized by having 3 thermal floors: medium, very much cold in its largest extension. On the other hand, the influence of 3 climates: humid, pluvial and very humid with a bimodal rainfall regime.

Table 1. Distribution of areas of the Moor of the Duende Complex by department and municipality (compiled by the authors)

Department	Percentage	Municipalities	Percentage
Choco	59.6 %	Santa Genoveva de Decordó	59.6 %
Valle del Cauca	40.4 %	Calima El Darién	24.1 %
		Trujillo	9.3 %
		Bolívar	4.1 %
		Riofrío	2.9 %

Table 2. Distribution of the areas of the Moor Complex and Moor of the Duende National Park in the 4 municipalities of the Department of Valle del Cauca (CVC, 2022)

Municipality	Complex Moor of the Duende		RNP Moor of the Duende PM 2022		Districts
	Area (ha)	%	Area(ha)	%	
Calima El Darién	1.058 ha	60	8.602 ha	48	Calima, El Boleo, San José, El Vergel, Río Bravo
Riofrío	123 ha	7	4.057 ha	22	Salónica, La Zulia, and Fenicia
Trujillo	427 ha	24	2.722 ha	15	La Sonora, Venecia, Naranjal
Bolívar	167 ha	9	2.746 ha	15	Santa Rita
Total	1.775 ha		18.127 ha		

The hydrological system comprises two drainages: one area that leads directly to the Pacific Ocean and the other to the Magdalena hydrographic area that drains to the Caribbean Sea. This territory is under the influence of active geological faults that can cause horizontal displacement and deformation. The terrain is 53% very steep (50% – 75%) and 41.5% steep (25% – 50%). These conditions make the terrain impenetrable and sensitive to water erosion and landslide phenomena. As for land cover, the areas with the highest percentage were forest cover (94.43%) and areas with herbaceous and/or shrub vegetation (4.41%) according to the Corine Land Cover (CLC) methodology (Figure 3a). In this area there are 5 ecosystems and 3 biomes, the most representative being the very humid cold forest in the fluvio-gravitational mountains (BOFMHMH), in the middle orobios of the Andes, which is found at 80.84% (Figure 3b). The predominant reliefs are moderately rugged to strongly steep. The slopes are characterized by being greater than 12% with well-drained soils, very deep and moderate fertility.

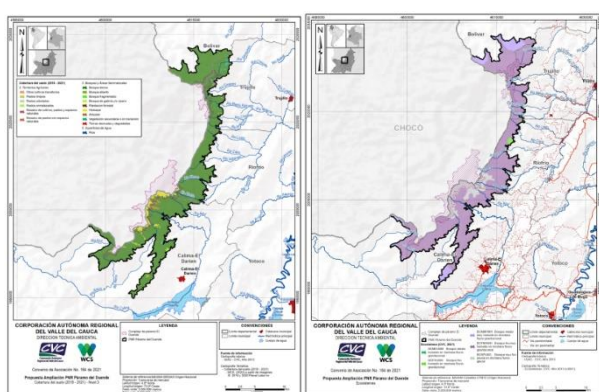


Figure 3. (a). Land covers of the Moor of the Duende National Park. (b). Ecosystems in the Moor of the Duende National Park (CVC, 2022)

On the other hand, in the Moor of the Duende National Park, it is identified that 93.1% of the area does not have conflict due to inappropriate land use. The potential use of the land is for environmental protection and conservation and for forest protection areas. Regarding the land cover in the area with the

buffer function, 72.61% corresponds to natural areas. A total of 79 species of flora, 18 species of mammals, 25 species of birds, 10 species of amphibians and 3 species of reptiles have been recorded. Additionally, in the last study for the expansion of the RNP in the Municipality of Bolívar (Valle del Cauca), 6 endemic flora species and 3 threatened species at the national level were found, 93 species of birds, 13 species of amphibians, 21 species of endemic amphibians and 17 species of mammals [3].

2.3. Methodology

2.3.1. Documentary analysis. Geohistorical compilation of the environmental dimension

Cartographic information is an essential input in the processes of environmental management and planning of a territory. In general, they are used as part of environmental and social diagnostic studies in an area or community. According to [4], these studies are built from a diagnostic baseline, which does not consider the evolution and history of a territory as well as the social, political, economic, environmental and cultural factors that have historically permeated a community. In addition, violent events, changes in ecosystems, regional influence, and the potential of a territory leave a mark on the territory, impacts that precede inadequate anthropic action [5]. In this sense, the use of the timeline tool for the analysis of documentary and cartographic information allows for the simultaneous analysis of historical processes. This is done through the establishment of dimensions (environmental, social, productive) and environmental aspects (ecosystems, life zones, climate, coverage, hydrography, land uses, protected areas, landscapes, zoning of use and environmental impacts) [6]. The information analyzed corresponds to the period between 1994 and 2022, taken from the compilation of studies, research, reports, technical documents of the first-generation TPS, an TPS update study and Geographic Information Systems platforms. Historical hotspots were used as a reference from the environmental context, compiling the existing cartography from the years 2001, 2015 and 2022, as shown in Figure 4.



Figure 4. Timeline of documents that contribute key information to the study (elaborated by the authors)

2.3.2. Geospatial Delimitation Using Geographic Information Systems (GIS)

The analysis of environmental criteria using the GIS tool allows the study of problems and multiple variables that are interrelated and that affect or influence a territory. The spatial representation articulating different variables and the evaluation of analysis criteria provide elements of technical and management decision-making for decision-making in territorial environmental planning [7]. During the development of the study, biophysical, environmental, vegetation cover, landscape units, land use, land distribution, environmental conflicts, among others, variables were analyzed to allow decisions to be made regarding the appropriate use of the land. This was based on information obtained from the historical compilation of studies and the cartographic archives of the research area.

The analysis using environmental criteria consisted of the selection of space-time variables, the result of the cartographic review and the interpretation of shapefiles in AUTOCAD and ARCGIS from GeoCVC, the Agustín Codazzi Geographic Institute and the Municipality of Trujillo. The areas of environmental protection and conservation and the conflict zones due to inappropriate land use were identified as a result of the use of map algebra superimposing the cartographic layers. This information allowed the evaluation of the variable of erosion, soil loss, slopes, current use, potential use and vegetation cover.

2.3.3 Social Cartography. Collective Construction of the Territory

Social cartography in territorial management and environmental planning works contributes to recognizing and understanding geospatial elements and giving sociocultural and technical attributes and meanings to elements specific to and historically in the territory. The construction of self-maps and the socio-spatial dynamics of the use and occupation of the territory contribute significantly to the participatory development of society and social actors [8]. Organizations, institutions and peasant communities participated through the exercise of social mapping to perform the territorial analysis of environmental

variables and identify the environmental impacts related to some sectors and protected areas. In this way, under the collective construction and social recognition of the territory, decisions were made and community environmental management practices and policies were directed. Two social mapping workshops were held in rural areas with the participation of 3 peasant organizations, 1 environmental NGO and 3 public officials and 18 people from the community, with a total attendance of 25 people.

2.3.4 Information Triangulation for the Validation of Different Geospatial Analysis Tools

Triangulation allows validating information obtained from different sources and types of methodological tools to strengthen research. This is achieved through the construction of comprehensive proposals and explanations, reducing observer bias and offering greater confidence in the research findings [9]. Using this methodology, the results obtained from the use of the following tools were compiled: documentary analysis, multicriteria analysis and social cartography (Figure 1). Triangulation of documentary, geohistorical, geospatial data and participatory methodologies was carried out as part of the growing use of digital sources and the challenges and opportunities that it represents for environmental planning and land use processes[1]. A zoning map of appropriate land uses was developed for the area studied, as a result of the superposition of layers of conflict due to inappropriate use, environmental impacts, soil degradation and environmental determinants for each figure of environmental protection areas. This is a proposal for the conservation, mitigation, recovery and restoration of ecosystems typical of Andean forests and national protected areas.

Based on the construction and analysis of the generated maps, a cartographic superposition was made between the areas of conflict due to inappropriate land use, the areas that are part of the main ecological structure (MES), the areas affected by soil erosion, vegetation cover, and potential land use (Figure 5). Once this zoning was consolidated, attributes were assigned to each area that belongs to the MES. The land uses assigned to the protected areas are those referred to in Law 2372 of 2010 and Decree 3600 of 2007, the environmental determinants of the CVC (Resolution 544 of July 6, 2023) and the uses established in the environmental management plans. Subsequently, using the ArcGIS program, with the use of clip, intersect, and extract tools for cartography preparation, each area of the MES was taken and, according to the degree of affectation presented, it was zoned according to the management that must be carried out to guarantee compliance with the

conservation objectives as established in Resolution 2372 of 2010 in its article 34.

