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Prioritization for the conservation of Mexico's cloud forests

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ABSTRACT

Cloud forests are ecosystems with a restricted distribution and high biodiversity, but they are highly threatened due to land use change. The objective of this study is to evaluate and prioritize existing cloud forest fragments to achieve their long-term conservation, combining threat levels and the potential response capacity of various conservation instruments in Mexico, through a triage tool. Threat levels were calculated based on human disturbance coverage, estimated specifically for Mexico. The response capacity was estimated using the presence of the different conservation instruments in each fragment. Once the triage level per fragment was obtained, these were analyzed by ecoregion. The results showed that the area of primary cloud forest has been reduced by 53–73%, and only 31.6% (including primary and secondary forest) is under some protection scheme. We identified a group of fragments on the Pacific slope that require special attention due to the small coverage and their high level of priority. The ecoregions: Sierra Madre del Sur of Guerrero and Oaxaca, Los Altos de Chiapas, Sierra Madre Oriental and Central Mexico corresponding to the largest concentration of cloud forest in the trans-Mexican volcanic belt, 70% of which are listed as a priority for emergency protection.

Keywords: Biodiversity; Government Protected Natural Areas; Social Instruments for the Conservation and Sustainable Use of Biodiversity; Montane Mesophyll Forest; Ecoregions

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1. Introduction

One of the ecosystems that harbors the greatest biodiversity in Mexico is found in the montane forests of the intertropical zone in the form of discontinuous patches with limited extension[1-3]. This ecosystem is generally called "montane mesophyll forest" (MMF) in reference to the mesophilic characteristics of the leaves of the dominant tree species and the physiographic zone in which it is found[4,5]. Under this name we find a heterogeneous set of ecological communities, as they constitute a complex transition between lowland communities and those that develop at higher altitudes[6,7]. The heterogeneity of this set of communities is reflected in the variety of names by which they have been referred to in the literature, such as deciduous temperate forest[8], cloud forest[9], montane rain forest[10], fog forest[11], and montane mesophyll forest[4,12,13], to mention a few.

In spite of the wide variation in the names used to refer to these ecological communities, they are unified by the characteristics of the climate where they develop, by the physiognomy and floristics of the vegetation[14]. This type of vegetation (**Figure 1**) develops in places where the mean annual temperature is between 12 and 23 °C, with a mean annual precipitation of not less than 1,000 mm, but reaching 3,000 mm and in some areas even more than 5,000 mm[15]. This indicates that it can be found in temperate or tropical climates with or without seasonality in precipitation[4]. Physiognomically, these forests are characterized by a great diversity of plants and a diversity of both vascular and non-vascular epiphytes[16,17]. In Mexico, in terms of floristic composition and number of species, there are important differences among authors. For example, González-Espinoza and collaborators[2,18] have described between 2,500–2,822 species, 650–815 genera and 144–176 families typical of this type of vegetation; highlighting the Lauraceae family and the Quercus genus as the best represented. On the other hand, Villasenor[7] mentions that in this type of forest there are at least 6,790 species belonging to 1,625 genera and 238 families of vascular plants. Of these, 2,361 species are endemic to Mexico. However, the main unifying characteristic is the constant or at least frequent presence of fog in the mountains where they develop[11]. In this context, without leaving aside the rest of their characteristics and complexity, it is more appropriate to call them cloud forests[1,2].

In the global context, cloud forests are rare. For example, it is estimated that they occupy about 0.26% of land area and 2.5% of the world's tropical forests[19]. In general, we can say that they are considered a priority worldwide both because of the small area they cover, as well as their distribution in relatively isolated fragments, but above all because of their unique particularity of capturing and filtering water through horizontal precipitation[20]. However, although in some places the cloud forest is maintained as such (Mexico is no exception), the surrounding matrix of tropical rainforests and temperate forests is not given the same priority. This could result in the elevation of the altitude at which clouds develop, causing the moisture of the forest floor to decrease with negative consequences for diversity (e.g. Anchukaitis and Evans[21]). Also, due to the close dependence on moisture in the form of both clouds and precipitation, these forests are particularly vulnerable to global climatic changes[22,23].

Figure 1. Examples of cloud forests of Teipan (upper left corner), Roayaga (lower left corner) and Sierra de Juárez (right); all from Oaxaca, Mexico. Photos: N. Mejía-Domínguez (Teipan) and L. Canseco-Márquez (Roayaga and Sierra de Juárez).

The combination of environmental factors that favor the development of a cloud forest can be found in all the montane regions of Mexico, depending on the altitude, between 600 and 3,200 m a.s.l.[5]. The distribution of cloud forests includes discontinuous regions of the montane zones of the Sierra Madre Oriental, Sierra Madre Occidental, Sierra Madre del Sur, Sierra Norte de Oaxaca, Faja Volcánica Transmexicana and Sierra Madre de Chiapas[24-26]. This distribution is the result of a complex biogeographic history and the environmental heterogeneity of the places where it is found[26,27]. These characteristics are considered to be the main causes of the great diversity of species and endemisms they harbor[3,28]. The high incidence of endemic species, as well as species of restricted distribution, attributes to highlight of cloud forests. A particularly interesting example is the tiny salamanders of the genus thorius. This genus is endemic to Mexico and has 23 restricted distribution species associated with the cloud forest. In addition, recent studies show that there is a distinct phylogenetic lineage of salamanders for virtually every cloud forest region[29]. In this context, the results of analyses to study the relationships of these areas indicate precisely that the evolutionary history of contemporary cloud forest lineages is complex. Although there are general patterns of vicariance, cloud forests have different biogeographic-evolutionary histories, making each of their areas unique and of great importance for conservation[28-31].

