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# Effects of Land Cover and Land Use Change on Nature's Contributions to People of the Shade-Grown Coffee Agroecosystem: An Analysis of Cumbres de Huicicila, Nayarit, Mexico

**Diana Laura Navidad Murrieta [1], Susana María Lorena Marceleño Flores [2,*], Areli Nájera González [1], Oyolsi Nájera González [2] and Juan Pablo Ramírez Silva [1]**

[1] Research and Postgraduate Studies Department, Universidad Autónoma de Nayarit, Ciudad de la Cultura "Amado Nervo", Tepic 63155, Nayarit, Mexico; 21000442@uan.edu.mx (D.L.N.M.); areli.najera@uan.edu.mx (A.N.G.); pablor@uan.edu.mx (J.P.R.S.)

[2] Cuerpo Académico Recursos Naturales, Universidad Autónoma de Nayarit, Ciudad de la Cultura "Amado Nervo", Tepic 63155, Nayarit, Mexico; oyolsi@uan.edu.mx

* Correspondence: susana.marceleno@uan.edu.mx

**Abstract:** The shade-grown coffee agroecosystem is rich in ecosystem services (ES). In recent years, pests and the decrease in coffee prices have caused producers to change their agricultural activities. These changes in land use have resulted in alterations in the vegetation cover that lead to the loss of ES. The objective of this research was to analyze the effects of land cover and land use changes on the ES associated with coffee production in Cumbres de Huicicila, a coffee-growing region in western Mexico. For this purpose, we analyzed land cover and land use maps for the period 2007–2019, calculated the annual rate of change and estimated the future rate of change to 2030. We used a literature review through the SALSA method to identify and estimate the impact of the ES of coffee plantations under the approach of nature's contributions to people. As a result, we found alterations with a decreasing trend in agroecosystem cover and loss of ES related to biodiversity. We hope that this research will serve to consolidate efforts for the conservation and sustainable use of the ES of the shade-grown coffee plantations.

**Keywords:** ecosystem services; coffee plantations; coffee crops; deforestation; vegetation; biodiversity



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## 1. Introduction

The manifold activities undertaken by humanity inevitably have repercussions for the environment and, at present, the discernible amplification of these repercussions can be perceived through climate change and the depletion of available natural resources. The loss or modification of biodiversity, beyond its connotation of species extinction, causes an intricate web of implications. As postulated by Quintero et al. [1], there is also the deterioration of ecosystem services (ES), which contributes to the direct or indirect detriment of human welfare, through food, health, human well-being, the regulation of air and water quality, etc.; all of these contribute to the economic development and quality of life of future generations [2]. Now, this loss or modification of ES can be seen through changes in land use, a consequence of human interactions on an area of land, which, due to its importance, is one of the most pressing issues in research.

Since the first approaches to the concept of ES, a pronounced emphasis has been directed towards anthropogenic dependency and the call for its conservation. This definition has been adopted by different authors. Avendaño-Leadem et al. [3] categorized the definition into two different currents: firstly, the phases and properties of the environment that interact to sustain human existence; secondly, an approach wherein services are interpreted as comprising both tangible resources and intangible processes that confer benefits to human life. Both lines are integrated in the initial framework of ES proposed in the Millennium Ecosystem Assessment (MEA), which classifies them into four principal typologies [2]: (1) regulatory services encompassing ecological, biogeochemical and biological processes; (2) supportive services associated with habitat preservation, biological conservation and genetic diversity; (3) provisioning as production services from inorganic to organic organisms that engender biomass; and (4) cultural services encompassing informational services linked to cultural contexts. Collectively, these classifications pivot upon the evaluation of natural processes as services to human communities, with the conceptualization of service from an anthropogenic, extraction-oriented and pecuniary standpoint.

This recent contemplation has led the academic community to engage in an ongoing discussion on the concept of ES, culminating in the proposition of an opposing perspective. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has advanced an innovative conceptual paradigm termed "Nature's Contributions to People" (NCP). This novel framework assesses the manifold influence that people derive from ecosystems encompassing the dimensions of quality of life, well-being and contentment. This transcends mere economic valuation, which differs from the tenets stipulated in the MEA framework [4]. Thus, the NCP evaluates the results of the interaction between human society and nature, guided by a vision of conservation and equilibrium. Díaz et al. [5] present the common line of some of the MEA ES that make up these contributions (Figure 1), dividing them into three different categories: (1) material contributions (food, supplies, materials and space), (2) non-material contributions (associated with socio-cultural benefits) and (3) regulatory contributions (maintenance of biogeochemical cycles, climate and biodiversity).

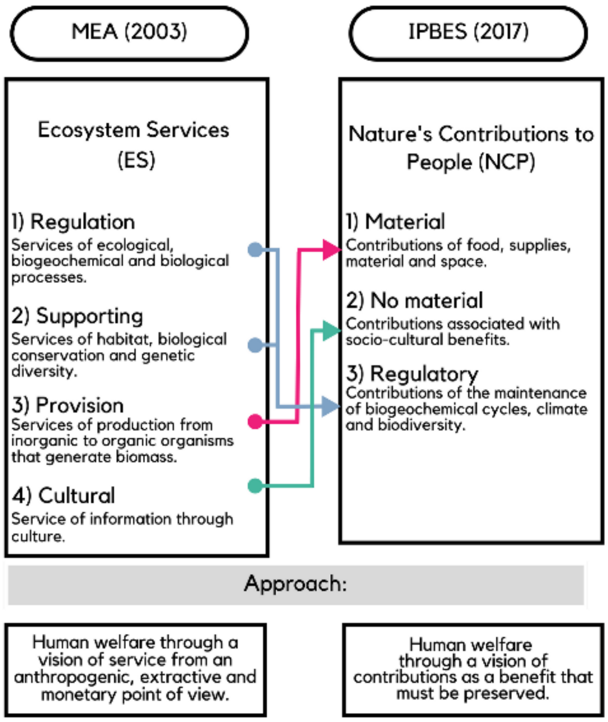



**Figure 1.** Conceptual scheme of evolution of the IPBES framework of Nature's Contributions to People (NCP), based on the Ecosystem Services (ES) concepts of the MEA framework. Source: Own elaboration from information in Díaz et al. [5].

The conceptual framework of NPCs is based on the preservation of ecosystems; therefore, alterations in vegetation cover exert an influence over the accessibility and advantages that these ecosystems confer upon human collectives. This not only encompasses shifts within natural landscapes but extends to modifications occurring within human-altered ecosystems, including agroecosystems.

Plant cover represents the biophysical composition of the Earth's surface, a facet of such profound significance to the scientific community that it prompted the United Nations to declare the Convention on Biological Diversity (CBD) and establish the Global Strategy for Plant Conservation (GSPC) in 1993. The primary aims of these initiatives encompass the safeguarding of biodiversity, its sustainable utilization and the equitable distribution of genetic resources [6]. In alignment with these objectives, the Food and Agriculture Organization of the United Nations (FAO) advocates the employment of methodolohies such as Conservation Agriculture to ensure the conservation of vegetative ground cover. This not only serves to improve soil attributes but also to potentially augment biodiversity within agroecosystems [7]. Concurring with this perspective, Tonolli [8] elucidates that an agroecosystem is a human-modified ecological domain, shaped in accordance with biophysical and socioeconomic components with the objective of generating sustenance, energy (such as food, fiber or fuel) and other ecosystem services.

Albarracín-Zaidiza et al. [9] propose that agricultural production stands as a contributing factor to the prevailing biodiversity decline. They advocate for the exploration of alternative approaches such as conservation farming, which has the potential to mitigate the environmental impact predominantly attributed to agricultural practices capable of engendering ecological perturbations. These practices, encompassing soil management and its potential erosion, the contamination of resources, seed modification and unskilled handling, generate an undue depletion of natural capital. Therefore, agricultural activities are fundamentally intertwined with ecosystem services. Consequently, any compromise or alteration to one invariably reverberates onto the other.

