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Participatory Landscape Conservation: A Case Study of a Seasonally Dry Tropical Forest in Michoacan, Mexico

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Abstract: Participatory landscape conservation is an innovative approach that weaves theory and practice to bridge the gap between theoretical models and practical applications. Intertropical regions as the case of Mexico face challenges to conciliate regional governability, social justice, and nature conservation. The State of Michoacan is one of these regions where the challenges exacerbate since nature conservation is last due to its ongoing territorial disputes. We implemented the participatory landscape conservation approach by creating a complementary form of protected areas with ongoing conflicts, drought conditions, and extreme poverty. We conducted participatory mapping and land cover/use analyses as main methodological tools to reach consensus among stakeholders. We integrated, macro, micro and social scales to provide sound arguments to integrate local, scholar and policy makers perceptions. The outcomes of the participatory mapping analyses were assessed. The present papers provide evidence of the positive outcome of using a Participatory Landscape Conservation to establish a Biosphere Reserve, safeguarding one of the most biologically diverse and delicate ecosystems consisting of seasonally dry tropical forests within a rather disputed region. We discussed the relevance of our findings and compared them to ongoing regional and global trends in the light of other forms of establishing protected areas.

Keywords participatory science; biodiversity conservation; landscape science; Michoacán; Mexico

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Introduction

1.1. Land-based conservation

An estimated one-third of the world's population relies on forests for subsistence, while more than two-thirds rely on resources and services derived from native vegetation areas (Díaz et al. 2018). Unfortunately, natural resources are dwindling rapidly, especially in tropical areas where community identity and culture are crucial to daily life. Such regions heavily depend on livelihoods derived from their ecosystems (Curtis et al. 2018). Protected Areas (PAs) have long been considered a primary tool for preserving natural biodiversity. However, due to different cultures and contexts, the effectiveness of these areas has become contested in recent years. For example, some studies suggest that PAs may be instrumental in ensuring long-term conservation efforts (Terborgh et al. 2002). Nevertheless, other researchers argue that their failure to prevent deforestation in tropical regions is cause for alarm (Brunner 2002; Yannelli et al. 2022).

Additional research must be conducted to discover solutions that will safeguard the environment. Studies suggest that half of all PAs are inadequately managed, resulting in ecological upheaval, vegetation cover depletion, and plummeting endangered species populations (Watson et al. 2014). Shockingly, in certain circumstances, ecological destruction increased after the Protected Area was created (Liu et al. 2001). Therefore, several authors are requesting new strategies to bolster PAs performance, especially in tropical areas (Vanclay 2001; Brunner 2002), as a means of assuring that socio-geo-ecological systems and livelihoods will endure within these territories (Cumming and Allen 2017). Conservation should be done through interdisciplinary approaches (Berkes and Folke 1994; Holling and Gunderson 2002; Walker et al. 2006) where scientific and local knowledge and political wills are evenly integrated (Cash et al. 2003; Ens et al. 2012, 2015; Yannelli et al. 2022). In the face of our increasingly contested world, Bray and Velázquez (2009) proposed that a vital landscape approach should be conducted to redirect public policy decisions and financing in line with sustainability principles. Landscape approach is an ever-evolving construct comprising interactions between natural and sociocultural components. It is regulated to meet human values, such as equity and development targets, with long-term environmental repercussions (Pérez-Valladares et al. 2022). This approach aims at ensuring the sustainable utilization of existing resources while meeting societal objectives simultaneously.

1.2. Participatory science and landscape

As highlighted by Funtowicz and Ravetz (1993), the outcomes of scientific studies must abide by governance principles, forming a bond between those involved in public/civil society/citizenship matters and their institutions with ruling bodies such as government entities, private sector organizations, and related establishments. Robust codes of conduct, accountability, and effectiveness should be established to ensure sound stewardship. Such management must also be participatory and comprehensive (UNCEN 1992). As a result, stakeholders must collaborate to develop practical solutions that simultaneously address the territory's biophysical constraints and fulfill its socio-cultural expectations. Furthermore, this negotiation process is essential to effectively mediate conflicting interests on the landscape. Therefore, emphasis is placed on "pluralism" in negotiated landscapes (Wollenberg et al. 2001; Ingersoll 2003). This concept finds its best illustration in "national park" environments, where people who have been around since the beginning of these areas' conservation efforts and may still reside within them, assert their right to participate actively in their management (Bray and Velázquez 2009).

1.3. Geopolitical context

Despite representing a vital global biodiversity reservoir (Groombridge and Jenkins 2000; Sarukhán et al. 2015), tropical and intertropical countries, such as Mexico experience rapid deforestation (Velázquez et al. 2002; Figueroa et al. 2021). Mexico, as most countries worldwide, rely on Pas as a mean conserve their native genetic asset. In Mexico, 185 PAs have been established to protect biodiversity. These PAs cover 90,958,374 hectares (46.5% of the national territory), and only 11% is continental (CONANP 2022). Many PAs have been evaluated as nonfunctional in their decree objectives (Figueroa et al. 2011). In Mexico, land ownership consists of public properties that belong to the nation, individual private possessions termed small property, and ejidos and indigenous lands. These last two are classified collectively as social property or agrarian communities. Unique to Mexico, agrarian communities result from historic agricultural reforms in 1934 and 1992 that created separate forms of land ownership. As a result, a massive 102 million hectares of Mexican land are dedicated to two distinct types of property - ejidos, comprising 84.5 million ha, and indigenous communities with 17.4 million ha. It accounts for 53.4% of Mexico's total land surface (Morett-Sánchez and Cosío-Ruiz 2017). Mexico is the global leader in communal forest enterprises, with more than 80% of its forests managed by stakeholders (Thoms and Betters 1998). The highest governing body of ejidos and rural communities in Mexico is the general assembly, comprised of a commissioner, secretary, and treasurer to ensure effective management. More than 5.6 million commoners and owners raise numerous products for family use and to meet national demand - crops, livestock goods, and fodder- in more than 34,000 ejidos and communities in Mexico. They also manufacture construction materials, handicrafts, tourist services, and other items suitable for international purchase (FAO 2006). This natural asset is an integral part of the nation's capital. It provides invaluable services and resources, including its unparalleled biodiversity, carbon absorption capacity, groundwater replenishment capability, supportive ecosystem functions, regulations, and cultural heritage (Bray 2022). To our knowledge, there is scanty research that integrates political and social stakeholders to accomplish valuable long-term allies in biodiversity conservation on regions with ongoing territorial disputes (Durán et al. 2011).