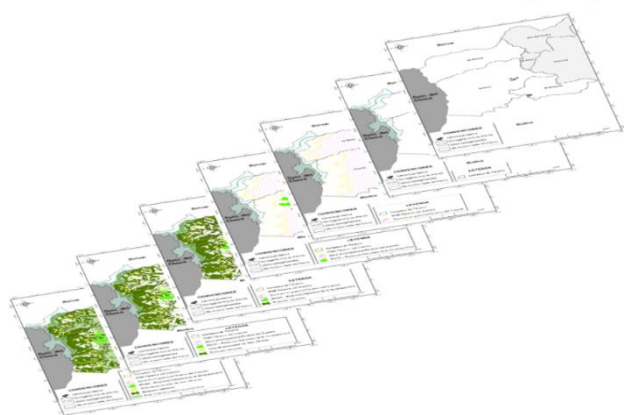


Figure 5. Overlapping areas (elaborated by the authors)

3. Results and Discussion

3.1. Geohistorical Analysis of the Environmental Dimension in the Buffer Function Zone of the Moor of the Duende National Park

The Municipality of Trujillo has gone through key historical moments that have contributed to the recognition, planning and protection of the Moor of the Duende Regional Natural Park (RNP). This history is marked by local events as well as national and international events that have influenced political and environmental decisions in this ecosystem. The history of the municipality of Trujillo is framed in the colonization process that began at the beginning of the 20th century, driven by merchants of Antioquian origin. In 1922, through acts of violence and land concentration, these merchants acquired large tracts of land to expand coffee crops toward the Central Mountain Range. This process involved massive deforestation through slash-and-burn practices, which transformed the natural landscape, generated loss of biodiversity, expanded the agricultural frontier and was associated with the massacres that occurred in the 1940s in the north of the department. This situation has marked the history of the municipality due to the recurring violence at different times, originating from the struggle for power, control of land and social inequalities [8].

During the 1940s and 1950s, Trujillo established itself as one of the main coffee producing centers in the Valle del Cauca region, accompanied by a process of agricultural specialization and intensive land use. The introduction of varieties such as Colombian coffee, with the use of fertilizers under the so-called Green Revolution, brought with it its productive benefits. However, serious ecological impacts were generated, such as the loss of biodiversity. These factors drove the strengthening of the coffee economy from 1976, a process that was consolidated until the

end of the 1980s. There began the economic crisis in this sector and the escalation of violence, marking the history of the municipality with the Trujillo Massacre (1988-1994), an event that devastated the region [10]. (Figure 6).

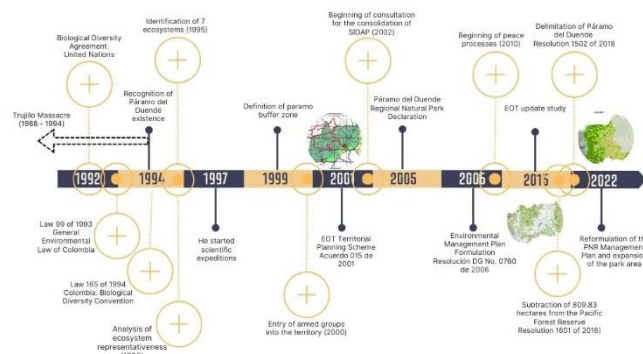


Figure 6. Line that compiles the historical milestones of the Municipality of Trujillo and the national and international context for the conservation of the Moor of the Duende National Park (elaborated by the authors)

On the other hand, the recognition of the Moor of the Duende began in the 1990s, when the existence of this ecosystem was recognized in 1994 and scientific expeditions were carried out that revealed the importance of this place. In 1995, a study was carried out to analyze its ecosystems, and seven were identified that were particularly valuable. This process was part of a broader context, where both national and international environmental policies were gaining strength. In Colombia, Law 99 of 1993 laid the foundations for the country's environmental legislation, while at a global level, the 1992 United Nations Convention on Biological Diversity promoted the protection of biodiversity, ratifying this commitment at a national level in the Convention on Biological Diversity with the issuance of Law 165 of 1994. These initiatives helped strengthen the care of the Moor of the Duende, through the recognition of the main ecosystems and species discovered with the scientific expedition in 1997 and the definition of the buffer zone in 1999.

At the local level, the Municipality of Trujillo integrated the moor for the first time in its territorial development plans through the Territorial Planning Scheme (TPS), adopted in 2001. This scheme although it presented deficiencies in the comprehensive knowledge of the moor, contributed significantly to its recognition and facilitated the establishment of conservation measures. The technical study of this document contributed to identifying, in the biophysical component, the environmental protection zones. (Figure 7), ecosystems, life zones (Figure 8), hydrography, land cover, environmental protection areas and landscape units. The cartography used to schematize these components was of low quality, with

gaps in the information on geographic boundaries and areas without data, and therefore did not contribute significant cartographic contributions with validity to the study.

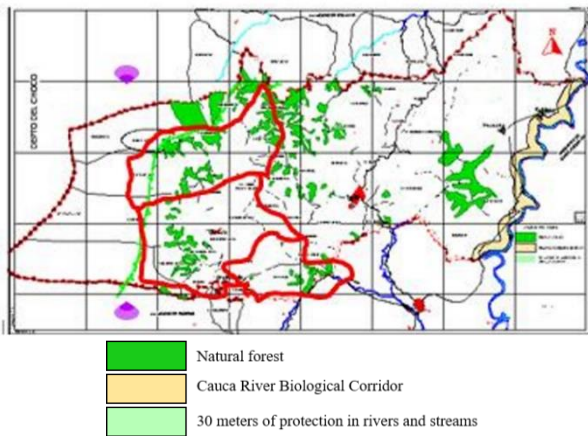


Figure 7. Environmental Protection Zones of the TPS (Municipality of Trujillo, 2001)

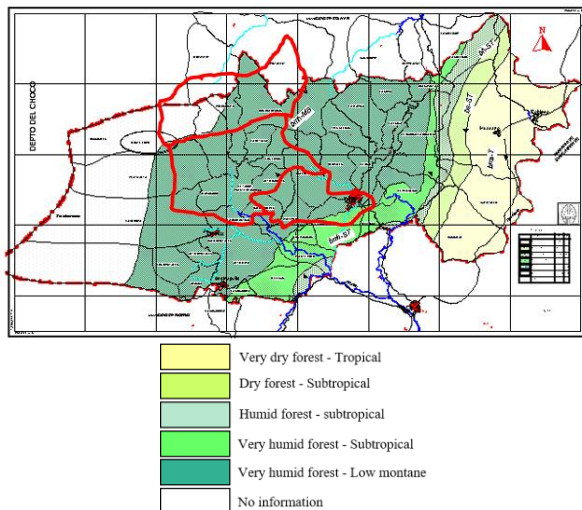


Figure 8. TPS Life Zones (Municipality of Trujillo, 2001)

In 2002, processes were initiated to consolidate the Departmental System of Protected Areas (DSPA), which emphasized the importance of this ecosystem and its formal declaration by the CVC as a Regional Natural Park through Resolution 760 of 2005. Additionally, planning and organization began, leading to the submission of the Environmental Management Plan for this moorland in 2006. However, this process was not easy because the territory was once again affected by armed groups, which made environmental protection efforts difficult. Despite these challenges, in 2010, the start of the peace processes allowed conservation projects to be resumed. In 2015, a technical study was conducted to update the TPS since this instrument had been outdated since 2013. In addition, the declaration of the RNP was made after the creation date of the TPS; therefore, it did not contain specific policies for the protection and conservation of the ecosystem. Through this study, the

cartographic information of the municipality was compiled and the Main Ecological Structure was established. (Figure 9). The structure is made up of the municipality protection and conservation areas, “which support the essential ecological processes of the territory, whose main purpose is the preservation, conservation, restoration, use and sustainable management of renewable natural resources” (Decree 3600, 2007, art. 1). Likewise, the areas in conflict due to the inadequate use of the land to date were identified (Figure 10).