Toledo and Miguel [10] propose five distinct categories of coffee agroecosystems based upon discerning criteria such as vegetation arrangement, species diversity, species constitution, as well as the magnitude and anthropogenic influence on the primal vegetation, traversing a gradient of intensification.

- Traditional Rustic System: In this system, coffee shrubs grow in the understory of a native forest, characterized by minimal alterations in the original ecosystem.
- Traditional Polyculture System ("Coffee Gardens"): Here, coffee cultivation coexists with a diverse array of utilitarian plant species, culminating in a verdant coffee plantation with a wide variety of tree, shrub, and herb species.
- Commercial Polyculture System: This category entails the removal of the original forest trees and the introduction of shade-bearing trees tailored to foster optimal coffee cultivation, prioritizing their function as provider of shade.
- Shade-Grown: A designated assortment of tree species are employed to provide shade exclusively to the coffee plants, resulting in a specialized plantation that integrates agrochemical application and pursues market-oriented goals.
- Sun-Grown Coffee: This modern approach to coffee production dispenses with tree shade, directly exposing coffee plants to sunlight. It is characterized by the deployment of genetically enhanced cultivars, chemical fertilizers, pesticides, and intensive mechanization throughout the year.

These various systems encompass different approaches and degrees of intervention in the coffee agroecosystem realm, with implications for the biodiversity, sustainability, and coffee quality.

Shade-grown coffee cultivation emerges as an agroecosystem that could make a substantial contribution to the dispensation of ecosystem services. Espinoza [11] affirms that the expanse devoted to shade-grown coffee cultivations not only facilitates reforestation but also engenders a resurgence in forest cover, thereby conferring benefits upon communities reliant upon this endeavor. The valuation of ES in conjunction with coffee cultivation is a recent research focus, as a contemporary discourse reveals that these services go beyond environmental functions or processes that solely cater to the current and prospective well-being of humanity. Therefore, there is a need for constant monitoring, the implementation of strategies, and the formulation of methodologies that effectively correlate ES and agroecosystemic projects to be applied to coffee plantations as well as other production systems.

According to data from the Ministry of Agriculture and Rural Development (SADER), Mexico is the eleventh-largest global contributor to coffee production [12]. The climatic conditions, topographical attributes, and diverse spectrum of soils prevalent across the nation bestows it with the capacity to cultivate varieties of coffee endowed with exceptional quality. The coffee-growing areas in Mexico span the central–southern and western regions. These geographic domains encompass the Sierra Madre Occidental and Sierra Madre del Sur.

Located in the western region, Nayarit emerges as a pivotal constituent of the paramount coffee cultivation states in Mexico. The coffee industry contributes 2.5% of Mexico's cultivated acreage, securing the eighth rank in the country in terms of agricultural expanse. It has a registry of 3961 practitioners of coffee production who are dedicated to this activity in the primary process, with approximately 19,000 hectares planted [13]. In Nayarit, Cumbres de Huicicila is the second largest coffee-growing region in the state [14].

Although Cumbres de Huicicila is a well-established growing region with a cultural history of coffee production, it has not been exempt from the array of challenges that currently beset the coffee industry [15]. Pests in coffee plants, climate changes due to global warming, low grain prices in the international market and the lack of sectoral policy have compelled coffee producers to diversify their agricultural pursuits and adopt alternative economic strategies [14].

In this sense, the objective of this research is to examine the evolutionary trajectory of the shade-grown coffee agroecosystem in the community of Cumbres de Huicicila, Nayarit, attributed to shifts in vegetation coverage and land utilization. A pivotal endeavor involves establishing a correlation between the effects on the ES provided by the coffee plantations. To achieve this, we analyzed the land cover and land use maps of the region for the years 2007 and 2019, calculating annual changes and net changes. After identifying the change trends, we projected the estimated land cover and land utilization for the year 2030. Finally, using the NCP approach, we characterized the ES offered by the coffee plantations in the Cumbres de Huicicila region and evaluated their possible effects based on the changes in land cover and land use.

We expect that the results of this research will contribute to the paradigm of the conservation of shade-grown coffee agroecosystems by highlighting the effects that changes in land cover and land use have on the ES it provides. This research work also contributes to the multidisciplinary vision required for tackling socio-environmental problems. Additionally, it delves into the consequences of land-use changes and the modification of ecosystem services on a transdisciplinary level.

## 2. Materials and Methods

### *2.1. Study Area Cumbres de Huicicila, Nayarit, Mexico*

Cumbres de Huicicila is community entrenched in coffee cultivation, located in the south of the state of Nayarit, in the Sierra Madre Occidental of Mexico. According to information from the National Institute of Statistics and Geography (INEGI), it is located between the coordinates 105°00′44.4 longitude and 21°19′05.4 latitude, and has an altitude of 954 m above sea level [16] (Figure 2). In an area of 35,000 hectares, different types of vegetation can be found: mesophilic mountain forest, oak woodlands, secondary low subcaducifolia woodlands, and evergreen forests [17]. This intricate tapestry rendes Cumbres de Huicicila a suitable suitable locale for the cultivation of medium-shade coffee. The intricate interplay between the topographical features and geological attributes of the region lead to conditions conducive to coffee growth by indirect exposure to the sun, ideal humidity, and interaction with other species. As per the National Agrarian Registry, Cumbres de Huicicila has 108 producers, with 440 coffee parcels that together make up 1251.6 ha dedicated to coffee production [18].

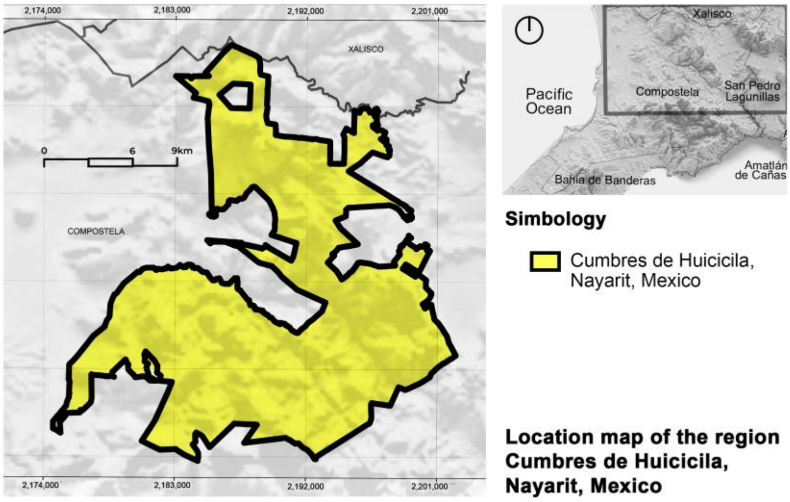



**Figure 2.** Location map of the Cumbres de Huicicila region, Nayarit, Mexico. Source: Own elaboration based on information from INEGI [16].