1.4. Objectives

The aim of the present paper is threefold. Our primary goal was to develop an active implementation of participatory landscape conservation and use it to create a system of conservation areas in the State of Michoacan. Our second goal was to apply our initial achievement by creating a complementary form of protected areas with ongoing conflicts, drought conditions, and extreme poverty. This complementary form of protected areas should ensure maximum protection while improving marginalized communities' lives. The third objective was to evaluate the success of the complementary form of protected area fifteen years after its establishment.

2. Methods

2.1. Study area

The research took place in the State of Michoacan one of the four most biodiverse states of Mexico. It is comprised by 113 municipalities and about half of its present area is governed by agrarian communities. Gopar-Merino et al. (2015) have provided a critical review of the biophysical complexity of Michoacan and it was referred as an outstanding ecogeographical complex macroregional state.

2.2. Macroregional state level

In consensus with the Michoacan State authorities, during 2005-and 2007, we conducted a state level consultation by active participatory workshops aimed at twofold goals: 1) identification of priority areas of environmental, social, and economic importance; 2) delineation of a consensual conservation strategy. The primary sources for the active participatory workshops were maps depicting abiotic (geology, landform and soils), biotic (biodiversity), and land tenure. The main source was the Mexican mapping agency (INEGI for its Spanish acronym). Furthermore, remote sensing tools such as satellite images and aerial photographs were used in conjunction with relational databases to produce maps showcasing population size and marginalization across the state territory, as well as vegetation and land use, deforestation processes, human settlements, industrial corridors, and environmental management policies. Six workshops were conducted with three stakeholders, namely: five with agrarian communities (most importantly their authorities in turn), and one with scholars and representatives from the federal, state, and municipal governments.

Due to the extent of the macroregion and the complexity for logistics, the State of Michoacán was split into five regions on basis of accessibility and positive neighbors relationships for workshops with agrarian communities and each of these followed three stages: first, the state governor of Michoacan issued a call-to-action; second, the Ministry of Urbanism and Environment (SUMA for its Spanish Acronym) handled logistical matters; third, authors and local authorities worked together for implementing the consultation process. Participants were organized in tables (of about ten to fifteen people) where maps were overlaid covered with acetates. On their maps, participants delineated areas of socio-environmental value. After the full-day workshop, partial results of each table were presented in a collective forum. During this presentation, agreements were made on proposing protecting certain areas for conservation without jeopardizing ongoing of future development projects.

The sixth workshop was attended by scholars from various backgrounds, including the natural, social, and humanities sciences in one room and split into interdisciplinary tables. Simultaneously, in another room representatives from municipal, state and federal government entities also conducted the same exercise. This workshop featured the same components as its regional counterparts, although with a heightened focus on delineating agreement among areas of immense socio-environmental merit. To maximize the effectiveness of this sixth workshop, a minimum mappable area was determined (100 hectares for maps at 1:250,000 scale). Additionally, preliminary

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data on biological richness (e.g., Cruz et al. 2019), climatic variability (e.g., Gopar-Merino et al. 2015), and vegetation diversity (e.g., Velazquez 2021) were provided in combination with geographical proximity to production systems (e.g., avocado plantations) and human settlements. At the end, groups of the two rooms were gathered together to review their outcomes collectively.

Outcomes of the six workshops were integrated using a Geographic Information System by overlapping all delineated areas on a raster map of cells of one squared kilometer. Each cell (pixel) was given a weight accordingly to the number of times it was selected by one of the stakeholders. Cells with less than three nominations out of the six workshops were not included in the second phase of the integrated analyses. In the second phase, assessment of contiguity, connectivity, fragmentation was computed so that cells most isolated (total distance to the next group of cells) and small (number of cells clustered together) were also pondered as second priority. This preliminary second phase weighted outcome was presented to municipal, state (Governor and Minister of Environment of the State) and federal authorities (National Commissioner of Protected areas of Mexico) so that a final decision was made to define a so-called the State System of Conservation (SSC). Policy makers pointed out that one of the areas of the SSC located in the tropical dry ecosystem was to be further evaluated for its social, cultural, environmental and political relevance.

2.3. Microregional level

The zone number 16 (Figure 1) on the SSC was pinpointed by the state and federal authorities as the region to further explore willingness for establishing a protected area. This region referred as Zicuirán-Infiernillo is one the most diverse and extended tropical dry forest, it faces high social complexity and governability; and it is regarded as vulnerable to climate change. Zicuirán-Infiernillo regional comprised parts of Huacana, Arteaga, and Churumuco municipalities, and most of the Infiernillo Dam that happens to produce about 25 % of Mexico's electricity of all hydroelectrical dams (Ramos-Gutiérrez and Montenegro-Fragoso 2012).

To organize the public consultation in the assemblies of the agrarian communities, an intergovernmental group was formed by Arteaga, Churumucao, and La Huacana City Council members, five state government entities led by the Ministry of Environment of Michoacan, the National Commission of Protected Areas, and the authors of the present paper. The group held seven meetings to discuss how to present, disseminate, and eventually engage civil society, agrarian communities, and non-government organizations (NGOs). Three steps were considered prior to the consultation:

1.- Enrollment of active NGOs that have played an important role in making aware local inhabitants of their land's natural values (e.g., The Community Biodiversity Conservation Program, the Project for the Conservation and Sustainable Management of Forest Resources, El Bajo Balsas of the Non-Governmental Organization).