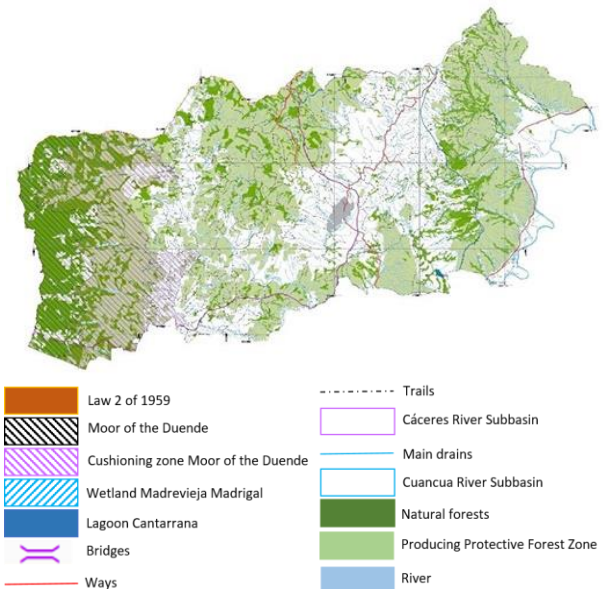


Figure 9. Main Ecological Structure (Municipality of Trujillo, 2015)

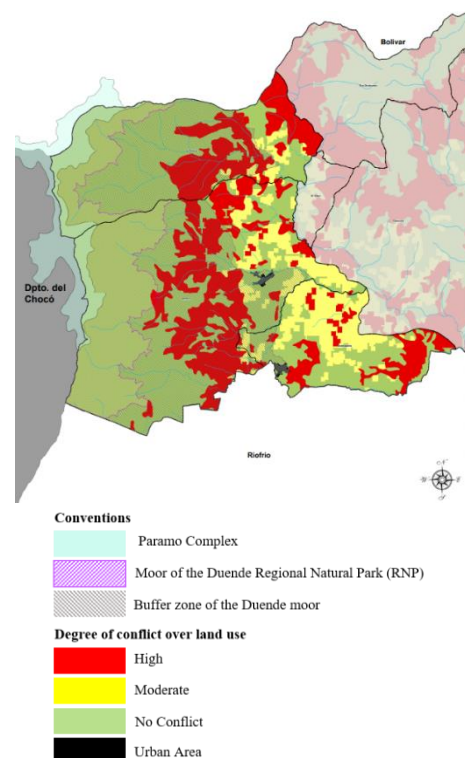


Figure 10. Conflicts due to inappropriate land use (Municipality of Trujillo, 2015)

The effort to protect the Moor of the Duende finally came to fruition in 2015, when its recognition as a Regional Natural Park was formalized. This achievement was the result of years of scientific studies (1994 to 2015) and political decisions at different levels (municipal, departmental, national and international). In 2016, the park boundaries were adjusted by subtracting a portion of the Pacific Forest area, and in 2018, the final boundaries of the park were defined through Resolution 1502.

Finally, the historical line of this ecosystem is consolidated with the reformulation of the Environmental Management Plan in 2022 and the formation of the co-management table of the Natural Park. In this process, the maps of Soil Cover, Potential Use, Main Ecological Structure (MES), erosion and conflict due to inappropriate land use were updated. This process allowed us to compile the history of the Moor of the Duende National Park from the context of the municipality of Trujillo and the way it has

transcended between local challenges and global dynamics. The context of violence and territorial transformation has impacted the region; however, from the environmental context, it has had a positive impact, leading the moor to greater protection, which is why it is currently classified as the most preserved moor in the country.

3.2 Geospatial Delimitation of Conflicts Due to Inappropriate Land Use

For the analysis of the conflict due to inappropriate land use in the buffer zone of the Moor of the Duende National Park, analysis criteria were established. These are based on the information on the main factors that affect the soil in this area and the availability of data and cartography available to official and competent entities such as CVC, IGAC and the Municipality of Trujillo. The environmental criteria are described in Table 3.

Table 3. Description of the environmental assessment criteria obtained from the RNP land use analysis (compiled by the authors)

Criteria	Description
Soil erosion	It is one of the biggest problems of the municipality due to the steep slopes and the geology of this territory, which is almost impenetrable.
Potential soil use	Using cartographic information on potential land use, the forestry vocation of the municipality of Trujillo is confirmed, as well as, specifically, the areas with a buffer function of the RNP.
Main Ecological Structure	It corresponds to the overlapping of the protection and conservation categories of the municipality, according to Decree 1472 of 2010. Information was compiled from 2015 to 2022. This cartographic map shows the following: moorland complex, Moor of the Duende RNP, buffer zone of the RNP, Civil Society Natural Reserves, natural forests, springs, rivers, forest areas, forests.
Coverages from the ground	The information collected on land cover belongs to data from 2001, 2015 and 2022, of which the largest forest cover is identified toward the main area of the PNR, however, there is evidence of anthropic intervention toward the areas of greatest concentration of property.
Property distribution	The mapping of the relationship between properties in the studied area provides an overview of the districts that exert the greatest pressure on the RNP ecosystem.

The analysis of environmental criteria using GIS allowed the delimitation of the areas of conflict due to inappropriate land use in the municipality of Trujillo. It was identified that the main conflicts arise from the overlap between the areas destined for agricultural production and the areas designated for environmental conservation. The data show a growing expansion of the agricultural frontier in the areas of environmental protection, particularly in the buffer zone of the Moor of the Duende National Park.

In the analysis of the years 2015 and 2022 compared to 2001, the spatial information of the conflict areas in the buffer zone showed a notable increase of 30% and 60%, respectively. This is due to the overuse of land in agricultural activities, such as the cultivation of coffee, blackberries and bananas, as well as extensive livestock farming.

3.2.1 Soil Erosion

This is one of the main problems in the municipality of Trujillo, due to intensive agricultural practices in soils with high susceptibility to erosion. The loss of nutrients and soil degradation are common in areas where the slope and high rainfall favor erosive processes [11]. This phenomenon is particularly worrying in the buffer zone of the Moor of the Duende National Park, where severe erosion could affect the ecological balance of the park.

The comparative analysis of the erosion maps for the years 2001, 2015 and 2022 shows a progressive increase in severe erosion in the areas surrounding the RNP (Figure 11), which coincides with the expansion of the agricultural frontier and the intensification of the use of agrochemicals in crops not appropriate for these areas [7].

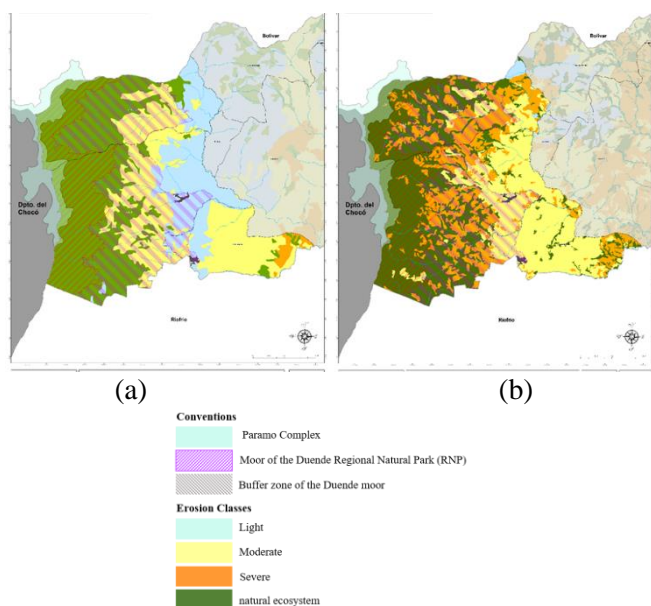


Figure 11. Soil erosion. (a). Soil Erosion Classes (2015). (b). Soil Erosion Classes (2022) (Municipality of Trujillo, 2015)

3.2.2 Potential Land Use

Most of the buffer zone of the RNP has been defined as a Protective Forest and a Protective-Producing Forest. This classification is due to the geological conditions due to the presence of geological faults and slopes that range from steep to very steep and soil instability (Figure 12).