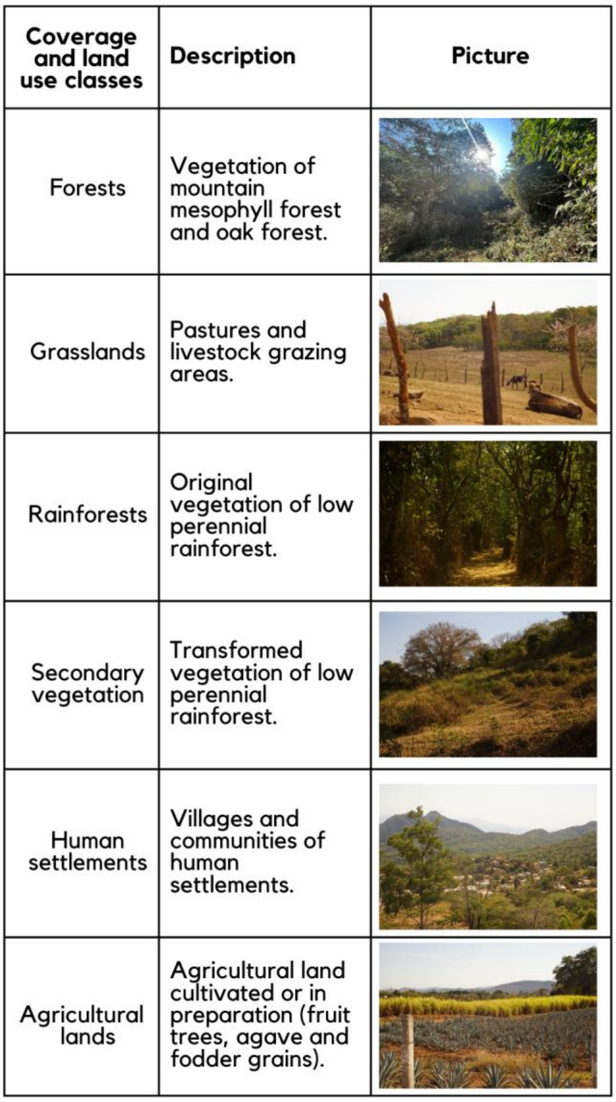
### 2.2. Methods

The methodology employed in this study was structured into four different sections: (1) an analysis of land cover and land use maps for the years 2007 and 2019, (2) the discernment of patterns pertaining to changes and the projection of the land cover and land use values for the year 2030, (3) characterization of the ES provided by shade-grown coffee plantations, and (4) estimation of the effect of changes in land cover and land use on the ES provided by the coffee agroecosystem.

#### 2.2.1. Analysis of Land Cover and Land Use Maps for the Years 2007 and 2019

We conducted an examination of the vegetation and land use mapping databases from the INEGI series IV (2007) [19] and VII (2019) [17], using the Cumbres de Huicicila region as the study polygon. These materials were generated from the manual interpretation by digital means, using multispectral and orthorectified SPOT images from 2007, while the 2019 information was generated from the analogical interpretation by the digital means of multispectral LandSat TM8 sensor Geomedian images from 2018; in both cases, this was supported by the respective field verification endeavors. Both series are available at a scale of 1:250 000 and were generated through the supervised classification of satellite imagery, a process overseen and ratified by INEGI (utilizing SPOT 5 imagery for Series IV and Landsat 8 imagery for Series VII). The cartography and database are conveniently accessible at www.inegi.org.mx. Throughout this investigation, QGIS version 3.28.9 was harnessed to refine the data, facilitate image analysis, and generate comprehensive cartographic depictions of outcomes. Microsoft Excel was employed to synthesize tabular datasets and engender illustrative graphical representations.

The databases sourced from INEGI Series IV (2007) comprise a compilation of seven different maps of vegetation cover and land use. In contrast, the database obtained from Series VII (2019) includes six specific categories. Therefore, the decision was made to synthesize the forest category for processing. Coverages were grouped according to characteristics and uses described in previous research on the study area, leading to a final proposal of a reclassification that defines five classes. Three coverages were used: forests, grasslands, rainforests and secondary vegetation, and two uses: human settlements and agricultural lands (Figure 3).



| Coverage and land use classes | Description | Picture |
|---|---|---|
| Forests | Vegetation of mountain mesophyll forest and oak forest. | |
| Grasslands | Pastures and livestock grazing areas. | |
| Rainforests | Original vegetation of low perennial rainforest. | |
| Secondary vegetation | Transformed vegetation of low perennial rainforest. | |
| Human settlements | Villages and communities of human settlements. | |
| Agricultural lands | Agricultural land cultivated or in preparation (fruit trees, agave and fodder grains). | |

**Figure 3.** Land cover and land use classification of the study area. Source: Own elaboration based on information from INEGI land cover and land use cartography series IV y VII [17,19]. Photographs taken by the authors.

Shade-grown coffee agroecosystems do not conform to a distinct and narrowly circumscribed cover group. As posited by Soriano [20] the shade coffee cultivated within Cumbres de Huicicila is found between forest, rainforest and secondary vegetation ecosystems. This assertion was made based on the author's field description. Therefore, the coffee agroecosystem is dispersed among these three cover types, mostly in the forest-type cover (Figure 4).

To identify the transformations that occurred in the two analyzed time periods, we calculated the annual rate of change and net change using a simplification of the formula defined in Ruiz et al. [21]:

$$\text{Annual rate of change } = \left[\frac{S_2}{S_1}\right]^{\frac{1}{n}} - 1$$

The annual rate of change is the result of dividing the area of the recent date ($S_2$) by the area of the historical date ($S_1$), exponentiated to one by the number of years from the historical date to the recent date (n), minus 1. This result is then expressed as a percentage.

**Figure 4.** Photos of shade-grown coffee agroecosystem in forest, rainforest and secondary vegetation cover. Source: Photographs taken by the authors.

#### 2.2.2. Identification of Trends in the Change and Projection of Land Cover and Land Use Values for the Year 2030

After obtaining the calculation of the annual rate of change, the value of the area for each land cover and land use class was estimated for the year 2030. This projection methodology hinges upon the foundational supposition that alterations within land cover and land use adhere to a stochastic process of temporal variation. Consequently, by representing this process as a continuous annual series, it becomes feasible to estimate future values considering the number of years that were analyzed in the past.

It is important to note that the estimation does not account for change stressors, resulting in a linear calculation. This involves adding the area value from the recent date (2019 values) to the product of multiplying the annual rate of change by the number of years between the historical date (2007) and the recent date (2019), which equals 12 years. This procedure is illustrated through the following formula:

$$Future\ estimation = S_2 + (annual\ rate\ of\ change \times \text{ number of years that passed between } S_1\ and\ S_2)$$

The future estimate is the result of summing the area of the recent date ($S_2$) plus the result of the annual rate of change multiplied by the number of years that passed between the recent date ($S_2$) and the historical date ($S_1$). The results are displayed as a percentage to visualize the increase or decrease in each land cover and land use class.

#### 2.2.3. Characterization of the Ecosystem Services Provided by Shade-Grown Coffee Plantations

To characterize the ES of the coffee agroecosystem and associated ecosystems in the Cumbres de Huicicila region, we conducted a systematic review of the literature using the Search, Appraisal, Analysis and Synthesis method (SALSA), as explained in the guide of Codina [22]. The method contains three phases: search for information, inclusion and exclusion of search results, and analysis and synthesis of the information obtained.

The primary objective of this review was to discern and delineate the array of the ecosystem services (ES) discussed by other authors in research related to coffee plantations and agroecosystems in Mexico and Latin America. As a result, the search was constrained to these regions, utilizing search terms such as "coffee plantations," "land use," and "ecosystem services", found within the title, abstract, and keywords.

In the second phase, we employed a process of inclusion and exclusion to filter the articles obtained from the initial search. This process was performed manually, meticulously assessing whether the methods, results, and discussions presented in the articles met the predefined criteria from the search phase. As a result, a total of 19 articles were selected for analysis, through which the primary ecosystem services (ES) of the coffee agroecosystems were identified. To extend the focus to our study area, we conducted a similar search, encompassing the thesis research available in institutional repositories, including the Resources of Scientific, Technological, and Innovation Information (RIACTIs) in Mexico, accessible through the Institutional Repository of the National Council of Humanities, Science, and Technology (CONAHCYT).

Building upon this information and adhering to the principles of sustainable development, we opted to adopt the Nature's Contributions to People (NCP) approach to examine the ecosystem services associated with coffee plantations in the studied region. Using this approach, NCPs were categorized according to the three groupings proposed by Díaz et al. [5]: material contributions, non-material contributions, and regulatory contributions.

#### 2.2.4. Estimation of the Effect of Changes in Land Cover and Land Use on the Ecosystem Services Provided by the Coffee Agroecosystem

Finally, we integrated the results of the land cover and land use change analysis and assessed the potential impact on NCP associated with coffee agroecosystems in the community of Cumbres de Huicicila. To do this, we identified the predominant land cover and land use in each contribution. Then, considering their tendency to change, we indicated how the provision of the contribution would be affected, using an arrow signaling method similar to the one proposed in the framework of the Millennium Ecosystem Assessment [2].