2.- Preparation of detailed cartography at a medium scale (1:100,000 and 1:50,000) to illustrate the agrarian community's interconnectedness of their lands in various basins and sub-basins (water is a critical resource in the region), land cover, land use, human settlements, primary and secondary roads, and boundaries of agrarian communities.

3.- Planning open public consultations to include small landowners, experienced service providers, ejido counselors, and livestock associations.

The consultation process took place from February to July 2007, and it was conducted in presentations in general assemblies of the 64 agrarian communities identified with legal jurisdiction within zone 16 of the SSC. Due to boundary disputes, the National Agrarian Registry's boundaries were not displayed on maps during presentations in assemblies when two a more agrarian communities were participating. The goals of each assembly focused on approval for adding an agrarian community as part of the ongoing construction of the Zicuirán-Infiernillo Biosphere Reserve (hereafter as ZIBR), as well as exploring their willingness to become part of the core zone (area uniquely used for biodiversity conservation purposes). Agreements of the assemblies were stated in minutes (official debriefings) so that collective decisions were backed up legally.

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2.4. *Efficiency assessment of the Zicuirán-Infiernillo Biosphere Reserve*

To assess the efficiency of the ZIBR, we conducted landcover/use change analyses by crossing two databases of different years (2005 and 2021). The established polygon of the ZIBR and its peripheral (buffer) zone (an adjacent area delimited by the National Commission of Protected Areas) were combined to assess the regional landcover/use trends.

We used as baseline (database T1) the National Institute of Statistics and Geography (INEGI) series III of 2005 (scale 1:250,000) as the year just previous to the establishment of the ZIBR. T1 database was constructed by the visual analysis of Landsat 7 images and comprised land use and vegetation formation classes. The labels used for these classes and their distribution patterns were confirmed during on-site inspections in 2007 and supplementary aerial images. A thorough description of the integration, correction, and compilation of T1 database was given by Cuevas and Mas (2008).

The T2 database featured vegetation formations (scale 1:100,000), and it was obtained from the automated classification of SPOT images from 2018 and further verified through field research during 2020 and 2021, which included sampling tree species, according to Velazquez et al. (2021) and Rangel-Landa et al. (2022). A scale of 1:250,000 was used to ensure that the two databases (T1 and T2) were compatible. Additionally, the minimum mapping area was set to be at least one km^2; thus, all polygons smaller than one km^2 had to be merged with the largest adjacent polygon for compatibility.

We reclassified T1 and T2 databases into three distinct cartographic classes: temperate dry forests, tropical dry forests, and cultural land use types. This latter class included crops, settlements, and livestock grazing areas where native vegetation was not predominant. Water bodies were kept as one stable land cover. We overlapped T1 and T2 databases by layering them onto a geographic information system and analyzing shifts and patterns across different periods following the procedure described by Velázquez et al. (2003b). We then computed yearly rate of changes among classes by using the method described by Velázquez et al (2002).

3. Results

3.1. *The State System of Conservation*

In the Macroregional level, two hundred ninety-eight people attended the six workshops, and 2,659 surveys were collected from those who could not participate After executing surveys and workshops, we mapped out 18 initial areas, covering 10,399 km^2 or about 18% of the landmass of Michoacan (Table 1). The SSC surpasses the combined federal and state protection efforts by ten times (Figure 1). This result combines bottom-up and top-down participatory processes, where social actors are the catalysts for defining, limiting, and managing potential regions to become protected areas.

Table 1. Eighteen areas were determined through a consensus of 95% agreement between the three social sectors participating in consultations and workshops. The Protected Areas column denotes those that have been legally set aside and encompass, to a full or partial extent, the objectives of this academic exercise.

		Michoacan		**Established protected areas by 2014**	
Number on map	Areas	Surface (Km^2)	%	Surface (Km^2)	%
1	Cuitzeo-Copandaro	421.52	0.71	2.54	0.02
2	Monarch Butterfly Biosphere Reserve	562.79	0.95	562.79	5.37

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3	Tiquicheo-Tzitzio-Madero	546.14	0.93	0.00	0.00
4	Morelia-Tzitzio	540.64	0.92	66.59	0.64
5	Madero-Tacambaro	317.19	0.54	0.77	0.01
6	Opopeo	244.18	0.41	0.00	0.00
7	Pico de Tancítaro	1,193.98	2.02	222.22	2.12
8	Parque Nacional Lago de Camecuaro	0.11	0.00	0.11	0.00
9	Los Reyes	206.49	0.35	0.00	0.00
10	Parque Juárez de Jiquilpa	0.08	0.00	0.08	0.00
11	Coalcoman	1,110.34	1.88	0.00	0.00
12	Chinicuila-Coahuayana	1,615.54	2.74	33.94	0.32
13	Aguililla-Coalcoman-Tumbiscatio	649.26	1.10	0.00	0.00
14	Playa Mexiquillo	31.35	0.05	31.35	0.00
15	Arteaga	241.73	0.41	0.00	0.00
16	La Huacana-Churumuco-Artega	2,418.77	4.10	0.00	0.00
17	Huetamo-Turitzio	298.40	0.51	0.00	0.00
18	Chorros del Varal (Los Reyes)	0.73	0.00	0.73	0.01
Total		10,399.24	17.63	921.13	8.79