Unfortunately, cloud forests are also characterized by a high loss of vegetation cover and a high incidence of other economic activities that modify their structure and species composition[32]. Globally, land use change is one of the greatest threats to biodiversity, and cloud forests are no exception. It should be noted that the loss of cloud forest area implies the loss of all ecosystem services, particularly hydrological services, provided. For the year 2007, it was reported that 71.5% of the primary cloud forest area remained of the 11,885 km^2 that existed in 1976. In addition, the area covered by secondary cloud forest increased by 52.7%[33]. Undoubtedly, estimating the area covered by this type of vegetation represents a challenge. But assessing the degree of conservation of the remaining fragments is no less complicated[34,35]. In addition to these evaluations, conservation planning for cloud forests requires determining the degree of threat to them, and a good approximation is the level of human disturbance[25,36]. The only way to counteract these threats is conservation strategies. Bezaury-Creel and Gutiérrez-Carbonell in 2009[37] reported that of the more than 18,000 km^2 of cloud forest (primary and secondary) in Mexico, only 1,543 km^2 were under some conservation status. The case of cloud forests is not particularly encouraging and highlights the absence of conservation strategies, especially in the long term. In this context, our objective was to prioritize cloud forest fragments for long-term conservation, combining threat levels and the potential response capacity of conservation instruments located in each fragment. A triage tool was used for this purpose. This tool assigns each fragment a level that allows us to determine the most appropriate actions to follow in terms of conservation costs. Finally, considering the unique history of each of the cloud forest areas and the values obtained through the triage tool, the representation by ecoregions was evaluated to establish priority sites for conservation and propose strategies for their long-term protection.

2. Material and methods

2.1 Spatial data (vegetation coverages)

The vegetation layers generated by the National Institute of Geography and Statistics of Mexico (INEGI) were used. To date, INEGI has published 5 Series of vegetation types: I, II, III, IV and V in chronological order. The set of land use and vegetation layers Series I was published in 1993[38] contains information from 1968–1986. Series II[39] contains information from 1993–1996. Series III was published in 2005, Series IV in 2010[40] and Series V[41] contains information from 2011. For each layer, satellite images were used, mostly Landsat (which has changed in size and the latest resolution, the TM series, is 30 m), with field verification. The detailed process by which these spatial databases were generated can be consulted at http://www.inegi.org.mx/.

Although more accurate vegetation coverages are now available, only general comparisons can be made between the estimated areas of cloud forest that originally existed in the country and what exists today. To make such a comparison, we used the layers of all Series I-V of land use and vegetation mapping, and the estimates of potential primary vegetation made by CONABIO, which are based on Rzedowski[42]. Area calculations were made in km^2 using Lambert's Conformal Conic plane projection, calculating the extent of cloud forest, both primary and secondary determined as arboreal, in order to obtain an estimate of cover loss and transformed area. The classifications of primary and secondary vegetation were taken directly from the metadata of the land use layers, as there may be controversy regarding their definition. Primary Vegetation: "natural condition, real or apparent (when there is no evidence of a different climax condition), and when disturbance factors have not yet affected the general structure and phlogistic composition of the community"[43]. Secondary Vegetation: "altered or modified state of the community in its floristic or structural composition, generally due to anthropogenic influence or natural catastrophes"[43].

To evaluate the proportion of cloud forests with conservation initiatives, we used the coverages of different types of conservation instruments and the latest land use coverage (Series V). These initiatives include government protected natural areas with three categories: Federal, State and Municipal; and in non-government protected areas or land conservation initiatives through social action that include: areas voluntarily set aside for conservation, payments for environmental services (updated to 2012), management units for wildlife conservation[44] and territorial community ordinances. The latter are not strictly conservation instruments, since their primary objective is to organize land use on ejido and communal lands[45], although they often present spaces for the conservation and sustainable use of ecosystems.

The layers of federal natural protected areas (NPA) that we used were modified from the coverages published by the National Commission of Natural Protected Areas[46], the rest was developed by Bezaury-Creel *et al.*[45]. Geographic overlaps between the coverages of the various instruments are common. In practice, there is no conflict since if there are resources from two different sources (e.g. federal and state), both are reversed. In addition, the hierarchy of laws on conservation instruments is very clear. However, when working only with coverages in the analysis, if these overlapping areas are not eliminated, overestimates can be generated and make it appear that a larger area is being protected than it should be. This is why we removed all duplicated areas, giving hierarchical priority; first, to federal natural protected area decrees over state natural protected areas, except in the case of natural resource protection areas where state decrees prevail by law; and second, state natural protected areas prevail over municipal natural protected areas in all cases. Finally, following the same logic, we only take into account land protection initiatives through social actions that are located outside of government natural protected areas. After extracting all overlapping areas, we determined the extent of cloud forests under some conservation instrument.