## 3. Results and Discussion

### *3.1. Transformations in Land Cover and Land Use from 2007 to 2019 in the Cumbres de Huicicila Region*

Through meticulously scrutinizing the cartographic delineations of land cover and land use pertaining to the years 2007 and 2019, we derived two cartographic representations that visually illustrate the disparities in the territorial composition within the Cumbres de Huicicila region (see Figure 5). The study area encompasses a total land area of 34,471 hectares.

The area extensions of each land cover and land use class, along with the net change and rate of change between 2007 and 2019, are provided in Table 1. Notably, forests emerged as the predominant land cover category across both temporal junctures, constituting a substantial portion ranging from approximately 33% to 35% of the overall polygonal expanse. This was trailed by secondary vegetation, captating a range of from 20% to 24% of the total area, and rainforests, comprising approximately 18% of the total area. Concerning land use, agricultural activities prevailed, covering 21% of the total polygon area during both years. Pastures encompassed 2% of the polygon in 2007 and expanded to 6% in 2019. Human settlements occupied a lesser proportion, constituting 0.3% of the area. Graphically, a vertically oriented green arrow signifies an increase in coverage and land use, while a red arrow in the opposite direction indicates a decrease.

**Table 1.** Area extension, net change, and rate of change (2007–2019) of land cover and land use in Cumbres de Huicicila.

| Coverage and Land Use Classes | 2007 | 2019 | Net Change | Tendency | Rate of Change 2007–2019 |
|---|---|---|---|---|---|
| | Ha | Ha | Ha | | % |
| Forests | 12,052.6 | 11,593.5 | −459.1 | ⬇ | −3.9% |
| Grasslands | 750.4 | 2121.3 | 1370.9 | ⬆ | 108.6% |
| Rainforests | 6203.9 | 6029.5 | −174.4 | ⬇ | −2.8% |
| Secondary vegetation | 8128.1 | 7384.6 | −743.4 | ⬇ | −9.5% |
| Human settlements | 95.9 | 99.9 | 4.1 | ⬆ | 4.1% |
| Agricultural lands | 7240.2 | 7242.2 | 3.9 | ⬆ | 0.03% |

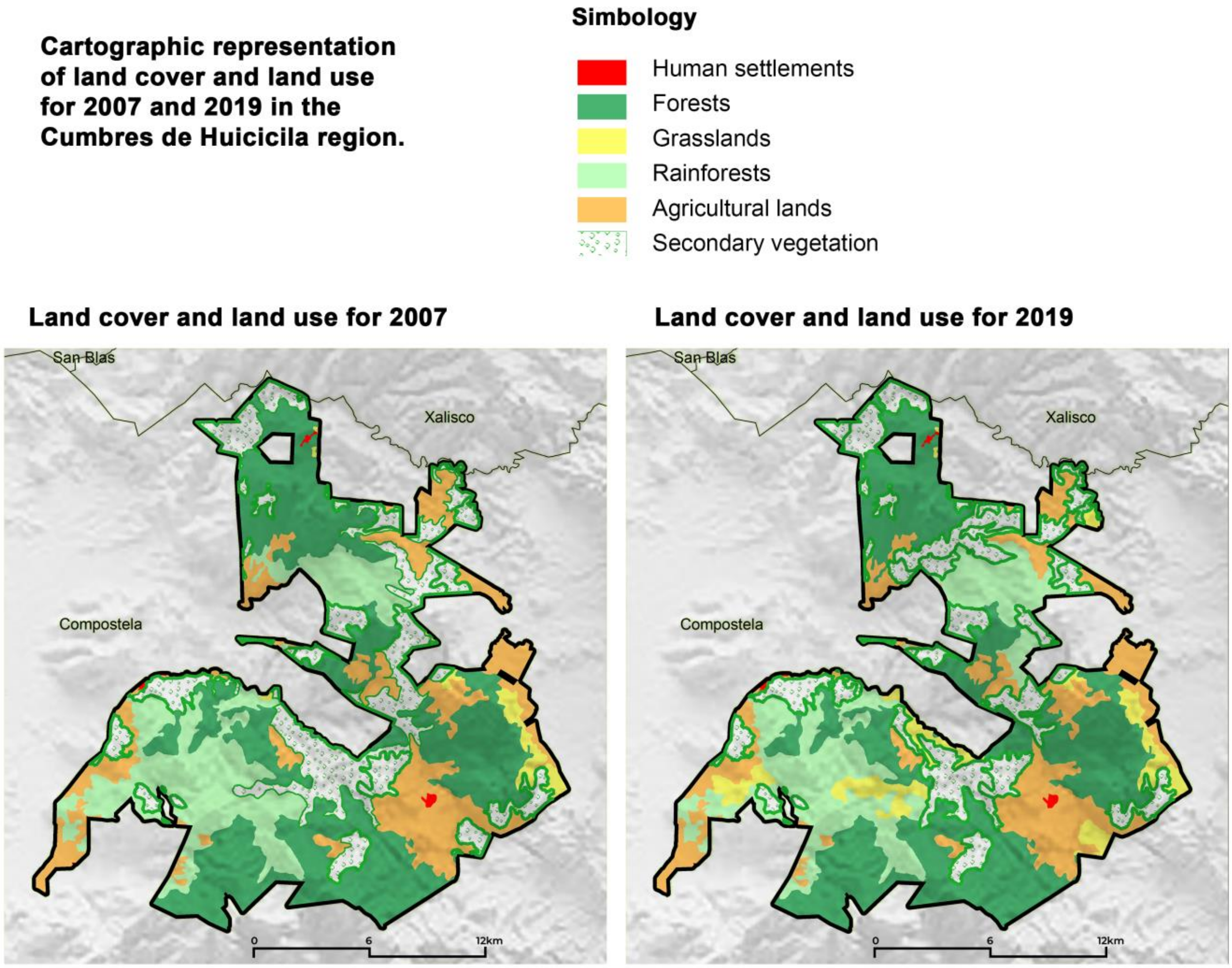



**Figure 5.** Cartographic representation of land cover and land use for 2007 and 2019 in the Cumbres de Huicicila region. Source: Own elaboration based on information from INEGI land cover and land use cartography series IV y VII [17,19].

The trend analysis revealed an escalation in grasslands and agricultural utilization, essentially signifying agroecosystems designated for food production. This connection corresponds to Flores' assertion [23], which affirms that the primary livelihoods in the region encompass livestock rearing and agricultural activities. Notably, grasslands underwent an impressive surge of 108.6% between 2007 and 2019, implying a consistent yearly augmentation of 9.05%. Agricultural use exhibited a minor alteration, maintaining a meager annual pace of 0.002% throughout the period, with crops such as lemon, avocado, and agave taking precedence. Even though the change was marginal, the utilization of human settlements advanced by 4.1% within the timeframe, notably with the community of Cumbres de Huicicila, where they occupied a prominent expanse.

Conversely, we observed a decline in the coverage of secondary vegetation, forests, and rainforests, displaying annual depletion rates of −0.8%, −0.3%, and −0.2% respectively. Consequently, these rates culminated in a cumulative reduction of −9.5% for secondary vegetation, −3.9% for forests, and −2.8% for rainforests over the period spanning from 2007 to 2019. This discernible decrease in original vegetation coverage transpired at an annual rate of 1.4%, attributable to the conversion into grasslands and agricultural uses. The shade-grown coffee agroecosystems, disseminated across forests, rainforests, and secondary vegetation are included within these diminished rates.

The upsurge in grasslands leads to a concerning scenario due to their scarcity of tree and shrub elements, making them enticing areas for intensified livestock production. This shift prompts land parcel owners to alter the surrounding areas, often comprising original forest, rainforest, and shade coffee agroecosystems, into grazing grounds. As highlighted by the National Commission for the Knowledge and Use of Biodiversity (CONABIO), subpar livestock management hampers the flourishing of more nutritious and less invasive plant species, subsequently hindering their growth and reproductive capacities [24]. Furthermore, overgrazed land leads to soil compaction from cattle trampling, impeding future crop yield and hindering the permeation of water into the ground.