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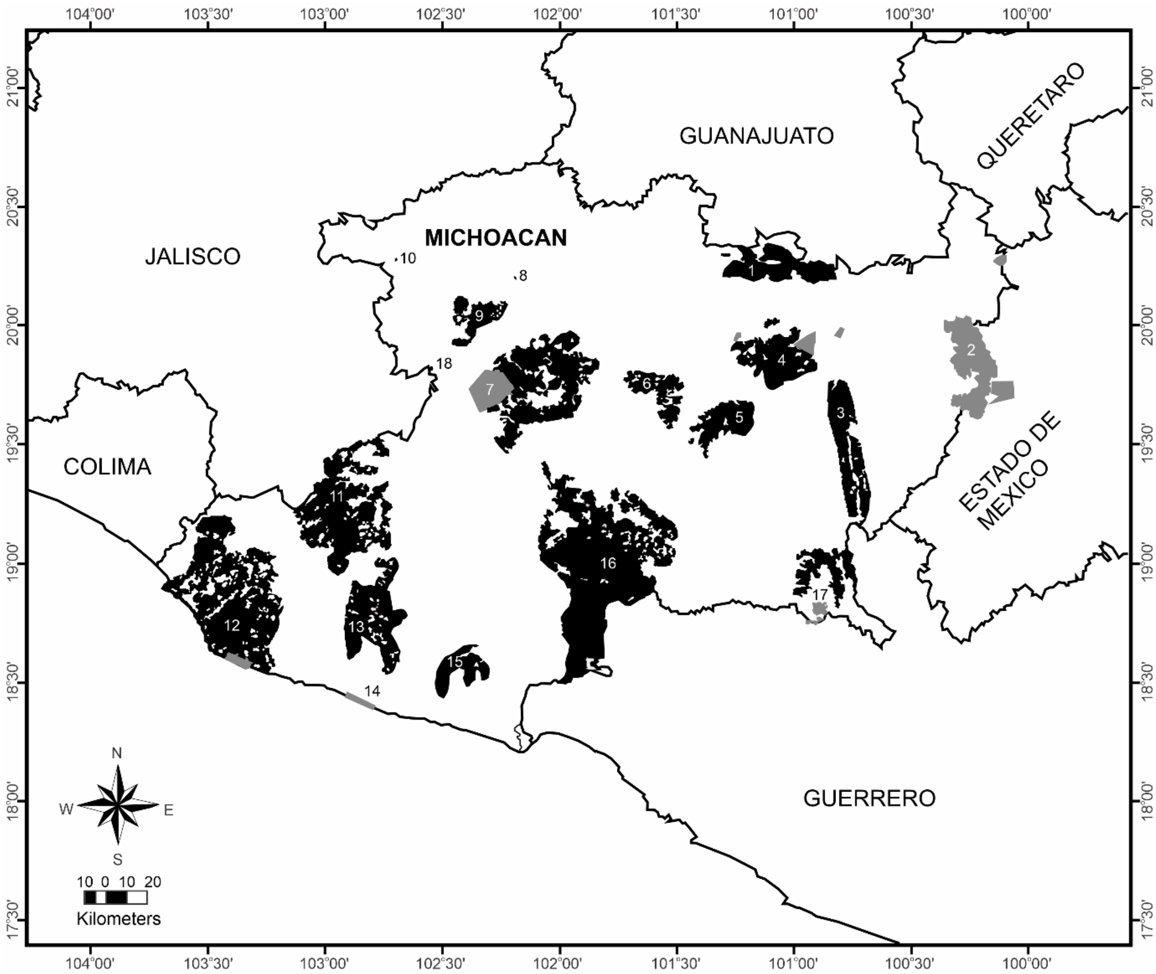

Figure 1. Reconciled areas from consultation among civil society and rural communities, academic circles, and government institutions. Numbers 16 became a priority because of its biocultural nature, and it was chosen as the target area to explore further participatory conservation.

Our research into participatory landscape conservation unveiled the fact that eight of the eighteen designated territories (illustrated in Table 1: 3, 6, 9, 11, 13, 15, 16, and 17) had never been taken into consideration for conservation. The Monarch Butterfly Biosphere Reserve (No. 2) and the Pico de Tancítaro Flora and Fauna Protection Area (No. 7), both temperate ecosystems, are currently at the heart of highly contested social disputes. Despite their ecological relevance, numbers 8, 10, 14, and 18 were relatively small areas to be considered as priorities at the state level. Numbers 11, 12, and 13 comprised outstanding biodiversity, yet these are currently ongoing social disputes, so environmental considerations are not at the top of the agenda for municipal, state, and federal governments.

3.2. Zicuirán-Infiernillo Biosphere Reserve consultation

A total of 115 assemblies were conducted in six municipalities and 64 agrarian communities with the participation of 1,999 ejidatarios (members of the agrarian communities with legal rights for land tenure). Sixty out of the 64 outvoted the other submissions to support the creation of a new biosphere reserve with signed assembly minutes. Out of the 60 agrarian communities, only 26 have agreed on establishing a portion of their land as a core zone, which implies no human action other than biodiversity conservation. For a comprehensive overview of the rural communities' name, municipality, proposed and agreed-on core zones, and agreement instrument, please refer to Appendix A1.

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After a thorough assessment, it was decided that 265 thousand hectares of land should be allocated in the Arteaga, Churumuco, Huacana, and Tumbiscatío municipalities. This area would encompass four core zones spanning 22 thousand hectares and an additional 189 thousand hectares buffer zone. Sixty agrarian communities and 134 small owners joined this conservation proposal. On November 30, 2007, the Zicuirán-Infiernillo region was officially established as a Biosphere Reserve (SEMARNAT-CONANP 2014).

3.3. Biosphere reserve model efficiency

In 2005 (T1), most of the region was covered by tropical dry forest (71.56% or 317,888 hectares). Cultural land use types accounted for 19.77%, while temperate dry forest comprised 4.79%. By 2021 (T2), the tropical dry forest had significantly increased its surface by 10%, expanding to 360,781 hectares (81.22%). On the other hand, cultural land use declined to 48,202 ha accounting for 10.85%; whereas temperate dry forests almost remain even since changes accounted for less than one percent (Figure 2).