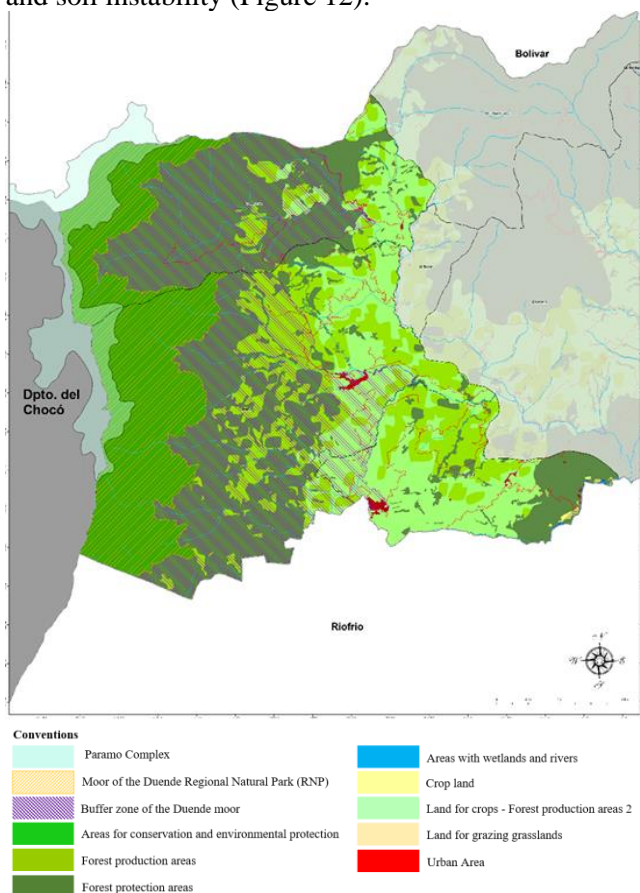


Figure 12. Potential Land Use (2022) (Municipality of Trujillo, 2015)

3.2.3 Main Ecological Structure (MES)

According to Decree 3600 of 2007, the MES (Figure 13) is an environmental planning tool to be used in updating second-generation land use plans in Colombia. It facilitates the identification of complementary elements and incompatibilities arising from land use in rural areas. It reflects the complexity of a rurality in constant transformation [12]. This approach contributes to the analysis of the state of ecosystem health, the vocation, current and potential use of the land, and the zoning of its use, promoting interdisciplinary planning of the rural territory. In this way, it is possible to integrate key variables in rural planning and adopt complex, systemic, transdisciplinary, participatory and self-generating management schemes [5].

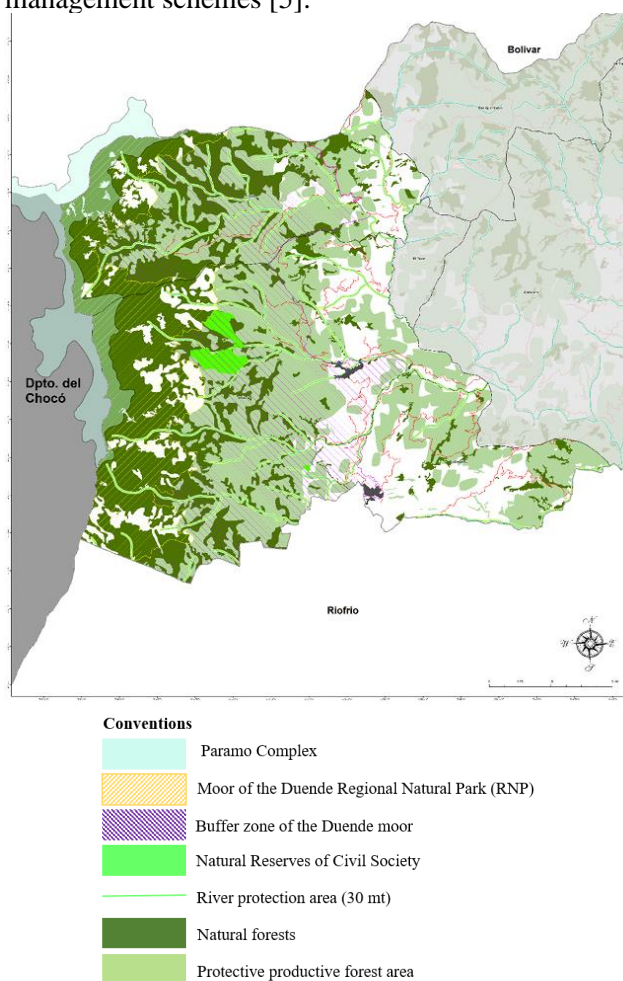


Figure 13. Main Ecological Structure (Municipality of Trujillo, 2015)

3.2.4 Soil Cover

Most of the vegetation cover analyzed between 2001 and 2022 is located in the areas of influence of the moor ecosystem and its buffer zone. However, the mapping obtained in 2022 reflects an increase in the areas used for agricultural production compared to previous periods, evidencing an increase in productive activities that possibly generates environmental tensions and conflicts. Figure 14 shows the degree of

intervention in the territory and the growth of agricultural areas, especially herbaceous crops, which are advancing toward the protected area. In the Moor of the Duende RNP, around 3 areas with significant interventions were identified (marked in red).

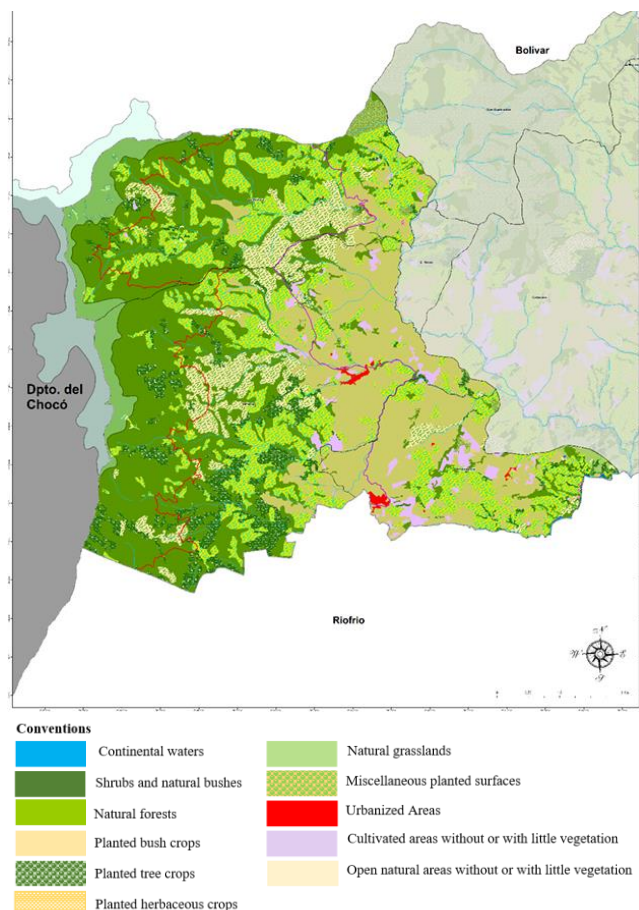


Figure 14. Land Use Coverage (Municipality of Trujillo, 2015)

This agricultural expansion underlines the urgent need for policies and strategies that limit the agricultural frontier and extractive activities in the protected area. The reduction of conservation areas reflects the lack of territorial planning adapted to environmental characteristics, where the current TPS does not integrate areas of environmental importance, as recommended [13].

3.2.5 Distribution of Rural Property

The history of the municipality analyzed through the timeline shows the conflict over land ownership. While the relationship of owners in the municipality of the rural and urban area represents 8% of the owners as owners of half of the total area and 3 owners with more than a tenth of the territory [10]. This information is consistent with the analysis of violence due to armed conflict in Colombia and the generation of displacement, dispossession of property, control of land and

natural resources. These processes are linked to extractivism and intensive, high-impact economic activities, a differentiating factor of violence in Latin America[14]. Figure 15 identifies that in the north-western area of the municipality, there is influence of at least 3 properties (circled in red on the map) in the border area of the PNR and that they are causing pressure from anthropic activities.

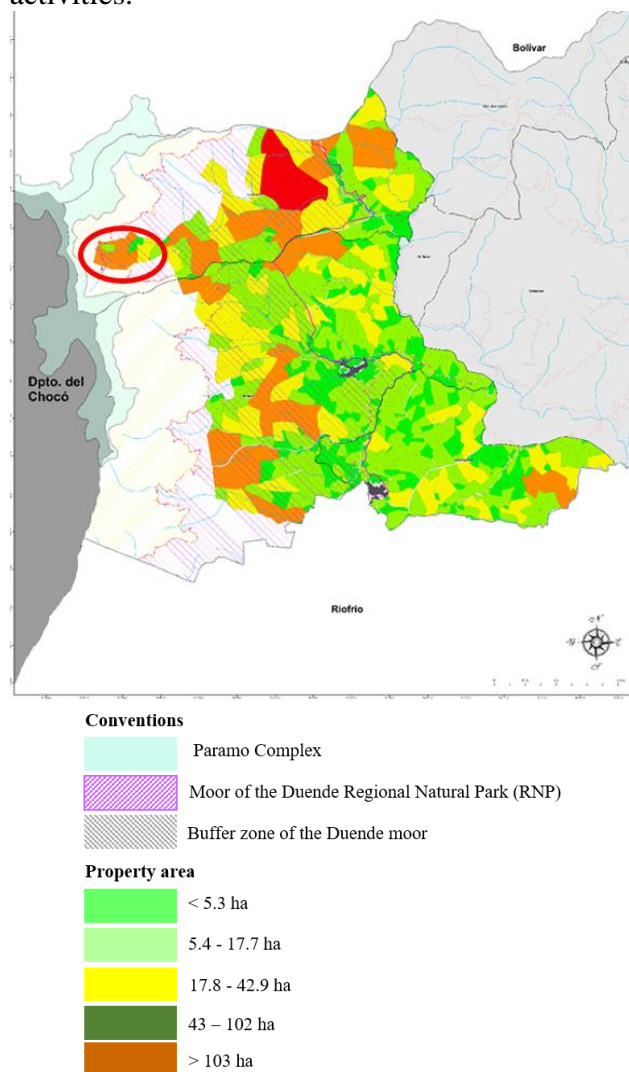


Figure 15. Distribution of rural property. Cartography adapted from GeoCVC (elaborated by the authors)