However, the bibliographic search did not yield substantial evidence linking land-use changes with other coffee agroecosystems at a global scale. This gap offers an opportunity to explore alternative dynamics related to land use modifications and their interactions within various coffee agroecosystems.

### *3.2. Land Cover and Land Use Change Trends and Estimates for the Year 2030 in the Cumbres de Huicicila Region*

The projection of future land cover and land use reveals that forests, rainforests, and secondary vegetation would be the most-impacted categories (Table 2). This outcome stems from the potential escalation of direct anthropogenic activities, including heightened demands for food production through agriculture and livestock, amplified human settlement expansion, and the need for raw materials.

**Table 2.** Estimated land cover and land use for 2030 in the Cumbres de Huicicila region.

| Coverage and Land Use Classes | 2007 | 2019 | 2030 | Tendency | Rate of Change 2019–2030 |
|---|---|---|---|---|---|
| | Ha | Ha | Ha | | % |
| Forests | 12,052.6 | 11,593.5 | 11,172.6 | ↓ | −3.7% |
| Grasslands | 750.4 | 2121.3 | 3373.9 | ↑ | 47.4% |
| Rainforests | 6203.9 | 6029.5 | 5869.6 | ↓ | −2.7% |
| Secondary vegetation | 8128.1 | 7384.6 | 6703.1 | ↓ | −9.6% |
| Human settlements | 95.9 | 99.9 | 103.6 | ↑ | 3.7% |
| Agricultural lands | 7240.2 | 7242.2 | 7247.9 | ↑ | 0.1% |

If current conditions persist without factoring in change variables, our estimations indicate that, by 2030, we could witness a 7.6% reduction in forest cover, a 5.5% decrease in rainforests, and a substantial 19.1% loss in secondary vegetation compared to 2007. Conversely, grasslands are predicted to swell by 160%. Consequently, the dominance of grassland cover would surge from 2.2% in 2007 to 9.8% in 2030, primarily supplanting secondary vegetation and forested regions. This trajectory raises speculation about the direct impact that the expansion of pastureland for livestock would have on the shade-grown coffee agroecosystem within the area. Figure 6 illustrates the transformation of some forested areas into grasslands.

Camacho et al. [25] assert that the primary threats to forests are a result of human-induced pressures, including ilicit deforestation, the excessive extraction of non-timber resources, commercialized agricultural practices, and the expansion of new plantation areas. An analogous situation is evident in the transformation of land cover within the shade coffee-growing region of Orinoquia, Colombia. Here, the transition toward increased oil palm cultivation has led to a discernible alteration in ecosystem biodiversity. Moreover, it has engendered a severe degradation of socio-cultural ecosystem services in the region, manifested through diminished soil fertility, unemployment, migration, and social conflicts [26].

**Figure 6.** Aerial photographs captured during a visit to the Cumbres de Huicicila region in March 2023. Source: Photographs Taken by the Authors.

It is vitally important to take actions to avoid the loss of forests and rainforests, which are important for the ecosystem services and maintenance of the coffee agroecosystem. Compromising these habitats would affect the variety of shade trees in the coffee system, and cause an increase in the temperature of the agricultural system, soil erosion and fertility loss, and reduction in carbon stocks and the richness of biodiverity in flora and fauna, resulting in a poor agricultural system and weak coffee production, susceptible to pests infestations and other diseases [27].

### *3.3. Ecosystem Services (ES) of Shade-Grown Coffee Plantations Using the Nature's Contributions to People (NCP) Approach*

The characterization of ES depends on the type of vegetation cover associated with the coffee agroecosystem in question. For example, shade-grown coffee plantations located in areas with forest vegetation have different ES compared to agroecosystems located in extensive flatlands, fully exposed to sunlight and with dimished vegetation diversity. In other words, each agroecosystem has particular characteristics that collectively provide unique ES. As a complex system, it is vital to maintain the balanced interaction of its components in order to preserve the ES.

Table 3 presents a compilation of the ecosystem services (ES) associated with coffee agroecosystems in Cumbres de Huicicila region, identified as a result of a literature review of various studies on coffee and its sustainable production from economic, social, and environmental perspectives. Considering the characteristics of the Cumbres de Huicicila region, ES that did not correspond to the context or were mentioned for a particular case study were excluded. The resulting ES were categorized according to the NCP approach into material, non-material, and regulatory contributions.

**Table 3.** Compilation of ecosystem services (ES) according to the Nature's Contributions to People (NCP) approach associated with coffee agroecosystems in the Cumbres de Huicicila region.

| NCP Category | Contribution | Indicator | Reference |
|---|---|---|---|
| Material | Food production | Coffee production | Status and trends of ecosystem services [24] |
| | | Production of other foods | Status and trends of ecosystem services [24] |
| | Generation of materials | Wood and/or firewood | Ecosystem-based adaptation: Effect of shade trees on ecosystem services in coffee plantations [28] |
| | | Use of coffee waste material | Potential ecosystem services in the Colombian coffee sector [29] |
| | | Medicinal resources | Ecosystem-based adaptation: Effect of shade trees on ecosystem services in coffee plantations [28] |
| | | Ornamental resources | The floristic diversity of cloud forest and shade coffee plantations in Cumbres de Huicicila, Nayarit, Mexico [20] |

**Table 3.** *Cont.*

| NCP Category | Contribution | Indicator | Reference |
| --- | --- | --- | --- |
| Non-material | Landscape or scenic beauty composition | Scenic viewpoints | Ecosystem Services Associated with Soil in Agroecosystems specific to Specialty Coffees [30] |
| | | Routes or trails | The Valuing Cultural, Social and Tourists from All Cultural and Natural Resources As Tools for Planning Tourism, Coffee Cultural Landscape Conservation and Sustainable Development of the Territory Tourist [31] |
| | | Sociocultural landscapes | Community-based Rural Tourism focused on the actor in the coffee-growing locality of Cumbres de Huicicila, Nayarit [32] |
| | Conservation of culture | Architectural heritage of the coffee farm | Coffee plantations as wildlife conservation systems. Case study: Cumbres de Huicicila, Compostela, Nayarit [33] |
| | | Traditional knowledge | Traditional knowledge as scholarly practice among coffee producers in Xico, Veracruz, Mexico [34] |
| | Socioeconomic support for communities | Employment creation | Contributions to People Shape Sense of Place in the Coffee Cultural Landscape of Colombia [35] |
| | | Other productive activities associated with coffee | Status and trends of ecosystem services [24] |
| | | Capacity-building | Touristic Capacity building of an Agroecotourism Route in Coffee Crops in Cumbres de Huicicila, Compostela, Nayarit [36] |
| Regulatory | Water regulation | Water infiltration capacity | Potential ecosystem services in the Colombian coffee sector [29] |
| | Climate change regulation | Soil carbon storage | Ecosystem-based adaptation: Effect of shade trees on ecosystem services in coffee plantations [28] |
| | | Biomass carbon storage | Potential ecosystem services in the Colombian coffee sector [29] |
| | | Temperature regulation | Status and trends of ecosystem services [24] |
| | Biodiversity maintenance | Conservation of biological corridors | Use of wild mammal fauna in the coffee-growing community of Cumbres de Huicicila, Compostela, Nayarit, Mexico [37] |
| | | Conservation of wildlife species | Coffee plantations as wildlife conservation systems. Case study: Cumbres de Huicicila, Compostela, Nayarit [33] |

From an anthropogenic perspective, coffee is an input that goes beyond being a resource of nature that is directly converted into food, energy and other material wealth for human beings, as it also provides intangible benefits. Biodiversity contributes to improving the quality of human life at the psychological level, such as recreation and capacity-building. Moreover, regulatory inputs are linked to natural processes and factors that regulate the formation of tangible and intangible inputs, such as the regulation of biogeochemical cycles [38]. In this regard, González et al. [36] acknowledges that the conservation of coffee plantations can be achieved by implementing projects under various schemes, including payments for environmental or ecosystem services, water-related environmental service payments, carbon capture, and specialty coffee programs.