2.2 Risk classification

The Human Affectedness coverage over the Mexican land territory (Human Affectedness[47]) was used to determine the degree of threat. This layer has values of human affectation per pixel (–1 km^2), ranging from 1 to 15, from the lowest to the highest level of affectation. This layer combines different anthropogenic activities that can be a threat to biodiversity. For each fragment of cloud forest, the values of the corresponding pixels were extracted, as well as those within a buffer zone of 1, 5, 10 km and an average was calculated. Subsequently, 5 threat categories were assigned: Level I, when the area has an average value of 0.1 to 2.9 of human impact; Level II from 3 to 5.9; Level III from 6 to 8.9; Level IV from 9 to 12.9 and Level V from 13 to 15. An index was used to evaluate the potential response capacity to reduce the threat of conservation instruments, the classification and values were taken from Ochoa-Ochoa *et al.*[36]. The values used for the index were: federal natural protected areas = 5, state and municipal = 4, areas voluntarily destined for conservation and private community protected areas = 3, community territorial ordinances (CTO) = 2, finally both payments for environmental services (PES) and wildlife conservation management units = 1. Although the theoretical maximum value of the response capacity index is 20, the probability of this happening is very low (not zero); therefore, the same ranges of values of the threats were chosen to determine the categories of the potential response index.

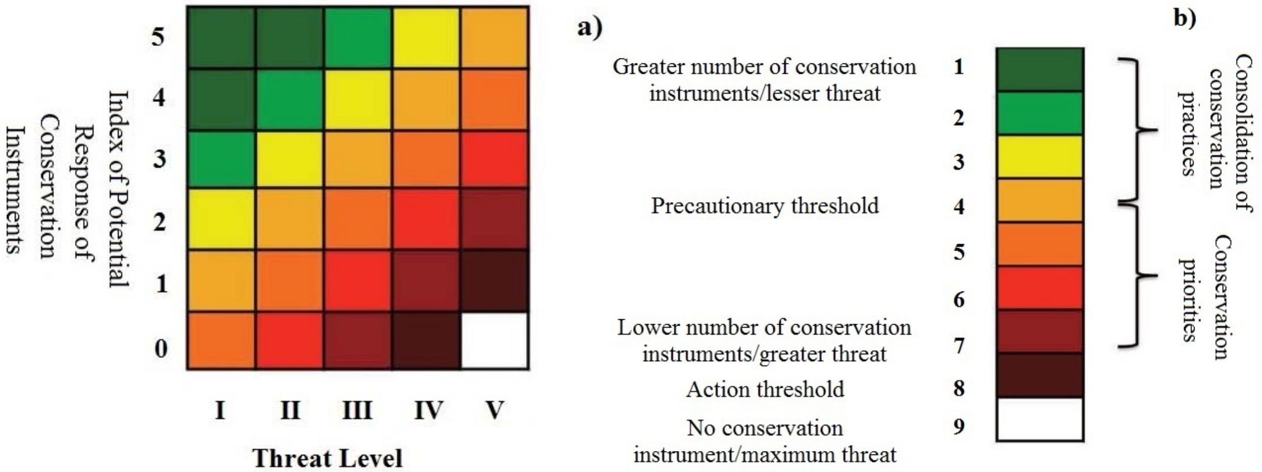

Figure 2. Triage tool to determine conservation priorities.

Subsequently, the cloud forest fragments were periodized by the triage tool proposed by Ochoa-Ochoa *et al.*[36]. The tool is based on the triage principle, commonly applied to accident victims, in which if a cloud forest fragment (in this case) has a too high level of threat and no conservation instrument (**Figure 2**) it is discarded because it is unlikely to be conserved in the long term, while forest fragments with medium levels of threat and with some conservation instrument are the priority ones to be addressed because the probability that they will be maintained in the long term is high. Finally, priority areas were established according to the percentage of cloud forest in the ecoregion and the percentage of forest at each triage level. Level III of the ecoregion layer proposed by INEGI *et al.*[48] was used.

This tool evaluates, on the one hand, the threats and determines the level/status of the forest fragment; on the other hand, it evaluates the potential response of the conservation instruments (NPA, CTO, UMA, private reserves, payment for environmental services, etc.) present in the fragment. Both aspects are integrated into the triage matrix (a), where the triage level is established for each forest fragment (b). Level 1 represents cloud forest fragments with a low level of threat with a high potential for response in terms of conservation instruments; levels 1 to 3 represent sites where, in order to preserve in the long term, it is only necessary to consolidate the conservation practices already existing in the area. Level 4 represents a precautionary threshold and it is from this value and up to level 7 where conservation priorities must be concentrated and adequate conservation strategies implemented. Level 7 represents cloud forest fragments with a high level of threat and a low conservation response potential; it is at this level where the threshold for action is established, i.e., it is necessary to evaluate whether it is worth investing, given the cost in terms of conservation, to establish conservation actions. Fragments located at level 9 represent sites with the highest level of threat and no conservation instrument, so it will be ineffective to invest in conservation actions.