3.2.6 Conflict over Inappropriate Land Use

Figure 16 shows a comparison of the cartographic layers of areas with conflict due to inappropriate land use in different periods. The overlapping of cartographic layers between productive areas and conservation areas represents a significant conflict in land use in this municipality and its environmental protection areas. The decrease in conservation areas is a result of the expansion of the agricultural frontier, putting the integrity of ecosystems and biodiversity at risk [8]. The sum of the areas in the severe conflict amounts to 60% of the buffer zone of the Moor of the

Duende National Park. This alteration of the ecosystems endangers the function of preserving the natural resources of the National Park due to its accelerated expansion in the last period. This reflects the need to implement policies and processes for land management that harmonize productive activities with the conservation of ecosystems. It is relevant for these areas belonging to the park, the management of investment and implementation of sustainable production projects and regulated ecotourism alternatives, to reduce the pressure on natural parks[15].

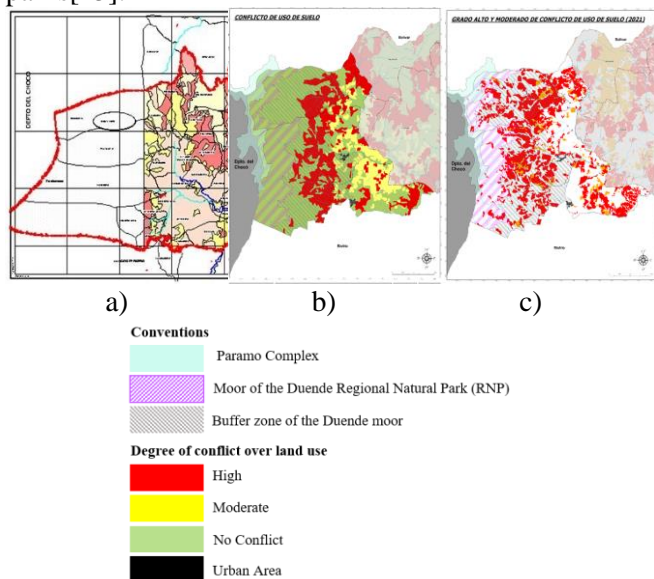


Figure 16. Comparison of areas with conflict due to inappropriate land use a) 2001, b) 2015, and c) 2022 (Municipality of Trujillo, 2001; Municipality of Trujillo, 2015; GeoCVC, 2022)

3.2.7 Implications of Inappropriate Land Use

The historical-geospatial analysis reveals that the transformation of ecosystems has been driven by a combination of socioeconomic, political and environmental factors. Between 2001 and 2022, changes in land use have been observed that have accelerated the transformation of ecosystems. The expansion of the agricultural frontier for establishing crops and livestock has led to a significant loss of biodiversity and habitat fragmentation. These transformations are related to deforestation and the felling of native forests, especially in the western part of the municipality.

Ecosystem fragmentation is one of the main drivers of biodiversity loss globally and is linked to the expansion of productive activities in conservation areas. Analysis of areas with land use conflicts confirms that productive activities are incompatible with the ecological vocation of the soil, which has aggravated the degradation of these ecosystems [6].

The pressure exerted by agricultural and livestock activities in the RNP buffer zone has led to a considerable loss of forest cover, which directly affects

the species that depend on these ecosystems for their survival. In addition, deforested areas tend to be more susceptible to erosion processes and soil degradation, which perpetuates a cycle of environmental deterioration [5].

3.3 Social Cartography for the Participatory Construction of the Territory

The research carried out in the buffer zone of the Moor of the Duende Regional Park using social cartography has contributed to the interaction between local communities and the territory. The results focus on three main axes: (1) Territorial governance and community integration, (2) Community perceptions on environmental protection and land use, and (3) Socio-environmental conflicts and sustainability.

3.3.1 Territorial Governance and Community Integration

The application of social mapping facilitated the collective construction of the territory (Figure 17), as well as making visible the local dynamics of land use, cultural practices, and ecological structure. Most participants, both community members and institutional representatives, highlighted the importance of involving communities in territorial planning processes. This result has contributed to the greater legitimacy and governability of the decisions taken. According to Griggio [16], this participatory approach contributes to reducing socio-environmental conflicts by allowing local actors to feel an active part of the proposed solutions. In addition, generating territorial governability from a bottom-up perspective [17].



Figure 17. Social Cartography Workshop (elaborated by the authors)

Based on the analysis of the cartography carried out with the community, it was possible to identify critical areas for the conservation and management of the landscape. In this context, traditional productive

practices, such as agroecology, are harmoniously integrated with environmental protection. This statement coincides with what Garcés described [1] about the complementarity between rural development and the conservation of ecosystems in the territories of strategic areas of environmental importance.

3.3.2 Community Perceptions of Environmental Protection and Land Use

Semi-structured interviews with residents of the buffer zone (15 persons) revealed that there is a broad acceptance of environmental guidelines and conservation figures. The majority (78%) (Figure 18a) of respondents associated the protection of the territory with defense against macro-extractive projects and the possibility of accessing economic resources through conservation and ecotourism projects [15]. This perception has generated a greater willingness and acceptance to adapt production practices toward sustainable models, such as the transition from conventional crops to agroecological systems.

However, despite this widespread acceptance, some community groups expressed concern about the limited access to financial and technical resources that would allow them to improve their productive practices without compromising environmental sustainability (Figure 18b).

the support for the communities that inhabit these areas. Because the socioeconomic pressure on ecosystems is one of the main factors of environmental degradation.

3.3.3 Socio-Environmental Conflicts and Sustainability

Through the development of the research, socio-environmental conflicts related to the inappropriate use of land and the overexploitation of natural resources were identified. One of the main challenges is the expansion of monocultures, such as the Hass avocado, which has increased the pressure on the soil and water resources (Figure 18c). This type of conflict is related to the difficulties in reconciling conventional productive activities with the protection of conservation areas, as proposed in [6].

The interviewees also mentioned the lack of clear policies regulating productive activities in the buffer zone, which has generated tensions between the different local actors (Figure 18d). This situation is consistent with the previous studies [18], arguing that common resources tend to be overexploited in contexts where governance is weak or non-existent.

In this way, it is reiterated that the use of social cartography as a tool for the collective construction of the territory in the buffer zone of the Moor of the Duende National Park under a participatory approach allows local communities not only to better understand the environmental guidelines but also to actively contribute to their definition and application [16].

Social mapping has shown its potential to create spaces for dialog between the community, institutions and other key actors, which coincides with what was pointed out in [6] about the importance of including social, cultural and environmental aspects in land use planning processes. In addition, the applied methodology has facilitated the identification of conflict areas, which is key to developing management strategies that are adapted to local realities, as suggested by [5] and [11].

