

Ecosystem services in the *cocoa plantations*, as perceived by producers in southeastern Mexican

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Abstract

The recognition and inclusion of ecosystem services depend on the knowledge of local actors, wherein perceived social value complements economic and biophysical value, thus obtaining a complete range of ecosystem values. Via the perception of the cocoa producer, the present research studied local knowledge and the social value that these producers bring to the ecosystem services generated by their plantations, or *madreaos*. The study was carried out, via a mixed approach, in three communities of the municipality of Cunduacán, in the state of Tabasco. Thirty producers were sampled, at random, per community, selecting male subjects who presented a homogeneous socioeconomic stratum and level of educational attainment. The instruments used were surveys, semi-structured interviews, and feedback workshops, while the analysis was carried out by means of social representations and the use of the UCINET 6.85 program, finding that the community of 2nd Cúlico maintained a close relationship with its plantations. Their experiences of farming this crop demonstrate that the members of this community have a greater cultural attachment to it and that it contributes greater social value than that described for the other two communities sampled. Ninety percent of the entire population studied recognized that firewood and fruit are ecosystem services. The present study concludes that the producers are uninformed as to both the social value that they should attribute to their *cocoa plantations* and the total number of services that they generate. There is, therefore, strong demand for broader knowledge on such topics as the valuation of ecosystem services, pollination, water, and the mitigation of climate change.

Introduction

While ecosystem services (ESs) correspond to all those services or goods that nature provides to human beings (Lavelle *et al.*, 2014), the main ES generated by agro ecosystems is food. Ecosystem services have been categorized into those corresponding to provisioning services, regulating services, and cultural services, based on the benefits that people obtain from them (Echeverría, 2017). They are manifested, in traditional peasant

agriculture, through the conservation of biodiversity and local knowledge (Bridgewater, 2017). Of both great local importance and global impact, ecosystem services are of key importance to regulating ecosystem function (Altieri and Toledo, 2011).

Since the end of the 1970s, the subject of ESs has been disseminated with greater interest, with the aim of increasing public interest and information to promote their conservation and highlight the importance of ecosystems, above all, in terms of the well-being they generate for the population.

Because there are some studies showing that introduced plantations do not generate the desired results (Kouassi et al., 2023).

While, by the 1990s, significant progress had been made in formulating methodologies for the monetary valuation of ESs, it was not until the mid-2000s that the concept achieved international recognition through the publication of the comprehensive Millennium Ecosystem Assessment (MEA) in 2005. However, climate change poses a serious threat to agricultural production in the tropics; however, its impact on tropical tree crops such as cocoa has hardly been investigated (Ríos-Bolívar et al., 2022).

Despite the abundant information available on ESs, the present study aimed to ascertain both the local knowledge of producers and the social value attributed to ESs, as pertaining to one of the most important crops in the state of Tabasco – cocoa. Its main objective was to study local knowledge and the social value that cocoa producers, in their perception, attribute to the ESs generated by their *madreaos*. The results of this research allow us to know how informed cocoa plantation producers are about the ES

generated in their cocoa crops, thus contributing to the preservation of one of the most important crops in the state.

Materials and methods

Study area

The study area is made up of three localities: Huimango 1st Section, has 984 inhabitants, Cúllico 2nd Section 1406 and La Chonita 1698 inhabitants (INEGI, 2015), all belong to the municipality of Cunduacán. The area has an altitude of 20 masl, annual temperature of 27. 2°C, where three types of climates are identified: tropical humid and dry tropical (Aw), tropical monsoon (Am) and tropical humid (Af); the soils are composed of gleysols, vertisols and fluvisols with swampy areas, suitable for traditional agriculture, specifically for Cacao, according to the classification of Zavala-Cruz and collaborators (2016); as well as three types of vegetation where induced grasslands, acahuales and tulares were identified (Santos, Cuanalo and Ortiz; 1977; West, et al. 1987).