3. Results

According to the analyzed coverages, between 26% (if secondary tree vegetation is taken into account) and 53% (if it is not considered) of the cloud forest in Mexico has been lost to date, according to the vegetation proposed by Rzedowski[42] (**Figure 3**). But it is more dramatic if we consider the primary vegetation chart as original vegetation[49], where more than 57% has been lost if secondary vegetation is taken into account and more than 73%, if it is not considered (**Table 1**, **Figure 4**).

Approximately 31.56% of the cloud forest is within a conservation instrument (**Table 2**). Governmental instruments are the ones that protect the largest area of cloud forest. Of the government protected natural areas, it is not surprising that the Federal Protected Areas are the largest with more than 1,765 km^2, followed by the State ones with –536 km^2, and finally the municipal ones with 0.01 km^2. Among the social instruments for conservation, Community Land Use Plans are the main ones with –1,436 km^2, followed by management units for wildlife conservation (241.81 km^2), payments for environmental services (108.32 km^2), and of these, mainly hydrological ones with 104.41 km^2. Finally, there are areas voluntarily set aside for conservation together with private and community protected areas with almost 72 km^2.

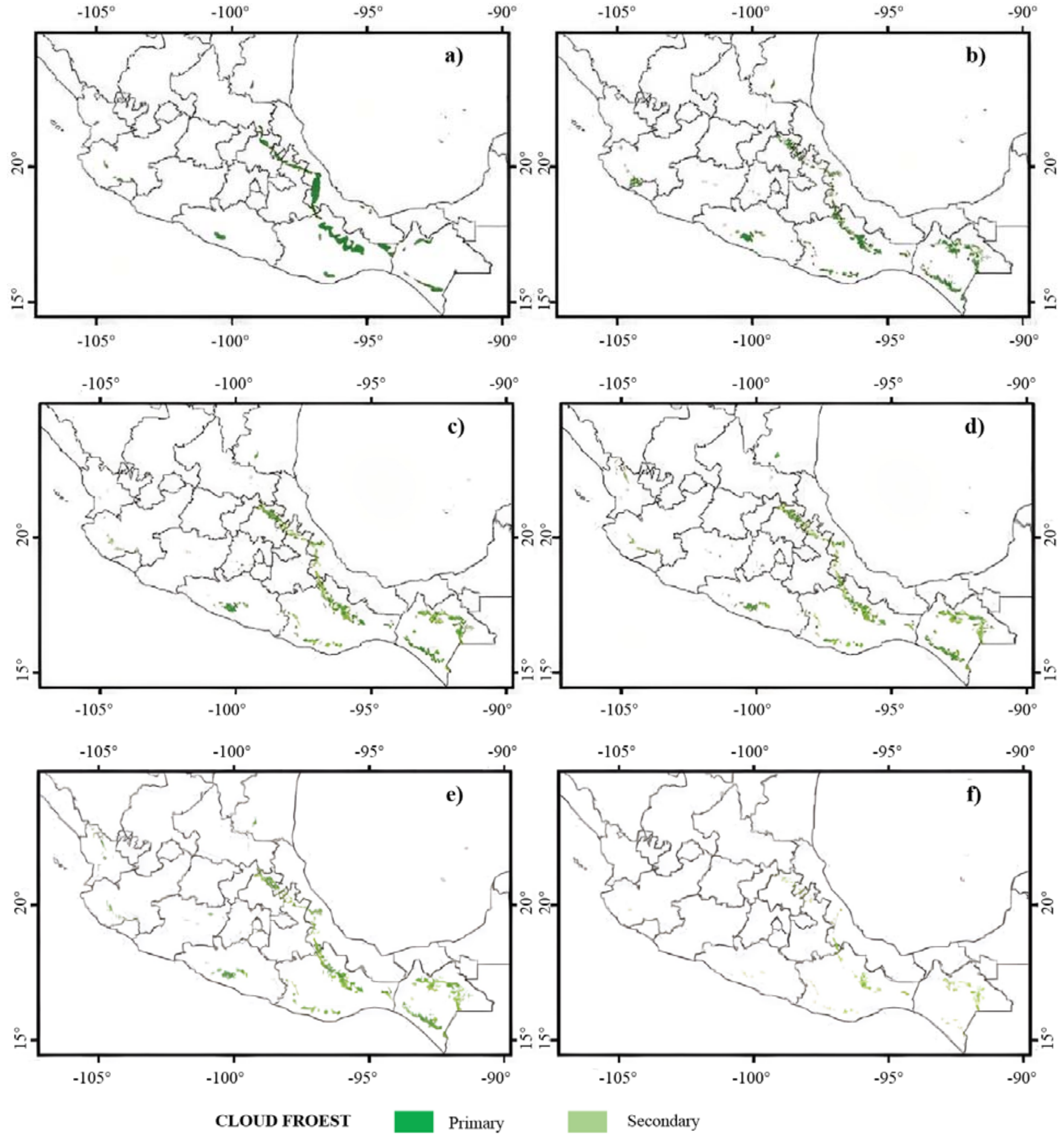

Figure 3. Distribution of montane mesophyll forest according to the different INEGI land use and vegetation coverages. Potential cloud forest according to CONABIO **(a)**, Series I **(b)**, Series II **(c)**, Series III **(d)**, Series IV **(e)** and Series V **(f)**.