However, one of the most important challenges of this research is the need to strengthen the mechanisms of technical and economic support for the communities, as proposed in [7] and [18]. Although social mapping has promoted greater governance and cohesion among local actors, the sustainability of agroecological practices and the conservation of ecosystems will depend on the availability of external resources. This type of investment will allow communities to implement sustainable development models through incentives for environmental conservation. On the other hand, the research also highlights the divergences between the ecological structure and rural development, which reflects the difficulty in reconciling productive and conservationist interests in the region. The

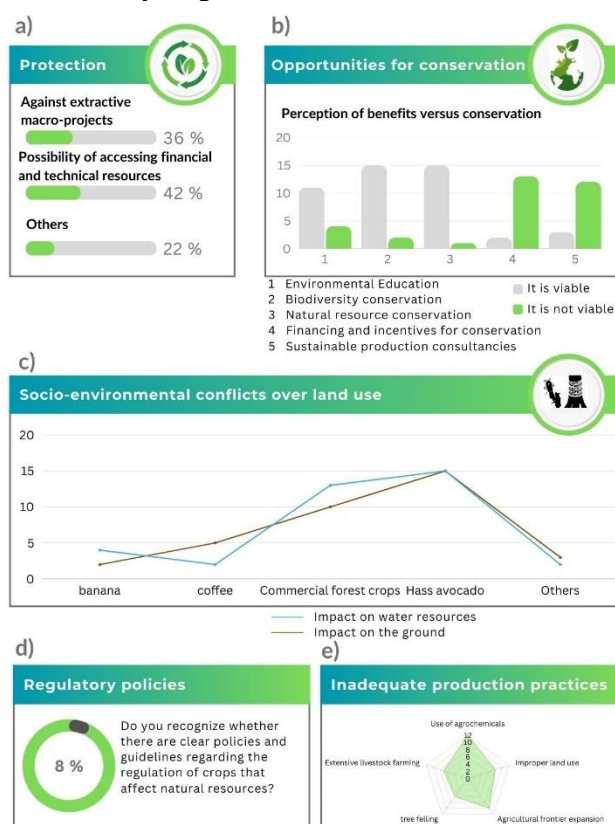


Figure 18. Results of the semi-structured interviews (elaborated by the authors)

As argued in [8], the protection of areas of environmental importance cannot be separated from

interviewees relate productive practices that support the inappropriate use of land and that go against the conservation of protected areas (Figure 18e). As argued in [16], these types of conflicts can be mitigated through participatory and democratic environmental planning processes that not only focus on the protection of ecosystems but also consider the economic and social needs of local communities.

3.4. Mapping Appropriate Land Uses

3.4.1 Conflicts and Zoning Proposal

Three levels of conflict were identified in the area, classified as low, medium and high. Areas of severe conflict (highlighted in red) present problems of erosion, soil loss and steep slopes, which are critical factors that limit the sustainability of productive activities [5]. The zoning proposal made within the framework of this research (Figure 17) proposes restoration areas for severe conflict zones within the RNP. These zones must be transformed, after their recovery, into strict preservation areas, as specified in the national and international regulatory framework for the management of moors [15].

For buffer areas, sustainable use is recommended, aimed at recovering vegetation cover and reforestation with native species. In the districts of Andinópolis, Venecia and La Sonora, zoning indicates that most production areas are incompatible with conservation areas. This justifies the allocation of buffer areas to ecological recovery practices [19]. According to the guidelines of the RNP Management Plan, uses must focus on the provision of ecosystem goods and services to promote sustainable rural development and competitiveness [8].

3.4.2 Environmental Determinants and Proposal for Appropriate Uses

CVC Resolution 564 of 2015 and the studies by Carrion [4] and del Río [5] highlight that the incorporation of environmental determinants to define appropriate uses in buffer zones is crucial to maintain the function of mountain ecosystems. In this context, a map of suitable uses was designed (Figure 19). The soils with a high productive potential located in the external zone of the protected area can be used for productive forest crops or for sustainable use under agroforestry and agroecology practices.

Areas that serve as buffer zones should prioritize their ecological recovery and subsequently be allocated to sustainable uses that maintain their integrity as preservation zones. These results contribute to the updating of planning instruments, aligning land use with sustainability criteria and environmental governance for the region [18].

In the process of zoning the proposed uses, the districts of Andinópolis, Venecia and La Sonora were evaluated, where a marked incompatibility was

observed between the areas of environmental conservation and the areas of intensive agricultural production.

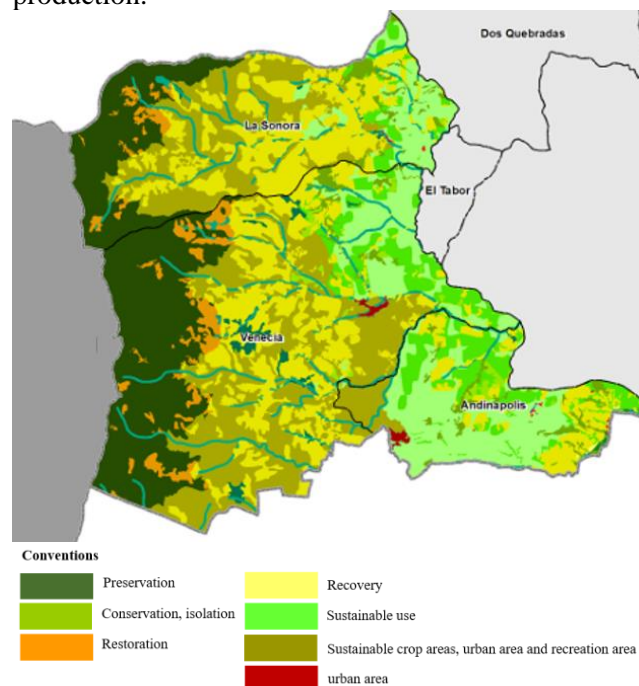


Figure 19. Proposal for appropriate land uses (elaborated by the authors)

This analysis showed the need to allocate ecological recovery and sustainable use activities in the buffer zone of the Moor of the Duende National Park due to the current pressure from anthropic activities and land use conflicts. The biophysical conditions of the territory, together with the cartographic analysis of the conflicts, allowed us to define restrictions and propose measures to reduce, control and rehabilitate the environmentally affected areas [7], [15].

For areas outside the PNR and without protection figures located in the three mentioned districts, the establishment of forest crops for production, recovery and sustainable use is recommended. These areas have high levels of impact due to erosion processes, soil loss, and steep slopes, factors that limit their use options.

The proposal for zoning and appropriate land uses, represented in Figure 18, integrates environmental sustainability into the development of the territory, in line with Araujo's vision [6] on the compatibility between the environment and agricultural production. The implementation of these uses will maintain the role of the countryside in the provision of ecosystem goods and services [20]. The proposed land use plan strengthens rural sustainability and competitiveness, promotes community participation, and improves governance in the region [1].

Intervention in the severe conflict areas, cataloged in this research, must focus on ecological restoration processes. This approach will allow a transition of

these areas toward sustainable use or, where appropriate, toward strict preservation management once the recovery work is completed. Proposals for sustainable use in buffer zones and the emphasis on ecological restoration are essential to mitigate anthropogenic pressures and preserve the ecosystem functionality of the RNP and its adjacent areas [19].

4. Conclusion

The historical line of the Moor of the Duende National Park and the municipality of Trujillo reflects how colonization processes, agricultural expansion and tensions over land use have affected the sustainability of local ecosystems. Historical events such as massive deforestation, the development of the coffee economy, and the intensive use of agrochemicals during the green revolution contributed to a significant loss of biodiversity and expansion of the agricultural frontier. However, these circumstances prompted subsequent recognition and environmental protection of the moor, motivated by regional, national and global policies that managed to integrate strategic ecosystems into territorial planning.

The consolidation of the Moor of the Duende as a natural park has been a complex process influenced by cultural, political, social and environmental factors. Conservation efforts faced challenges such as violence and the presence of armed groups in the territory, which limited interventions. Despite these obstacles, environmental policies and the creation of the SIDAP contributed to establishing a protection framework, which was consolidated with the reformulation of the environmental management plan and the delimitation of the park in 2018. This trajectory has positioned the Moor of the Duende as the most preserved ecosystem in Colombia, standing out for its resilience and the commitment of the local community.

The analysis of conflicts due to inappropriate land use in the buffer area of the Moor of the Duende National Park reflects how agricultural expansion and overuse of land have generated significant pressures on local ecosystems. The implementation of productive activities in conservation areas has increased the loss of forest cover and the fragmentation of habitats, affecting biodiversity and ecological balance. These results underline the need for land management policies that harmonize land use with ecological vocation, promoting sustainable production alternatives and reducing agricultural expansion in areas of high environmental sensitivity.

Soil erosion in the municipality of Trujillo, especially in the RNP buffer area, represents a critical problem associated with intensive and unplanned land use, increased by agricultural practices on steep and highly erosive terrain. The increase in areas with severe erosion between 2001 and 2022 shows the pressure exerted by intensive agriculture in this buffer

zone, which compromises the protective function of this region. This highlights the need to implement soil management strategies that reduce erosion and prioritize its conservation, specifically in areas adjacent to highly vulnerable ecosystems.