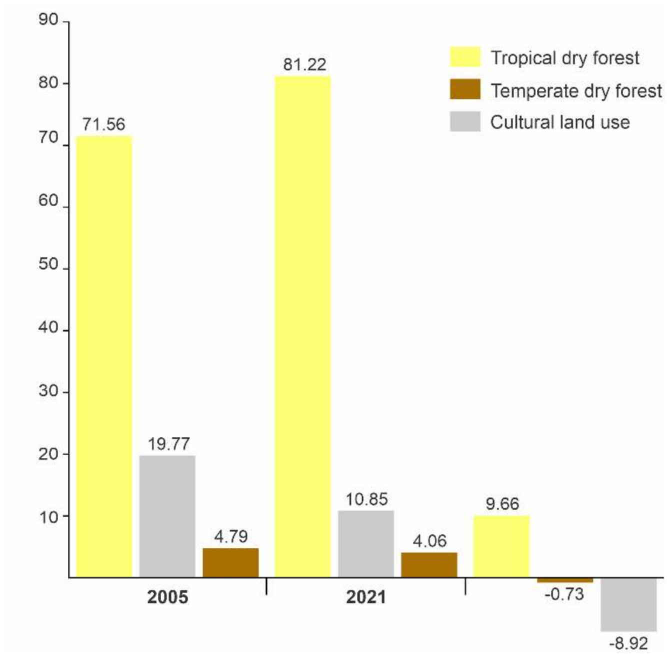

Figure 2. Conversion data among land cover classes. Tropical dry forests have increased by about 10% on their surface over 15 years within the Zicuirán-Infiernillo Biosphere Reserve and its buffer zone. Most of the increase occurred due to cultural land use, whereas changes in temperate dry forests have been negligible.

The participatory landscape conservation approach allowed us to reveal spatially explicit conversion processes (Figure 3) expressed in annual rates of change (Figure 4). Protected area establishment, however, may not be held accountable for these results alone. Factors such as territorial disputes, outmigration, and extreme drought effects have all contributed, although these have not been thoroughly studied yet.

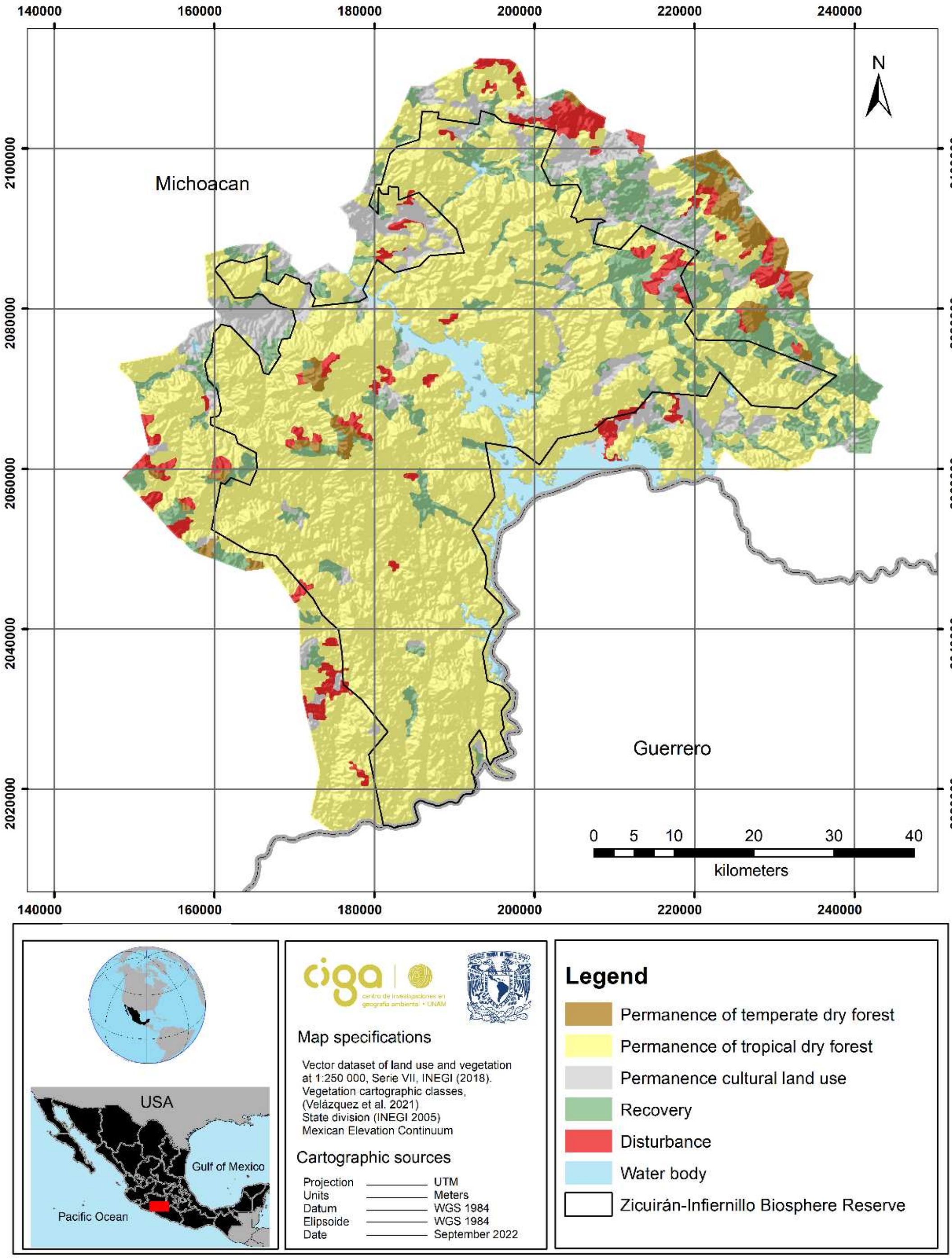

Figure 3. Spatially explicit conversion processes occurred in the entire region and within the Zicuirán-Infiernillo Biosphere Reserve. The green areas depict polygons where recovery from cultural land uses turned into tropical dry forests, in contrast to red polygons labeled as Disturbance, where the opposite land cover change occurred.