Table 1. Area in square kilometers of cloud forest according to land use and vegetation coverage generated by INEGI in different years. *Sum of the area of primary and secondary tree vegetation.

Coverage	Primary vegetation	Secondary vegetation		Total
		Arborea	**Shrub and herbaceous**	
CONABIO potential	17.887			
INEGI potential	30.883			
Series I (1993)	18.113			
Series II (1999)	10.020	3.189	4.931	13.209
Series III (2005)	8.695	3.960	5.597	12.655
Series IV (2010)	8.475	4.528	5.415	13.003
V Series (2013)	8.472	4.708	5.348	13.180

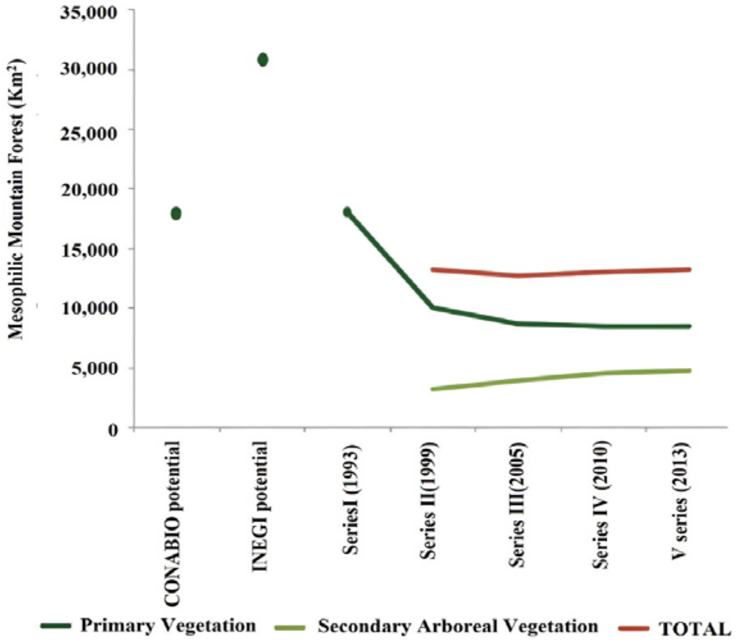

Figure 4. Area in square kilometers occupied by mesophyll mountain forest in Mexico according to different vegetation coverage and land use.

Table 2. Area of cloud forest under some type of protection in km^2

Type	Protected area of cloud forest (km^2)
Governmental	**2,301.59**
Federal natural protected areas	1,765.62
State natural protected areas	535.96
Municipal natural protected areas	0.01
Non-governmental	**1,857.49**
Areas voluntarily set aside for conservation and private and community protected areas	**71.80**
Community	69.43
Small property	2.36
Community land use planning	**1,435.56**
Community	689.25
Ejido	146.56
Others	599.75
Environmental services	**108.32**
Biodiversity conservation	3.90
Hydrological environmental services	104.41
Wildlife conservation management units	**241.82**
Total	4,159.08

In total, 747 fragments of cloud forest were detected, of which 291 are secondary forest and 456 primary forest. Threat levels, potential conservation response index and triage level are reported together (**Table 3**). The table shows the number of fragments that fall into each category of the tool (see **Figure 2**) depending on the buffer zone used. Of the total number of fragments, 85 have a value of zero, i.e., zero threat value and no conservation tools. These fragments were placed in a separate category because, although in these analyses they do not present any threat, they are still vulnerable to

Table 3. Evaluation of cloud forest fragments according to the triage tool based on threats and potential resilience of conservation instruments

		Triage	**Mist forest Series V**	**Buffer 1 km**	**Buffer 5 km**	**Buffer 10 km**
	Zero threat level/regardless of response rate	0	101			1
Consolidation of conservation practices	Greater number of conservation instruments/lesser threat	**1**				
		2				103
		3			82	
	Precautionary threshold	4				233
Conservation priorities		**5**	260	261		183
		6				
	Lower response rate/higher threat	7				0