The implementation of social mapping in the buffer zone of the Moor del Duende Regional Park has facilitated a greater understanding of local dynamics and the interaction between communities and their territory, promoting inclusive governance. Through this participatory tool, it was possible to make visible both the critical areas for conservation and community perceptions on sustainable land use. This approach has allowed local actors to identify and prioritize socio-environmental conflicts that affect the sustainability of their productive practices, strengthening community integration in land management and promoting a rural development model that respects and protects local ecosystems.

The generation of a map of appropriate land uses in the Moor of the Duende National Park and its buffer zone has allowed us to identify priority areas for preservation, restoration, recovery, conservation and sustainable use. Finally, the superposition of cartographic layers is a method that allows the consolidation of a cartography of appropriate uses based on the zoning of conflicts due to inappropriate land use and the main ecological structure (MES). The resulting zoning reveals incompatibilities between productive and conservation areas and establishes measures to reduce pressure in areas of severe conflict, promoting land use that balances environmental sustainability and rural development.

Declarations

Author Contributions

Conceptualization, A.M.R.-C and C.L.S.-M; methodology, A.M.R.-C and Z.E.R.-G; software, A.M.R.-C and C.L.S.-M.; validation, A.M.R.-C. and C.L.S.-M.; formal analysis, A.M.R.-C. and Z.E.R.-G; investigation, A.M.R.-C.; writing—original draft preparation, all authors contributed equally; writing—review and editing, A.M.R.-C.; visualization, A.M.R.-C and Z.E.R.-G.; project administration, A.M.R.-C; All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available in this article.

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Institutional Review Board Statement

Rigorous ethical guidelines were adhered to throughout the study to ensure participant privacy and data confidentiality, in compliance with institutional and national research standards.

Informed Consent Statement

Participation in the study was voluntary and informed consent was obtained from all participants prior to their involvement.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and submission, and redundancies have been completely observed by the authors.

References

- [1] MONTOYA C, AGUILAR RODRÍGUEZ D, MAZORCO SALAS J, JIMÉNEZ GARCÍA L, ORTÍZ CLAVIJO L, ROJAS CAMPOS S, & JIMÉNEZ DURANGO V. *Social cartography: a mix of knowledge and methodologies*. Unaula, Editions Unibagué. Ibagué, Colombia, 2024. <http://doi.org/10.35707/9789587544305>
- [2] REGIONAL AUTONOMOUS CORPORATION OF THE VALLEY CVC. *Expansion of the Moor of the Duende Natural Park and Update of the Management Plan*. Technical Support Document, 2022. https://ecopedia.cvc.gov.co/sites/default/files/archivosAdjuntos/CVC-WCS_Cartilla%20Duende.pdf
- [3] REGIONAL AUTONOMOUS CORPORATION OF THE VALLEY CVC. *Zoning and Use Regime of the Area of the Moor of the Duende, in the Department of Valle del Cauca, Outside the Moor of the Duende Regional Natural Park, Jurisdiction of the Regional Autonomous Corporation of Valle del Cauca – CVC*, 2022. <https://www.cvc.gov.co/sites/default/files/2022-12/ZONIFICACION%20Y%20REGIMEN%20DE%20USOS%20AREA%20DEL%20PARAMO%20EL%20DUENDE%20POR%20FUERA%20DEL%20PNR%20DEL%20DUENDEFINALPARA%20CD.pdf>
- [4] CARRION P, and PÉREZ MY. Social Cartography as a Participatory Territorial Research Tool: Diagnosis of Ancestral Landscapes in Indigenous Communities of the Ecuadorian Amazon. *Pasos. Journal of Tourism and Cultural Heritage*, 2022, 20(1): 123-137. <https://doi.org/10.25145/j.pasos.2022.20.008>.
- [5] DEL RÍO DUQUE ML, RODRÍGUEZ T, PÉREZ LORA AP, LÖHR K, ROMERO M, CASTRO-NUNEZ A, SIEBER S, and BONATTI M. Understanding the systemic dynamics of land use in conflict-affected territories: the cases of Cesar and Caquetá, Colombia. *PLoS ONE*, 2022, 17(5): 1-19. <https://doi.org/10.1371/journal.pone.0269088>
- [6] ARAUJO COSTA RC, PEREIRA GT, TARLÉ PISSARRA TC, SILVA SIQUEIRA D, SANCHES FERNANDES LF, VASCONCELOS V, FERNANDES LA, and PACHECO FAL. Land Capacity of Watersheds for Multiple Forms of Relief with Environmental Land Use Conflicts. *Land Use Policy*. 2019, 81(1): 689-704. <https://doi.org/10.1016/j.landusepol.2018.11.041>
- [7] CARREÑO SUAREZ ND, ALVAREZ GONZALEZ JA, and SERRATO VELOSA YA. *Using QGIS for Sustainable Land Management in San José del Guaviare*. National Open and Distance University of Colombia, 2024. <https://repository.unad.edu.co/jspui/handle/10596/62415?locale=es>
- [8] NOGUERA DE ECHEVERRI AP, ARIAS PINEDA AA, TORO PÉREZ C, BARRETO SÁNCHEZ DE, VILLOTA MARTÍNEZ DA, PINEDA MUÑOZ JA, MONCADA MC, PÁRAMO POSADA SM, and VARGAS FRANCO V. *Thinking about environmental policies in Colombia from the perspective of Latin American environmental thought*. National University of Colombia Publishing House, Manizales, 2024. <https://repositorio.unal.edu.co/handle/unal/85897>
- [9] TORRES RUIZ AE. Transitioning in qualitative research: an approach to triangulation. *Journal Scientific*, 2021, 6(20): 275-295. <https://doi.org/10.29394/Scientific.issn.2542-2987.2021.6.20.15.275-295>
- [10] PEREZ MARTÍNEZ ME, VARGAS NAVARRO F, ROJAS PINILLA H, ORTIZ VILLA JA, and ARANGO LAURA M. *Between lands and boundaries: challenges for territorial environmental management in Trujillo and Restrepo (Valle del Cauca)*. Pontifical Javeriana University Publishing House, Santa fé de Bogotá, 2021. <http://hdl.handle.net/10554/55530>
- [11] PRÁVÁLIE R, BORRELLI P, PANAGOS P, BALLABIO C, LUGATO E, CHAPPELL A, MIGUEZ-MACHO G, MAGGI F, PENG J, NICULIȚĂ M, ROȘCA B, PATRICHE C, DUMITRAȘCU M, BANDOC G, NITA I-A, and BIRSAN M-V. A unifying modelling of multiple land degradation pathways in Europe. *Nature Communications*, 2024, 15(1): 1-13. <https://doi.org/10.1038/s41467-024-48252-x>
- [12] PÉREZ RRB. Main Ecological Structure and its Importance in the Spatial Organization Processes of the Municipality of Santa Cruz de Lorica. Doctoral Thesis, University of Córdoba, 2022.
- [13] WINKLER K, FUCHS R, ROUNSEVELL M, and HEROLD MARTÍN. Changes in global land use are four times greater than previously estimated. *Nature Communications*, 2021, 12(1): 1-10. <https://doi.org/10.1038/s41467-021-22702-2>
- [14] PÉREZ-RINCÓN M, PERALTA-ARDILA MDP, VÉLEZ-TORRES I, and MÉNDEZ F. Internal Armed Conflict and Environment in Colombia: Analysis from Ecological Conflicts, 1960–2016. *Journal of Political Ecology*, 2022, 29(1): 672-703. <https://doi.org/10.2458/jpe.2901>
- [15] MADRIGAL-MARTÍNEZ S, and MIRALLES I GARCÍA JL. Land-change dynamics and ecosystem service trends across the central high-Andean Puna. *Scientific Reports*, 2019, 9(1): 1-12. <https://doi.org/10.1038/s41598-019-46205-9>
- [15] LUGO LINARES AC, PEÑUELA JP, and AREVALO JE. *Community ecotourism: a sustainable alternative for the conservation and restoration of the Chingaza moor*. Bachelor's thesis. Specialization in Project Management, EAN University, 2024.