The changes depicted in the conversion processes map (Figure 3) were field-cross-checked with the aid of the director of the protected area (Hugo Zepeda). The current maps help him to share with the rural communities to find triggers of positive or negative trends. Transition trends were also calculated, as shown in figure 4, where the annual rate of changes is indicated. This information was crucial for managing the protected area because transition matrices were requested per municipality to design sound land-based oriented public policies. These include different incentives for those rural communities that have promoted the recovery of the native tropical dry forests in contrast to the ones that have not.

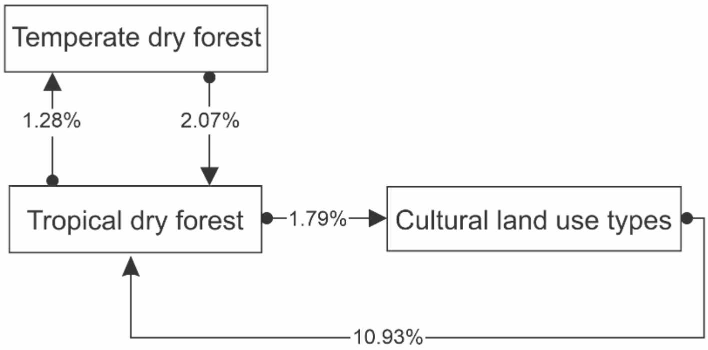

Figure 4. Land use transition matrix (T1=2005, T2= 2021). Annual rates of change depict yearly transformation trends from one class to another. Conversion between forest types is relatively stable compared to the recovery speed observed in converting cultural land use types into tropical dry forests. Values below one percent were regarded as negligible.

4. Discussion

4.1. Multiscale integration

The State System of Conservation for Michoacan derived from a participatory exercise that brought environmental perceptions of stake-right-land-holders. The Michoacan governor at the time (Lázaro Cárdenas Batel) and his team understood the need to develop an extensive consultation. The leading participation of public universities (in this case, Universidad Nacional Autónoma de México and Universidad Michoacana de San Nicolás de Hidalgo) provided trustable grounds to have everyone on board during workshops. One example to reveal the relevance of the neutral ground of the call made by universities happened in Aguililla Municipality, where even violent organized groups could express their views since they had traffic control in specific areas, so small polygons were consensually appointed as relevant for conservation without jeopardizing local interests. Agrarian communities delineated small, specific well-located areas. In contrast, scholars, knowledgeable about the natural richness of Michoacan, insisted on selecting large conservation areas so that integral biocultural attributes may be protected. As a result, scholars delineated about 70% of the whole surface of the State of Michoacan. Overall, overlapping common interests became a powerful negotiation tool so that all "holders" became aware of the 18 areas depicted as potential for biocultural conservation policies.

Regional participatory experience in Huacana, Churumuco, and Arteaga municipalities was initially considered a burden. The first assemblies resulted in disputes among participants, sometimes claiming rights over their neighbors. At the local scale, people believe their area is more significant and affluent than one of their neighbors. To avoid that, local maps at the rural community level were prepared so that no comparisons could happen during assemblies and workshops. Nonetheless, 115 assemblies to engage 60 rural communities were needed to establish the Zicuirán-Infiernillo Biosphere Reserve (ZIBR) in Michoacan. This became a powerful platform to protect, conserve, and manage its natural resources. The abundant tropical dry forests in the ZIBR are a richly diverse ecosystem of many endemic species at risk due to human interventions. Hugo Zepeda, ZIBR Director, commented recently, "…the outcomes of the participatory approach have been remarkably positive and striking, and this area has proven resilient in the face of significant disruptions". Utilizing the participatory landscape conservation strategy, peasants, local governments, producer organizations, and land management groups could join forces to achieve a unified regional goal. Establishing un-consensually protected areas has often triggered disputes rather than safeguarding long-term ecosystem processes (e.g., Figueroa et al. 2011; Brechin et al. 2012). A sound progress assessment of the ZIBR's performance was needed to provide evidence of its significance. This

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contribution revealed that native tropical dry forests are increasing their surface so that participatory environmental public policies have proven more efficient.

The last yearly assessment (2022) conducted by Hugo Zepeda Castro, Director of the Zicuirán-Infiernillo Biosphere Reserve, concluded that a synergistic effect exists between encouraging people to abandon agricultural lands and subsequent recovery of dry tropical forests. "All agrarian communities are different, yet two reasons presented themselves again and again: government disruptions due to organized crime taking over critical spaces, combined with a lack of support when faced with extreme weather conditions that adversely affect the productivity of their operations. Land fallows are then not always a result of pure environmental concern. Nowadays, the "Sembrando Vida" (https://programasparaelbienestar.gob.mx/sembrando-vida/) new policy targeted at supporting peasants to engage them in productive rural landscapes seems offering positive results; however, the extent of its impact is yet to be ascertained.

4.2. From state to national scale

In Mexico, as in most hot spot countries, this participatory landscape approach seems promising for melding together ideas and perspectives by stakeholders to formulate and execute environmental public policies. This strategy aims at engaging local players as allies in protecting their heritage; thus, their land holds more cultural and environmental values. This strategy was crafted to prevent social problems from being implemented and managed without prior discussion (Maldonado et al. 2018). A legitimate validation process needed to occur due to the constant territorial disputes in Michoacan. We can illustrate this with the Mexican Monarch Butterfly Biosphere Reserve, where academics and conservationists are behind its establishment. However, local actors were not on board with the original initiative, and current disputes persist despite the biological importance and outstanding budget allocated. At "El Vizcaíno" Biosphere Reserve in Baja California Sur, researchers concluded that its destiny relies upon a consensual governance regime.