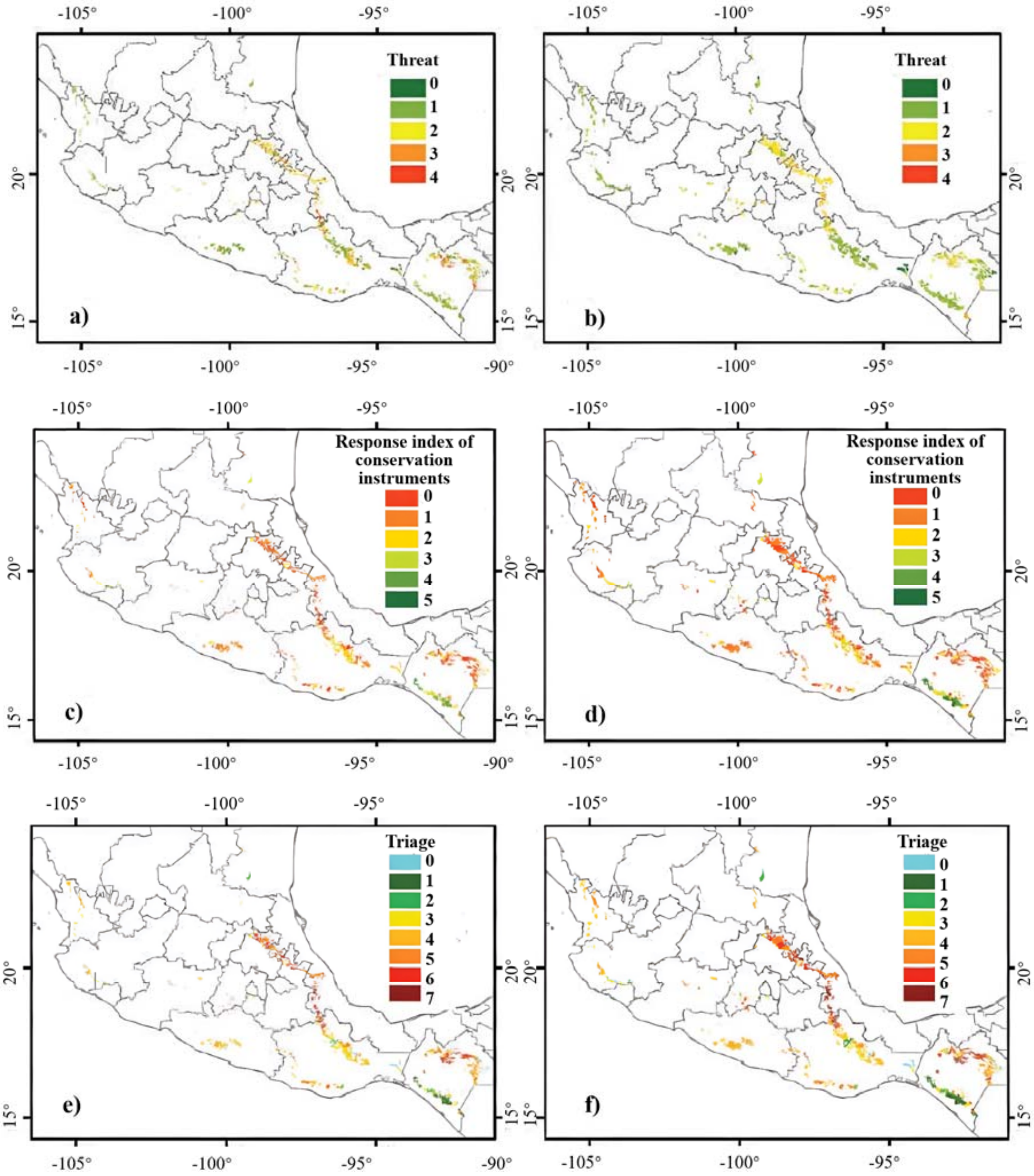

Figure 5. Evaluation of the fragments of montane mesophyll forest according to human disturbance; potential response index according to the presence of the different conservation instruments; and finally the evaluation of the triage tool. Fragments alone (**a**, **c**, e correspondingly) and fragments with a zone of influence of 1 km (**b**, **d**, **f**).

any that may arise. Of the remaining fragments, 89 should have their conservation strategies consolidated and 531, 71%, are conservation priorities, i.e., strategies should be implemented for these sites. Finally, 42 fragments, equivalent to 5.6% of the total, need to be evaluated to verify whether it is worth investing in conservation strategies, to focus efforts on restoration or not to invest. Most of these fragments are located in the southern Sierra Madre Oriental, where the largest area is located between Coscomatepec and Huatusco, in Veracruz. Another group of sites in this category is located around Rayón and Simojovel, Chiapas (**Figure 5**).

The ecoregion with the largest area of cloud forest is the Sierra Madre del Sur of Guerrero and Oaxaca with more than 36%, of which almost 74% is classified as a priority to be conserved according to the triage results. This is followed by the Sierra Madre Centroamericana, an area more commonly known as Sierra Madre de Chiapas, with 16%, of which almost 83% only requires the consolidation of conservation instruments. This is followed by Los Altos de Chiapas with almost 15% of the country's cloud forest, of which more than 82% is classified as a priority. Then follows the cloud forests of the Sierra Madre Oriental with a little more than 11%, of which more than 85% is considered a priority. In fifth place is Central Mexico with more than 9%, of which almost 79% is considered a priority. These 5 ecoregions have almost 88% of the country's cloud forests. The next 5 ecoregions together have 11.35% (see **Table 4, Figure 5**), and the rest of the ecoregions together have less than 1% of the cloud forest. However, it is worth noting that in total 65.4% of cloud forests is a priority for conservation.