- [16] GRIGGIO P, ERRO VELÁZQUEZ M, GUZMÁN A, and CARIGNANO M. Santiago mountains and peasants: an experience of social mapping in a community of the Monte Quemado Forest-Industrial Basin, Argentina. *Centro de Estudios Sociales, Argentina*, 2019. <https://estudogeral.uc.pt/handle/10316/87437>
- [17] TUQUINGA JY, HIDALGO SZP, and TARABÓ EM. Bottom-up in sustainable tourism planning: the case of the communities of the Santa Elena coast in Ecuador. *Journal Ciencias Pedagógicas e Innovación*, 2021, 9(2): 46-53. <http://dx.doi.org/10.26423/rcpi.v9i2.429>
- [18] JIMENEZ GARCÍA L, and ORTIZ CLAVIJO LF. *Researching with and from social cartography. Participatory methodology and data science. Social cartography. Minga of knowledge and methodologies*, University of Ibagué, 2024. https://www.academia.edu/119127479/Investigar_con_y_desde_la_cartograf%C3%ADa_social_Metodolog%C3%ADa_participativa_y_ciencia_de_datos
- [19] KOR L, FERNÁNDEZ-LUCERO M, GRANADOS FLÓREZ DA, DAWSON TP, and DIAZ GRANADOS M. Bringing together local and scientific knowledge for the conservation of useful plants in Colombia. *Ambió*, 2024, 53(1): 309–323. <https://doi.org/10.1007/s13280-023-01921-5>
- [20] SCHIRPKE U, GHERMANDI A, SINCLAIR M, VAN BERKEL D, FOX N, VARGAS L, and WILLEMEN L. Emerging technologies for assessing ecosystem services: A synthesis of opportunities and challenges. *Ecosystem Services* 2023, 63(1): 101558. <https://doi.org/10.1016/j.ecoser.2023.101558>
- 参考文献:**
- [1] MONTOYA C, AGUILAR RODRÍGUEZ D, MAZORCO SALAS J, JIMÉNEZ GARCÍA L, ORTÍZ CLAVIJO L, ROJAS CAMPOS S 和 JIMÉNEZ DURANGO V. 社会制图：知识和方法论的结合。Unaula, Unibagué 版。哥伦比亚伊巴格，2024。 <http://doi.org/10.35707/9789587544305>
- [2] 山谷地区自治公司 CVC。Duende 自然公园沼泽的扩建和管理计划的更新。技术支持文件，2022 https://ecopedia.cvc.gov.co/sites/default/files/archivosAdjuntos/CVC-WCS_Cartilla%20Duende.pdf
- [3] 山谷地区自治公司 CVC。考卡山谷省杜恩德荒原区域分区和使用制度，杜恩德荒原区域自然公园外，考卡山谷自治公司管辖范围 - CVC，2022 <https://www.cvc.gov.co/sites/default/files/2022-12/ZONIFICACION%20Y%20REGIMEN%20DE%20USOS%20AREA%20DEL%20PARAMO%20EL%20DUENDE%20POR%20FUERA%20DEL%20PNR%20DEL%20DUENDEFINALPARA%20CD.pdf>
- [4] CARRION P 和 PÉREZ MY. 社会制图作为参与式领土研究工具：对厄瓜多尔亚马逊土著社区祖先景观的诊断。帕索斯。旅游与文化遗产杂志，2022，20(1): 123-137 <https://doi.org/10.25145/j.pasos.2022.20.008>
- [5] DEL RÍO DUQUE ML, RODRÍGUEZ T, PÉREZ LORA AP, LÖHR K, ROMERO M, CASTRO-NUNEZ A, SIEBER S 和 BONATTI M. 了解受冲突影响地区土地利用的系统动态：以哥伦比亚塞萨尔和卡克塔为例。PLoS ONE, 2022, 17(5): 1-19 <https://doi.org/10.1371/journal.pone.0269088>
- [6] ARAUJO COSTA RC, PEREIRA GT, TARLÉ PISSARRA TC, SILVA SIQUEIRA D, SANCHES FERNANDES LF, VASCONCELOS V, FERNANDES LA 和 PACHECO FAL. 流域土地容量用于多种形式缓解环境土地利用冲突。土地使用政策。2019, 81(1): 689-704. <https://doi.org/10.1016/j.landusepol.2018.11.041>
- [7] CARREÑO SUAREZ ND, ALVAREZ GONZALEZ JA 和 SERRATO VELOSA YA. 使用 QGIS 在 San José del Guaviare 进行可持续土地管理。哥伦比亚国立开放远程大学，2024。 <https://repository.unad.edu.co/jspui/handle/10596/62415?locale=es>
- [8] NOGUERA DE ECHEVERRI AP, ARIAS PINEDA AA, TORO PÉREZ C, BARRETO SÁNCHEZ DE, VILLOTA MARTÍNEZ DA, PINEDA MUÑOZ JA, MONCADA MC, PÁRAMO POSADA SM 和 VARGAS FRANCO V. 从拉丁美洲环境思想的角度思考哥伦比亚的环境政策。哥伦比亚国立大学出版社，马尼萨莱斯，2024 <https://repositorio.unal.edu.co/handle/unal/85897>
- [9] TORRES RUIZ AE. 定性研究的转变：三角测量方法。科学杂志，2021，6(20): 275–295. <https://doi.org/10.29394/Scientific.issn.2542-2987.2021.6.20.15.275-295>
- [10] PEREZ MARTÍNEZ ME, VARGAS NAVARRO F, ROJAS PINILLA H, ORTIZ VILLA JA 和 ARANGO LAURA M. 土地与边界之间：特鲁希略和雷斯特雷波（考卡山谷）领土环境管理面临的挑战。教皇哈维里亚纳大学出版社，圣菲德波哥大，2021。 <http://hdl.handle.net/10554/55530>
- [11] PRĀVĀLIE R, BORRELLI P, PANAGOS P, BALLABIO C, LUGATO E, CHAPPELL A, MIGUEZ-MACHO G, MAGGI F, PENG J, NICULIȘĂ M, ROȘCA B, PATRICHE C, DUMITRAȘCU M, BANDOC G, NITA I-A 和 BIRSAN M-V. 欧洲多种土地退化路径的统一模型。自然通讯，2024，15(1): 1-13. <https://doi.org/10.1038/s41467-024-48252-x>
- [12] PÉREZ RRB. 圣克鲁斯德洛里卡市的主要生态结构及其在空间组织过程中的重要性。博士论文，科尔多瓦大学，2022
- [13] WINKLER K, FUCHS R, ROUNSEVELL M

和 HEROLD MARTÍN。全球土地利用的变化是之前估计的四倍。自然通讯, 2021, 12(1): 1-10

<https://doi.org/10.1038/s41467-021-22702-2>

[14] PÉREZ-RINCÓN M、PERALTA-ARDILA MDP、VÉLEZ-TORRES I 和 MÉNDEZ F。哥伦比亚的内部武装冲突与环境: 从生态冲突分析, 1960-2016 年。政治生态学杂志, 2022, 29(1): 672-703。 <https://doi.org/10.2458/jpe.2901>

[15] MADRIGAL-MARTÍNEZ S 和 MIRALLES I GARCÍA JL。中部高安第斯普纳地区的土地变化动态和生态系统服务趋势。科学报告, 2019, 9(1): 1-12。 <https://doi.org/10.1038/s41598-019-46205-9>

[15] LUGO LINARES AC、PEÑUELA JP 和 AREVALO JE。社区生态旅游: 保护和恢复 Chingaza 荒原的可持续替代方案。学士论文。项目管理专业, EAN 大学, 2024

[16] GRIGGIO P、ERRO VELÁZQUEZ M、GUZMÁN A 和 CARIGNANO M。圣地亚哥山脉和农民: 阿根廷克马多森林工业盆地社区的社会测绘经验。阿根廷社会研究中心, 2019

<https://estudogeral.uc.pt/handle/10316/87437>

[17] TUQUINGA JY、HIDALGO SZP 和 TARABÓ EM。自下而上的可持续旅游规划: 以厄瓜多尔圣埃伦娜海岸社区为例。教育科学与创新杂志, 2021, 9(2): 46-53

<http://dx.doi.org/10.26423/rcpi.v9i2.429>

[18] JIMENEZ GARCÍA L 和 ORTIZ CLAVIJO LF。使用社会制图进行研究。参与式方法和数据科学。社会制图。Minga 知识和方法, 伊瓦格大学, 2024

https://www.academia.edu/119127479/Investigar_con_y_desde_la_cartograf%C3%ADa_social_Metodolog%C3%ADa_participativa_y_ciencia_de_datos

[19] KOR L、FERNÁNDEZ-LUCERO M、GRANADOS FLÓREZ DA、DAWSON TP 和 DIAZ GRANADOS M。汇集当地和科学知识, 保护哥伦比亚有用的植物。志向, 2024, 53(1): 309-323

<https://doi.org/10.1007/s13280-023-01921-5>

[20] SCHIRPKE U、GHERMANDI A、SINCLAIR M、VAN BERKEL D、FOX N、VARGAS L 和 WILLEMEN L 评估生态系统服务的新兴技术: 机遇与挑战的综合。生态系统服务 2023, 63(1): 101558 <https://doi.org/10.1016/j.ecoser.2023.101558>

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