Within the socio-economic context, Caro-Caro et al. [26] assert that the decline in ecosystem services intensifies the problems of marginalization and inequality within vulnerable sectors of society. This decrease makes it difficult to satisfy the basic needs for a healthy life, economic independence and overall well-being. Therefore, they consider proper planning for the conservation, restoration, and sustainable use of ecosystems as vital, as it generates ecological, social, and economic benefits. Rosa et al. [39] propose management alternatives that involve productive diversification in agroecosystems through supporting community ecotourism programs. Through the potential of tourism, the communities can enhance the valuation of ecosystem services in their territory with the support of rural enterprises or community organizations.

An illustrative endeavor that embodies the integration of ecosystem service conservation into its planning is the Cultural Coffee Landscape (Paisaje Cultural Cafetero–PCC®) brand located in Colombia. Due to the favorable climate, soils, and hydrography, it has established a commitment to non-mechanized practices for the sustainable planting and cultivation of shade-grown coffee. In 2018, Fromer's, the renowned tourism guide in the United States, recognized it as the top destination to visit due to the scenic beauty derived from ecosystem services. The PCC® offers a diverse array of visual perspectives, making it a remarkable landscape globally, with its native forests and biological corridors contributing to its natural and aesthetic value. These programs serve as a source of motivation for producers to maintain sustainable production processes, implement trade strategies, and pursue productive diversification [40].

### *3.4. Effects of Land Cover and Land Use Changes on the NCPs Provided by the Coffee Agroecosystems in Cumbres de Huicicila*

The changes in land cover and land use in the community of Cumbres de Huicicila are directly related to the NCPs provided by coffee agroecosystems. Diminishing vegetation cover results in a reduction in available NCPs for the local human communities.

As a result of analyses of the transformations that occurred in the composition of land cover and land use between 2007 and 2019, Table 4 presents the potential impact on the described ecosystem services in the NCP approach, indicating their estimated trend of increase or decrease. Graphically, a vertically oriented green arrow signifies an increase in contribution, while a red arrow in the opposite direction indicates a decrease in contribution. The yellow arrow is employed to indicate contributions influenced by both declining land cover and increasing land uses. The arrow is vertically aligned when the contribution is mainly shaped by increasing land uses and faces the opposite direction when the contribution hinges on diminishing land cover.

Initially, a direct impact on shade-grown coffee agroecosystems becomes evident, reflecting a downward trend in coffee production due to potential losses in forests, rainforests, and secondary vegetation expanses. This contrasts with the production of other food types. Subsequently, an adverse trend is observed in the generation of the remaining materials necessary to fulfill primary needs as part of the material contributions.

Similar effects manifest in the non-material contributions, such as landscape aesthetics or scenic worth. This could result in the forfeiture of opportunities centered on tourism appeal and hinder the pursuit of production diversification. Additionally, this impacts the preservation of traditional knowledge, particularly when accessing non-traditional markets where their coffee could command enhanced prices and income. Examples include specialized markets for organic fair-trade coffee and the conservation of fauna species, bolstered by certifications such as Smithsonian Bird Friendly®, which endorses shade-grown and bird-friendly coffee cultivation [41].

The coffee farm's geographic disposition also has high potential regarding the conservation of its historical architectural heritage. However, it is worth discussing the prioritization of issues in a community that faces socio-economic fragility. A precedent example, as discussed by Caro-Caro et al. [26], interlinks the decline in coffee plantations to the pursuit of alternative income sources and migration. In other words, if there is a lack of interest in continuing these practices within the coffee community, there will be a potential loss of the traditional wisdom associated with coffee cultivation.

Lastly, with the decreasing trend in natural land-cover, such as forests, rainforests, and secondary vegetation, there could be a disruption in biodiversity, leading to a potential loss of the biological corridors that harbor native flora and fauna. This can result in alterations in the water and air-filtration capacity, soil quality, and climate instability.

**Table 4.** Estimated trends in the effects on the NCPs of shade-grown coffee agroecosystems due to transformations in vegetation cover and land use in Cumbres de Huicicila.

| NCP Category | Contribution | Indicator | Associated Land Cover and Land Use Classes (Rate of Change) | Estimated Trend Effects |
|---|---|---|---|---|
| Material | Food production | Coffee production | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |
| | | Production of other foods | Grasslands (47.4%) and agricultural lands (0.1%) | ↑ |
| | Generation of materials | Wood and/or firewood | Forests (−3.7%) and rainforests (−2.7%) | ↓ |
| | | Use of coffee waste material | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |
| | | Medicinal resources | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), grasslands (47.4%) and agricultural lands (0.1%) | ↓ |
| | | Ornamental resources | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |
| Non-material | Landscape or scenic beauty composition | Scenic viewpoints | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), grasslands (47.4%), agricultural lands (0.1%) and human settlements (3.7%) | ↓ |
| | | Routes or trails | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), grasslands (47.4%) and agricultural lands (0.1%) | ↓ |
| | | Sociocultural landscapes | Human settlements (3.7%) | ↑ |
| | Conservation of culture | Architectural heritage of the coffee farm | Human settlements (3.7%) | ↑ |
| | | Traditional knowledge | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), agricultural lands (0.1%) and human settlements (3.7%) | ↓ |
| | Socioeconomic support for communities | Employment creation | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), agricultural lands (0.1%) and human settlements (3.7%) | ↓ |
| | | Other productive activities associated with coffee | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), agricultural lands (0.1%) and human settlements (3.7%) | ↓ |
| | | Capacity-building | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%), agricultural lands (0.1%) and human settlements (3.7%) | ↓ |
| Regulatory | Water regulation | Water infiltration capacity | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%) and agricultural lands (0.1%) | ↓ |
| | Climate change regulation | Soil carbon storage | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%) and agricultural lands (0.1%) | ↓ |
| | | Biomass carbon storage | Forests (−3.7%), rainforests (−2.7%), secondary vegetation (−9.6%) and agricultural lands (0.1%) | ↓ |
| | | Temperature regulation | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |
| | Biodiversity maintenance | Conservation of biological corridors | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |
| | | Conservation of wildlife species | Forests (−3.7%), rainforests (−2.7%) and secondary vegetation (−9.6%) | ↓ |

As we can observe, changes in land cover and land use directly and indirectly impact both environmental and socio-economic factors within the coffee-growing community. Following the assertion made by Villarreyna-Rogelio et al. [28], the visibility and valorization of ecosystem services are crucial in decision-making for the sustainable management of agroecosystems and long-term planning, aiming to enhance the recovery of shade-grown coffee crops while also conserving the natural coverage of the agroecosystem.

Furthermore, focusing on non-material contributions allows for the identification of a variety of values or attributes that individuals and communities receive, thereby providing key factors for decision-making [29]. An example of this can be seen through the productive diversification of agroecosystems to avoid changes in land use. Activities such as agrotourism contribute to the sustainable development of communities and, consequently, the conservation of these valued and profitable agroecosystems. However, the achievement of such outcomes mandates the active involvement of governmental and educational institutions in the undertaking, in addition to securing the enthusiastic participation of proprietors of natural and agricultural resources [42].

## 4. Conclusions

The changes in land cover and land use were analyzed in the coffee-growing region of Cumbres de Hucicila between 2007 and 2019. It was found that there is a loss of 16.2% in vegetation cover within the agroforestry ecosystem, with a decrease of 2.8% in rainforest, 3.9% in forests, and 9.6% in secondary vegetation. This loss is primarily due to an increase in grasslands, which grew by 108.6% during this period due to the increased livestock activity. If current conditions persist, an approximate loss of 32.2% of vegetation cover is estimated by 2030 compared to 2007. The most affected type of vegetation coverage is secondary vegetation and forest. Based on this information, it is speculated that, since 2007, there has been a sustained process of transformation in the region towards livestock activities, directly affecting the land cover associated with the shade-grown coffee agroecosystem.

However, it is important to emphasize the intricate interplay of diverse socio-environmental determinants that contribute to the attrition of coffee plantations. According to the specific milieu encountered in Cumbres de Huicicila and in relation to the local losses of the coffee agroecosystem, there is no generalized one-to-one relationship with the loss of forest cover; rather, this represents a potential loss of ecosystem services provided by coffee plantations.