4. Discussion

Due to the nature of their distribution, restricted to islands and the large loss in the area they cover, cloud forests have always been considered a priority for conservation[1,2]. It has also been reported that there are overestimates in the calculation of cloud forest area in studies based on the quality of satellite images[50]. This means that it is possible that cloud forests are in a more precarious situation than currently believed[2]. Nevertheless, information and analytical tools based on remote sensing remain the most effective means for assessing the conservation status of vegetation in general[37], and is perhaps the only way to have an overall picture of the status of cloud forests, at least for the case of Mexico. The present study confirms the fact that the "primary" cloud forest has been dramatically affected, reducing its area by up to 73% (highest estimated value). Even the most encouraging figure (53% loss) almost doubles the loss value of 28.8% reported in 2007 for a 30-year period[33]. Although considering the secondary forest (only the tree component), the figure seems less discouraging, where only 31% of this area has some protection status.

Regardless of the conservation status, primary or secondary vegetation, due to the great wealth of natural resources, a high percentage of cloud forests have been settled by humans for a long time[51]. Studies on the diversity and structure of the vegetation have found evidence of their management; for example, it has been observed that forest harvesting has decreased species diversity, modified the spatial distribution of trees and changed the dimensional differentiation (diameter and height of trees). But the situation could be even worse, since in addition to land use change, there are other latent threats to cloud forests, such as climate change[32,51] and selective extraction of both orchid and tree litter[52]. These low-impact activities, apparently less serious, directly modify the composition of plant species and negatively affect the diversity and composition of animal species by modifying or losing microhabitats generated in the cloud forest[52,53]. However, it should be emphasized that almost no specific studies have been conducted in this regard for cloud forests in Mexico.

Due to the relative scarcity of cloud forests in Mexico and their biological importance[1,19], it is crucial to conserve 100% of their remaining cover and even consider the restoration of those portions of secondary forest with the potential to recover their structure and functions. However, achieving this figure is practically impossible, which is why the triage tool makes it possible to optimize the efforts and resources allocated to their conservation. Traditionally, natural protected areas have been seen as the ideal tool for conservation[54], but in

Table 4. Cloud forest, in percentage, according to the total area found in each ecoregion (INEGI *et al.*[48]) and the triage value obtained

Ecoregions	**Triage value**								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
1. Coniferous, oak and mixed forests of the Sierra Madre del Sur of Guerrero and Oaxaca.	3.700		5.941	16.033	39.084	29.110	5.470	0.661	36.323
2. Coniferous, oak and mixed forests of the Central American Sierra Madre.	5.448	41.829	22.652	18.253	4.718	2.234	4.091	0.775	16.081
3. Coniferous, oak and mixed forests of the Chiapas highlands.	4.749		0.521	11.649	6.697	46.902	28.516	0.966	14.853
4. Coniferous, oak and mixed forests of the Sierra Madre Oriental.	1.091		10.845	1.167	10.210	33.614	41.571	1.502	11.294
5. Lomerios and Sierras with coniferous, oak and mixed forests of Central Mexico.	4.119	2.648	2.105	5.202	19.635	33.981	25.116	7.193	9.147
6. Lomerios with evergreen rainforest.	12.758		6.143	10.338	12.583	29.795	24.784	3.600	3.907
7. Coniferous, oak and mixed forests of the Sierra Madre Occidental.	11.876				30.580	57.006	0.538		2.439
8. Coniferous, oak and mixed forests of the Sierra Madre del Sur of Jalisco and Michoacan.	22.644		3.090	27.329	35.929	11.008			2.275
9. Soconusco Coastal Plains and Lomerios with evergreen rainforest.		57.561	14.165	24.545			1.079	0.027	1.499
10. Lomeríos and Coastal Plains of Nayarit and Jalisco with evergreen rainforest.	2.931				86.172	10.734	0.163		1.231
11. Lomerios and Piedemontes of the Mexican South Pacific with thorny forest.	0.656		0.525	6.966	75.279	16.574			0.505
12. Lomerios and Interior Plains with xerophytic scrub and lowland mesquite forest.						100.000			0.210
13. Sierra de los Tuxtlas with evergreen rainforest.				100.000					0.081
14. Central Depression of Chiapas with Caducifolia Forest.				0.404		33.300	66.296		0.072
15. Lomerios of Sonora and Sinaloa and Canons of the Sierra Madre Occidental with xerophytic scrub and deciduous forest.	2.530					97.470			0.063
16. Balsas depression with deciduous forest and xerophilous scrubland.					19.845	80.155			0.019
17. South Texas Plains/Inland Plains and Lomerias with xerophytic scrub and oak woodland.						100.0			0.001
18. Tehuantepec canyon and plain with deciduous forest and thorny forest.				1.00					0.0003
Total by triage value	4.770	7.832	7.821	12.608	22.398	28.137	14.920	1.516	