According to Brenner and De la Vega (2014) and Rosete et al. (2014), the concept of a Biosphere Reserve can be relatively inclusive with significant potential for success. However, the redefinition of participation must be reviewed (e.g., Durand and Jímenez 2010). Mexican authorities launched an internet consultation before establishing a new protected area. Government consultation disregards that most local rural communities are not connected to the Internet, so regional agrarian conflicts are recurrent.

According to Kolb et al. (2013), solutions for sound environmental policies must be intricated due to the multi-leveled scope of institutional and geographical elements when approaching issues holistically. Thus, forming alliances and agreements is essential to establish collaborations and interventions (Velázquez et al. 2003a; Bray, 2022). According to López-Martínez and Cuanalo de la Cerda (2020), training in accounting public administrators can be instrumental in strengthening the community's ability to come together and successfully handle any identified disputes. Salas et al. (2015) analyzed participation in conservation activities between two neighboring communities in Baja, California, over ten years. Surprisingly, they found that prior experience with travelers and tourist-related development agents and temporary migration to vacation spots fostered engagement in sustainability practices and the launch of community initiatives to safeguard marine areas essential for fish reproduction. A digital atlas was created to evaluate resilience and formulate plans by actively engaging the community in research. In addition, local leaders were trained on how to use this resource effectively.

4.3.(. Inter)tropical outreach

Extensive research has demonstrated the benefits of a cyclical approach to enhancing resilience, which includes recognizing problems, brainstorming solutions with stakeholders, assessing responses, and making modifications as needed. By relying on this systematic process of constant improvement and iteration, meaningful progress can be made toward boosting landscape resiliency. With the imminent risks to food security and sovereignty, human health, biodiversity conservation, and ecosystem services in mind, indigenous and mestizo communities should be considered allies to seek alternative solutions. We must bear in mind that environmental public policies detached from other local social matters are meaningless. Climate change, one health, social security, education, cultural identity, and territorial governance are closely connected to the environment (Cumming and Allen 2017; Curtis et al. 2018; Díaz et al. 2018). Therefore, constructing effective environmental solutions requires a holistic place-based perspective that considers these aspects of achieving complete success. Overlooking this complexity implies a misjudgment of human understanding, yet articulation remains challenging in the face of new geopolitical realities.

Author Contributions: Neyra Sosa conceived the research framework, collected data, conducted social consultation, wrote a preliminary manuscript, and led the field research. Alejandro Torres contributed to the research framework, collected data, and conducted social consultation. Valerio Castro-Lopez performed statistical and geographical analyses and reviewed the last versions of the present paper. Alejandro Velazquez conceived the research framework collected data, performed statistical analyses, wrote the paper, and led the contribution of all authors.

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Appendix A

The table includes each agrarian nucleus's name, municipality, assemblies' dates, and meetings held to discuss core zones and agreements. After reviewing the 64 nuclei, four ultimately chose not to join the Biosphere Reserve by collective decision.

ID	AGRARIAN COMMUNITY	MUNICIPALITY	DATE OF THE ASAMBLIES (S)	CORE ZONE FIRST PROPOSAL	CORE ZONE SECOND PROPOSAL	CONSENSUAL CORE ZONE	MEAN OF AGREEMENT
1	AGUA NUEVA	CHURUMUCO	05 OF MAY 26 OF MAY	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
2	ARRONJADERO	LA HUACANA	15 MARCH 04 OF MAY 11 OF MAY	X			ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
3	CAJA DELA ZICUIRAN	HUACANA	4 OF MARCH	X			ASSEMBLY MINUTE
	CAYACO	LA HUACANA	11 OF MARCH 29 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE

4	CERRO DE LA LUMBRE	ARTEAGA	14 OF APRIL	X			ASSEMBLY MINUTE
5	CHURUMUCO Y ANX. LAS PILAS Y TIMBIRICHE	CHURUMUCO	6; 14, 16 OF MARCH 5 OF APRIL 28 OF APRIL		X		ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
6	COL. FRANCISCO VILLA	LA HUACANA	25 OF MARCH 1 OF APRIL	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
7	COLONIA LAZARO CARDENAS	LA HUACANA	11 OF MARCH	X	X	X	ASSEMBLY MINUTE
8	CONGURIPO	LA HUACANA	19 OF MARCH 25 OF MARCH 1 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
9	CUIMBO Y ANX.	LA HUACANA	1ª. 2 MARCH 2ª. 29 APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE
10	CUNUATO	CHURUMUCO	15 OF APRIL 13 OF MAY 2 OF JUNE 6 OF JUNE	X			ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
11	DOTACION CUERAMATO	CHURUMUCO	31 OF MAY	X			ASSEMBLY MINUTE
12	EL AHUIJOTE	CHURUMUCO	27 OF MAY	X			ASSEMBLY MINUTE
13	EL ALGODÓN Y OROPEO Y ANX.	LA HUACANA	5 OF MARCH	X		X	ASSEMBLY MINUTE
14	EL CASCALOTE	ARTEAGA	11 OF APRIL 15 OF APRIL	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
15	EL CHAUZ	LA HUACANA	11 OF MARCH 25 OF MARCH 4 OF MARCH	X			ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
16	EL CHILAR	LA HUACANA	27 OF APRIL	X			ASSEMBLY MINUTE