When vegetation cover is under pressure, its repercussions directly reverberate through the ecosystem services that enhance human well-being, including those provided by agroecosystems. Through a systematic literature review, a total of 20 ecosystem services, grouped into eight types, were identified for the shade-grown coffee agroecosystem in the Cumbres de Hucicila region. These services were categorized according to the NCP framework into material, non-material, and regulatory contributions.

For the category of material contributions, two types were identified: food production (production of coffee and other agricultural products) and the generation of materials (forest resources, medicinal plants, ornamental plants and the utilization of coffee waste materials). For the category of non-material contributions, scenic beauty (scenic viewpoints, routes or trails and socio-cultural landscapes), cultural (conservation of the historical heritage of the coffee farm and traditional knowledge of its cultivation) and socioeconomic (job creation, other productive activities related to coffee and capacity building) factors were identified. In the category of regulatory contributions, water regulation (water infiltration), climate change regulation (carbon storage in soil and biomass, and temperature regulation) and biodiversity maintenance (conservation of biological corridors and wildlife species) were identified.

Finally, we contrasted the effect of land cover and land use changes on the CNP of the Cumbres de Huicicila coffee agroecosystems. Our findings revealed that 85% of the identified NCP showed a decreasing trend attributed to the loss of vegetation cover. A favorable trend was only observed in the production of other food crops (such as lemon, avocado and agave), as well as in the sociocultural landscapes and the conservation of the historical architectural heritage of the coffee farm due to the growth of the Cumbres de Huicicila community.

The satisfaction and high demand for food and raw materials have induced a process of loss of vegetation cover and changes in land use in Cumbres Huicicila, Nayarit. This phenomenon could lead to a reduction in the mountain cloud forest characteristic of the coffee agroecosystem in that community. Along with the challenges associated with coffee production, this represents a threat to the remaining ecosystem services.

The pursuit of alternatives for productive diversification with a focus on the ES and NCP of agroecosystems will enable producers to access additional sources of income. This, consequently, will contribute to the conservation of shade coffee plantations and prevent the necessity for modifications to land coverage and land use. The provision of guidance, support, regulation, and oversight by the relevant authorities managing rural communities are crucial to the realization of this objective.

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## References

1. Quintero, J.; Castro, C.; Garcés, H.; Escobar, J. Geoprocessing processes in the spatialization of ecosystem services in areas of local interest. *Ing. USBMed* **2017**, *8*, 19–28. [CrossRef]
2. Alcamo, J.; Ash, N.J.; Bennett, E.M.; Biggs, R.; Butler, C.D.; Callicott, J.B.; Capistrano, D.; Carpenter, S.R.; Castilla, J.C.; Chambers, R.; et al. *Ecosystems and Human Well-Being: A Framework for Assessment*; Island Press: Washington, DC, USA, 2003. Available online: https://cgspace.cgiar.org/handle/10568/19290 (accessed on 20 June 2023).
3. Avendaño-Leadem, D.F.; Cedeño-Montoya, B.C.; Arroyo-Zeledón, M.S. Integrating the concept of ecosystem services in territorial planning. *Rev. Geogr. Am. Cent.* **2020**, *2*, 63–90. [CrossRef]
4. Pascual, U.; Balvanera, P.; Díaz, S.; Pataki, G.; Roth, E.; Stenseke, M.; Watson, R.T.; Dessane, E.B.; Islar, M.; Kelemen, E.; et al. Valuing nature's contributions to people: The IPBES approach. *Curr. Opin. Environ. Sustain.* **2017**, *26–27*, 7–16. [CrossRef]
5. Díaz, S.; Pascual, U.; Stenseke, M.; Martín-López, B.; Watson, R.T.; Molnár, Z.; Hill, R.; Chan, K.M.A.; Baste, I.A.; Brauman, K.A.; et al. Assessing nature's contributions to people: Recognizing culture, and diverse sources of knowledge, can improve assessments. *Science* **2018**, *359*, 270–272. [CrossRef] [PubMed]
6. United Nations. Convention on Biological Diversity. United Nations Environmental Program. 1992. Available online: https://www.cbd.int/doc/legal/cbd-en.pdf (accessed on 24 June 2023).
7. Food and Agriculture Organization [FAO]. Soil Organic Cover. 2022. Available online: https://www.fao.org/conservation-agriculture/in-practice/soil-organic-cover/es/ (accessed on 24 June 2023).
8. Tonolli, A.J. Propuesta metodológica para la obtención de indicadores de sustentabilidad de agroecosistemas desde un enfoque multidimensional y sistémico. *Rev. Fac. Cienc. Agrar. Univ. Nac. Cuyo* **2019**, *51*, 381–399. (In Spanish). Available online: https://revistas.uncu.edu.ar/ojs3/index.php/RFCA/article/view/2716 (accessed on 20 June 2023).
9. Albarracín-Zaidiza, C.; Sáenz-López, J.A.; Barrera-López, L.M.; Ramírez-Gil, J.E. Agroecological Practices as Contribution to the Sustainability of Agroecosystems. *Case Study Sumapaz Province. Cienc. Agric.* **2019**, *16*, 39–55. [CrossRef]
10. Valencia, I. Coffee Agroecosystems and Livelihood Strategies in the Sierra de Zongolica, Veracruz, Mexico. Master's Thesis, Facultad de Ciencias Biologicas y Agropecuarias, Universidad Veracruzana, Córdoba, Mexico, 2022. Available online: https://www.researchgate.net/profile/Ivan-Gonzalez-Valencia/publication/369197724_Agroecosistemas_Cafetalero_y_Medios_de_Vida_en_la_Sierra_de_Zongolica_Veracruz/links/640f9de592cfd54f84f91b6f/Agroecosistemas-Cafetalero-y-Medios-de-Vida-en-la-Sierra-de-Zongolica-Veracruz.pdf (accessed on 26 July 2023).
11. Espinoza-Mendoza, V.E. Drivers of Land Use Change and Carbon Storage along a Gradient of Human Modification of Landscapes in Nicaragua. Master's Thesis, CATIE, Turrialba, Costa Rica, 2016. Available online: https://repositorio.catie.ac.cr/handle/11554/8589 (accessed on 24 June 2023).