such a biologically diverse country (with high rates of species turnover; see Williams-Linera *et al.*[55]), not only biologically but also culturally (there is a great diversity of cultures with high turnover between regions), the use of a wide range of conservation instruments and/or strategies that adjust to the social requirements of each region is required for their use to be effective. Conservation instruments are not homogeneous and almost all of them contemplate a sustainable use of natural resources by human populations[37]. This means that in a certain way, cloud forests that are currently covered under some conservation instrument will continue to maintain some level of "threat". In this sense, the triage method is the most appropriate for prioritizing and making decisions about which fragments should be addressed first, in a long-term conservation context[36]. In a high percentage (>71%) of cloud forest fragments, it is necessary to implement conservation instruments immediately, either because of their high level of threat or because they are not yet covered by any instrument, i.e. they are a priority. The lesser ones are at a more affordable level for conservation, i.e., it is enough to consolidate the instruments currently in place. It is worth noting that the geographic location of the fragments is not only important in terms of their evolutionary history but also in terms of their social context, and is therefore a determining factor for the possible tools to be implemented to be truly effective. An interesting example is Oaxaca, where social/cultural issues have complicated the establishment of governmental natural areas, but social conservation initiatives have proven to be truly effective[56].

For a long time, there was discussion as to which were the best conservation strategies: top-down or bottom-up. There now seems to be a consensus on the importance of using both strategies. However, it is worth emphasizing that in practice, conservation is carried out by people (governed by laws and/or resources). In this sense, it is people who perceive and are affected by changes in the ecosystem around them. Moreover, in general, top-down strategies depend on the resources allocated, which vary temporally and spatially; social conservation strategies do not. Therefore, at least in Mexico, social conservation strategies have been particularly successful[37,57]. These rural communities are immediately dependent on the conservation status of their natural resources.

Weighing by ecoregions, it is interesting that in the regions where cloud forest is concentrated, in most cases more than 70% of the fragments are a priority.

Undoubtedly, these fragments are the priority for long-term conservation. They are located in the ecoregions: Sierra Madre del Sur of Guerrero and Oaxaca, Los Altos de Chiapas, Sierra Madre Oriental and Central Mexico corresponding to the Trans-Mexican Volcanic Belt. By covering a larger area, these ecoregions guarantee long-term success. However, it is very likely that ecoregions containing smaller areas of cloud forest are at a higher level of priority due to the small area of fragments they contain. The cloud forest fragments with the smallest area are mostly located on the Pacific slope and in areas where atmospheric humidity is lower on average than in the rest of the country's cloud forests[6]. This climatic variant represents another distinct set of cloud forest type that should be prioritized for conservation, as it surely represents rare and unique communities in terms of the composition and structure of the species that comprise them. The opposite case is the Sierra Madre de Chiapas, where only the federal protected natural areas of El Triunfo, the municipalities of La Concordia, Ángel Albino Corzo, Villa Flores and Jiquipilas (La Frailescana), La Sepultura and Volcán Tacaná, as well as the state protected natural area Cordón Pico El Oro Paxtal, need to be consolidated. Of course, this scenario is based on the assumption that the instruments will work ideally or adequately. Therefore, it is imperative to incorporate some measures related to socioeconomic variables as possible indicators of the success of the implementation and continuity of each of the conservation instruments as well as the surrounding area. In this sense, it would be important to evaluate the effectiveness of community land-use planning, since they cover a significant percentage of cloud forest fragments, mainly in areas where there are very few governmental reserves, such as Guerrero and Oaxaca. A relevant aspect of this type of conservation instrument is that it is the communities or ejidos that decide to manage, therefore they represent a "bottom-up" strategy where the landowners are the ones who are convinced that this measure is required[57]. And it is precisely the fact that they are convinced that favors or increases their success.

5. Final considerations

The overall conservation prioritization strategy for Mexico's cloud forests is a comprehensive and complex process. The assessment presented here is only a simplified guide to initiate a more comprehensive conservation planning process. This process should consider the effectiveness of the instruments and their viability in each proposed area. Likewise, socially owned lands (ejidos, agrarian communities, etc.) deserve special attention as they are home to a large area of cloud forest, so it is advisable to encourage long-term social conservation and/or reinforce it with other socially appropriate instruments. In this sense, the Payment for Environmental Services Component operated by the National Forestry Commission (CONAFOR), whose rules of operation favor the conservation of these cloud forests by granting them the highest payment per hectare, is of great importance. It is relevant that the first site supported by CONAFOR's Biodiversity Endowment Fund, through which the Commission makes payments for long-term environmental services, is the Sierra de Cacoma in Jalisco, which was selected precisely because of the presence of cloud forests.

Finally, the environmental services provided by cloud forests are broad and include the seven aspects identified as environmental services (water capture and filtration, mitigation of climate change effects due to their strategic position in altitudinal gradients, oxygen generation, biodiversity protection, soil retention, wildlife refuge and, of course, scenic beauty). However, particularly these forests have an additional unique value in the capture of water by the condensation of clouds and fog, so they are recognized and even sought for payment for environmental services for the large amount of water they capture and filter[19]. Given the above, the conservation of these forests is of vital importance.

Although the primary focus of this assessment is on cloud forest fragments, it is highly relevant to integrate information on the matrix of other ecosystems in which these fragments are immersed. Therefore, the results obtained from fragments that include a buffer zone are particularly important. Because it is inevitable that the changes that occur within the in-mediated area surrounding the fragment, whatever they may be, will have an impact on it.

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Conflict of interest

The authors declared no conflict of interest.

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