17	EL PALMAR Y ANX. (MESA DE VICENTELO PUERTA)	LA HUACANA	9 OF MARCH 28 OF APRIL	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
18	EL SAUZ	ARTEAGA	14 OF APRIL			X	ASSEMBLY MINUTE
19	EL TERRERO	LA HUACANA	14 APRIL	X	X	X	ASSEMBLY MINUTE
20	GENERAL LAZARO CARDENAS (CIRIANCITOS)	LA HUACANA	4 OF MARCH 1 OF APRIL 7 OF APRIL	X			ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
21	GUADALPE OROPEO Y ANX. LAS CRUCECITAS	LA HUACANA	1 OF MARCH 4 OF MARCH	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
22	HUATZIRAN Y ANEXOS (LAS VACAS Y LOS PLACERES)	LA HUACANA	18 OF FEB. 6 OF MARCH 22 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
23	ICHAMIO Y ANX. EL TIZATAL	LA HUACANA	4 OF MARCH	X	X	X	ASSEMBLY MINUTE
24	LA HIGUERITA Y ANX. (EL PASEO)	CHURUMUCO	26 OF MAY				ASSEMBLY MINUTE
25	LA HUACANA	LA HUACANA	22 OF MARCH 15 OF APRIL 22 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
26	LA LOMA	CHURUMUCO	11 OF APRIL				ASSEMBLY MINUTE
27	LA PAREJA	ARTEAGA	11 OF APRIL	X			ASSEMBLY MINUTE
28	LA PITIRERA	ARTEAGA	14 OF APRIL			X	ASSEMBLY MINUTE ASSEMBLY MINUTE
29	LA VINATA	ARTEAGA	1 OF APRIL	X	X	X	ASSEMBLY MINUTE
30	LAS ANONAS Y ANX.	LA HUACANA	29 OF APRIL	X			ASSEMBLY MINUTE
31	LAS CARAMICUAS	TUMBISCATIO	27 OF MAY	X			ASSEMBLY MINUTE

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			3 OF JUNE 9 OF JUNE				ASSEMBLY MINUTE ASSEMBLY MINUTE
32	LAS CRUCES	TUMBISCATIO	27 OF MAY 3 OF JUNE 9 OF JUNE		X		ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
33	LAS ESTANCIAS	LA HUACANA	10 OF MARCH 20 OF MARCH	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
34	LAS PILAS	CHURUMUCO	26 OF MAY		X		ASSEMBLY MINUTE
35	LAS TAMACUAS	LA HUACANA	28 OF APRIL 4 OF MAY		X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE
36	LIMON DE JORULLO	LA HUACANA	13 OF APRIL	X		X	ASSEMBLY MINUTE
37	LLANO DE OJO DEAGUA	CHURUMUCO	5 OF MAY 19 OF MAY				ASSEMBLY MINUTE ASSEMBLY MINUTE
38	LOS CHIVOS Y ANX.	TUMBISCATIO	9 OF JUNE				ASSEMBLY MINUTE
39	LOS COPALES Y ANX.	ARTEAGA	28 OF APRIL			X	ASSEMBLY MINUTE
40	LOS CUERAMOS DE LA VINATA		1 OF APRIL	X		X	ASSEMBLY MINUTE
41	LOS HORCONES	ARTEAGA	1 OF APRIL	X			ASSEMBLY MINUTE
42	LOS OLIVOS	LA HUACANA	1 OF MARCH	X			ASSEMBLY MINUTE
43	LOS POCITOS	LA HUACANA	6 OF MARCH 27 OF MARCH 1 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
44	MANGA DE CHAVEZ ANX. (EL PALMARCITO Y LA CRUCITA)	LA HUACANA	29 OF APRIL				ASSEMBLY MINUTE ASSEMBLY MINUTE
45	MANGA DE CUIMBIO	LA HUACANA	11 OF MARCH	X	X	X	ASSEMBLY MINUTE

			13 OF APRIL				ASSEMBLY MINUTE
46	MELCHOR OCAMPO	CHURUMUCO	6 OF MAY 20 OF MAY	X	X		ASSEMBLY MINUTE ASSEMBLY MINUTE
47	N.C.P. CUERAMATO	CHURUMUCO	31 OF MAY				ASSEMBLY MINUTE
48	N.C.P.ARTEAGA. LA ESTANCIA OLA BELLAS FUENTES Y ANX.	LA HUACANA	24 OF FEB 11 OF MARCH. 28 OF MARCH 20 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
49	N.C.P.E. ESFUERZO DEL CAMPESINO	LA HUACANA	4 OF MARCH 11 OF MARCH 6 OF MAY	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
50	PALMA, PALMA DE GUARO Y ANX. (LA CALERA, COPALITOS)	CHURUMUCO	6 OF MAY 12 OF MAY	X			ASSEMBLY MINUTE ASSEMBLY MINUTE
51	PIEDRAS NEGRAS	LA HUACANA	4 OF MARCH 06 OF MAY				ASSEMBLY MINUTE ASSEMBLY MINUTE
52	PINZANDARAN	ARTEAGA	1 OF APRIL		X	X	ASSEMBLY MINUTE
53	PUEBLO VIEJO	LA HUACANA	14 OF APRIL	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE
54	SAN FRANCISCO DE LOS RANCHOS	LA HUACANA	24 OF FEB 24 OF MARCH	X		X	ASSEMBLY MINUTE ASSEMBLY MINUTE
55	SAN ISIDRO Y LOS ADOBES	LA HUACANA	18 OF FEB	X			ASSEMBLY MINUTE
56	SAN JOSE DEL MILAGRO	ARTEAGA	12 OF APRIL	X		X	ASSEMBLY MINUTE
57	SIN AGUA	LA HUACANA	1 OF FEBRERO 28 OF FEBRERO 19 OF MARCH	X			ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE

58	TOLUQUILLA	ARTEAGA	14 OF APRIL 28 OF APRIL 1 OF JUNE		X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE ASSEMBLY MINUTE
59	VILLA HERMOSA	LA HUACANA	28 OF APRIL	X			ASSEMBLY MINUTE
60	ZICUIRAN	LA HUACANA	4 OF MARCH 10 OF MARCH	X	X	X	ASSEMBLY MINUTE ASSEMBLY MINUTE
61	EL CAPIRE DE OROPEO	LA HUACANA	29 OF APRIL	X			NONE
62	GRACIANO SANCHEZ	TUMBISCATIO	8 OF JUNE				NONE
63	LOS COPALES	ARTEAGA	28 OF APRIL		X		NONE
64	LOS LIMONES Y LOS ANEXOS (ELLA CHUPADERO Y LOS BARRILLOS)	HUACANA	17 OF MARCH 9 OF JUNE	X			NONE

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