12. Ministry of Agriculture and Rural Development [SADER]. Mexico, Eleventh Largest Coffee Producer in the World. 2018. Available online: https://www.gob.mx/agricultura/es/articulos/mexico-onceavo-productor-mundial-de-cafe?idiom=es (accessed on 20 June 2023).
13. Ministry of Agriculture and Rural Development (SAGARPA). National Evaluation of Results 2013: Productive Promotion Component of Coffee. 2015. Available online: https://acortar.link/14dCPb (accessed on 20 June 2023).
14. Mariscal Haro, E.I. The Coffee Sector and Its Productive Value Chain in the State of Nayarit. Ph.D. Thesis, Universidad Juárez del Estado de Durango, Durango, Mexico, Universidad Autónoma de Nayarit, Durango, Mexico, Universidad Autónoma de Sinaloa, Culiacán, Mexico, 2020. Available online: http://repositorio.ujed.mx/jspui/handle/123456789/108 (accessed on 25 June 2023).
15. Ovalle-Rivera, O.; Läderach, P.; Bunn, C.; Obersteiner, M.; Schroth, G. Projected Shifts in *Coffea arabica* Suitability among Major Global Producing Regions Due to Climate Change. *PLoS ONE* **2015**, *10*, e0124155. [CrossRef]
16. National Institute of Statistics and Geography [INEGI]. Cartografía Geoestadística Urbana, Cierre del Censo de Población y Vivienda 2010. 2010. Available online: https://www.inegi.org.mx/app/mapas (accessed on 24 June 2023).
17. National Institute of Statistics and Geography [INEGI]. Cartografía Digital de Vegetación y Uso de Suelo Serie VII. 2019. Available online: https://www.inegi.org.mx/temas/usosuelo (accessed on 24 June 2023).
18. National Agrarian Registry [RAN]. Agrarian Communities Register and History. 2012. Available online: https://phina.ran.gob.mx (accessed on 24 June 2023).
19. National Institute of Statistics and Geography [INEGI]. Cartografía Digital de Vegetación y Uso de Suelo Serie IV. 2010. Available online: https://www.inegi.org.mx/temas/usosuelo (accessed on 24 June 2023).
20. Soriano, J.F. The Floristic Diversity of Cloud Forest and Shade Coffee Plantations in Cumbres de Huicicila, Nayarit, Mexico. Bachelor's Thesis, Autonomous University of Nayarit, Nayarit, Mexico, 2017.
21. Ruiz, V.; Savé, R.; Herrera, A. Multitemporal analysis of land use change in the Miraflor Moropotente Protected Landscape, Nicaragua, 1993–2011. *Ecosistemas* **2013**, *22*, 117–123. [CrossRef]
22. Codina, L. How to do traditional or systematic bibliographic reviews using academic databases. *Revista ORL* **2020**, *11*, 139–153. [CrossRef]
23. Flores, E.R. Climate change: High Andean grasslands and food security. *Rev. Glaciares Ecosistema Mont.* **2017**, *1*, 73–80. [CrossRef]
24. Aburto, O.; Aguilar, A.; Aguilera, M.; Aluja, M.; Andrade, A.; Arroyo, I.; Ashworth, L.; Astier, M.; Ávila, P.; Bitrán, D.; et al. Status and trends of ecosystem services. In *Natural Capital of Mexico, Vol. II: Conservation Status and Change Trends*, 1st ed.; Jong, B., García, B., Muñoz, C., Eds.; CONABIO: Mexico City, Mexico, 2009; Volume 2, pp. 185–245. Available online: https://acortar.link/aWPaZH (accessed on 24 June 2023).
25. Camacho-Sanabria, J.M.; Pérez, J.I.; Pineda Jaimes, N.B.; Cadena Vargas, E.G.; Bravo Peña, L.C.; Sánchez López, M. Changes in land cover/use in a portion of the Mexican Mountain Transition Zone. *Madera Bosques* **2015**, *21*, 93–112. Available online: http://www.scielo.org.mx/scielo.php?script=sci_arttextamp;pid=S1405-04712015000100008amp;lng=esamp;tlng=es (accessed on 24 June 2023). [CrossRef]
26. Caro-Caro, C.I.; Torres-Mora, M.A. Ecosystem services as support for the management of socio-ecological systems: Application in agroecosystems. *Orinoquia* **2015**, *19*, 237–252. Available online: http://www.scielo.org.co/scielo.php?script=sci_arttextamp;pid=S0121-37092015000200011amp;lng=enamp;tlng=es (accessed on 24 June 2023). [CrossRef]
27. Soto-Pinto, L. Entre el dilema de producir café y mantener los beneficios socioambientales del cafetal. In *Caminar el Cafetal: Perspectivas Socioambientales del Café y su Gente*; Baltazar, E.B., Pinto, L.S., Palacios, G.H., Ruiz, J.G., Eds.; El Colegio de la Frontera Sur: San Cristóbal de Las Casas, México, 2019; pp. 239–251. Available online: https://biblioteca.ecosur.mx/cgi-bin/koha/opac-detail.pl?biblionumber=000059919 (accessed on 24 June 2023).
28. Villarreyna, R.; Avelino, J.; Cerda, R. Ecosystem-based adaptation: Effect of shade trees on ecosystem services in coffee plantations. *Agron. Mesoam.* **2020**, *31*, 499–516. [CrossRef]
29. González, G.M.; Serna, G.C.A. Potential ecosystem services in the Colombian coffee sector. *Rev. Cenicafé* **2018**, *69*, 35–46. Available online: https://acortar.link/bgP5i9 (accessed on 24 June 2023).
30. Ceballos, C. Ecosystem Services Associated with Soil in Agroecosystems specific to Specialty Coffees. Master's Thesis, Technological University of Pereira, Pereira, Colombia, 2020.
31. Duis, U. The Valuing Cultural, Social and Tourists from All Cultural and Natural Resources as Tools for Planning Tourism, Coffee Cultural Landscape Conservation and Sustainable Development of the Territory Tourist. *Anu. Tur. Soc.* **2007**, *8*, 1–12. Available online: https://ssrn.com/abstract=1509622 (accessed on 24 June 2023).
32. Castillo, C. Community-Based Rural Tourism Focused on the Actor in the Coffee-Growing Locality of Cumbres de Huicicila, Nayarit. Master's Thesis, Autonomous University of Nayarit, Nayarit, Mexico, 2018.
33. Medina, F.C. Coffee Plantations as Wildlife Conservation Systems: Case Study Cumbres de Huicicila, Compostela, Nayarit. Master's Thesis, Autonomous University of Nayarit, Nayarit, Mexico, 2018. Available online: http://dspace.uan.mx:8080/jspui/handle/123456789/2326 (accessed on 24 June 2023).
34. Arriaga, J.; Fabela, C.; Gutiérrez, L.; Sotelo, N. Traditional knowledge as scholarly practice among coffee producers in Xico, Veracruz, Mexico. In *Anthropology Research Notebooks*, 1st ed.; Garcia, P., Ed.; School of Anthropology, Pontifical Catholic University of Ecuador: Quito, Ecuador, 2021; Volume 24, pp. 114–130.
35. Murillo-López, B.E.; Castro, A.J.; Feijoo-Martínez, A. Nature's Contributions to People Shape Sense of Place in the Coffee Cultural Landscape of Colombia. *Agriculture* **2022**, *12*, 457. [CrossRef]

36. González, M.J.; Marceleño, S.L.; Nájera, O. Tourist Carrying Capacity of an Agroecotourism Route in Cumbres de Huicicila, Compostela, Nayarit, Mexico. In *Investigación Turística y Gastronómica*; Arvizu, L., Ramírez, A., Eds.; Universidad Tecnocientífica del Pacífico S.C.: Tepic, Mexico; Universidad Autónoma de Nayarit: Tepic, Mexico, 2020; pp. 147–155. Available online: https://acortar.link/tLmagd (accessed on 24 June 2023).
37. Medina, F.C.; Ramírez-Silva, J.P. Use of wild mammal fauna in the coffee-growing community of Cumbres de Huicicila, Compostela, Nayarit, Mexico. *Mex. J. Mammal.* **2020**, *2*, 29–42. [CrossRef]
38. Brauman, K.A.; Garibaldi, L.A.; Polasky, S.; Aumeeruddy-Thomas, Y.; Brancalion, P.H.S.; DeClerck, F.; Jacob, U.; Mastrangelo, E.; Nkongolo, N.V.; Palang, H.; et al. Global trends in nature's contributions to people. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 32799–32805. [CrossRef]
39. Rosa, H.D.; Machado, A.B.M.; Brito, M.C.W.; Alves, R.J.V.; Aleixo, A. Avifauna and ecotourism in the Brazilian Atlantic Forest: Integrating biodiversity conservation and local economic development. *Ornithol. Neotrop.* **2004**, *15*, 257–268.
40. Melgarejo, L.M. The Cultural Coffee Landscape (Paisaje Cultural Cafetero—PCC®): An exemplary project integrating ecosystem services into sustainable coffee production. In *Advances in Coffee Agronomy*; Aide, M.M., Aguirre-Gutiérrez, J., Ferreira, G.R.R., Andrade, R., Eds.; Springer: Berlin/Heidelberg, Germany, 2019; pp. 123–136.
41. Caudill, S.A.; Rice, R.A. Do Bird Friendly® Coffee Criteria Benefit Mammals? Assessment of Mammal Diversity in Chiapas, Mexico. *PLoS ONE* **2020**, *11*, e0165662. [CrossRef]
42. Apodaca-González, C.; Juárez-Sánchez, J.P.; Ramírez-Valverde, B.; Figueroa Sterquel, R. Revitalization of coffee farms through rural tourism: The case of Coatepec municipality, Veracruz. *Rev. Mex. Cienc. Agríc.* **2014**, *5*, 1523–1535. [CrossRef]