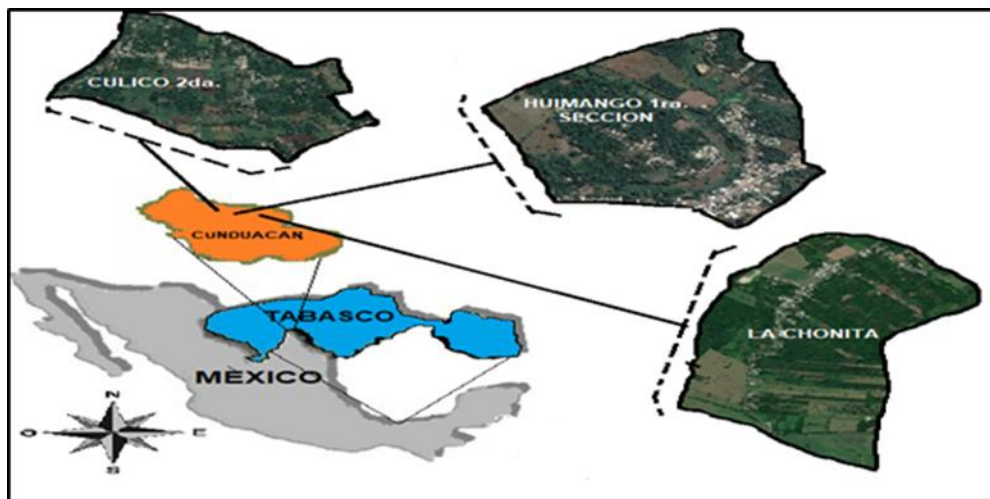


Figure 1: Study locations
Original source: Author's elaboration

Determination of the sample

The sample selection was delimited based on the scope of the study, which consisted of 90 producers of cocoa (*Theobroma cacao*), corresponding to the register of producers registered by the Secretariat of Agriculture and Rural Development (SADER) in the state of Tabasco, authorities, and community leaders. The field research was conducted in the period February - July 2019, through a survey structured in three sections with the following structure: 1) Demographic data, 2) Characteristics of *Theobroma cacao* plantations, 3) Ecosystem services (ES) of the *Theobroma cacao* plantation system. For the last section, a scale from 0 to 10 was established, adapted from Silva (2013), where ES are classified as not important (0-3), important (4-7) or very important (8-10). It is worth

mentioning that this research has the informed consent of the interviewees: municipal delegates, local leaders, and members of the producers' group.

Data processing

The information was processed through the construction of databases in Excel and the analysis of frequency distribution was carried out using the Statistical Package for the Social Sciences (SPSS) software, for the first two sections (demographic data and characteristics of the plantations). For the construction of the network composed of nodes and ties, a matrix of relationships was captured in a spreadsheet for section 3, on the ideas and expressions about the ES of the plantations. The UCINET 6.0 software (Borgatti, Everett and Freedman, 2002) was used for this analysis.

It is worth mentioning that, for this last section, a Social Representations (SR) approach is used, which Moscovici (1979) mentions as a form of common-sense knowledge, which manifests the operation of socially marked generative and functional processes. This research takes as reference works focused on SR where we can cite Fernández (2002), Lara and collaborators (2010) and Jiménez and Fernández, (2019).

The nodes represent the perception or ideas that the producers of the three communities have about the ES derived from the plantations and the ties are the relationships between them. The nodes present different shades and shapes, which are a function of their connectivity and the strength of the ties between the nodes is indicated by the thickness of the lines linked to each other. The density was obtained, which indicates the number of links in the network, i.e., how tightly connected they are, while the degree of centrality indicates the relationship between the highest connectivity and frequency in the nodes.

Finally, an analysis of the results is carried out to identify the vulnerability of the production systems due to the reduction of the ES at present, to generate recommendations according to the perception of each producer and identifying their situation individually and collectively.

Results and discussion

Characteristics of cocoa producers and their cocoa plantations

Ranging from 61 to 70 years old (Table 1), the producers possess both reliable information on the crop itself and historical data pertaining to the area. However, this age range has a negative impact in terms of plantation management, in that older producers need to hire additional staff for farming practices, such as pruning and weed control, which must be undertaken periodically, require more physical effort, and, ultimately, increase the cost of production (Córdova, 2015).

Table 1: Presents the overall results

Age range of the producer	Age (years)	Frequency	
		Absolute	Relative (%)
	30-40	6	6.66
	41-50	13	14.46
	51-60	26	28.88
	61-70	30	33.34
	71-80	14	15.55
	81-90	1	1.11
	Total	90	100
Frequencies in the educational attainment of cocoa producers	Educational attainment	Frequency	
		Absolute	Relative (%)
	Illiterate	6	6.67
	Truncated primary	35	38.89
	Completed primary	16	17.77
	Truncated lower secondary	4	4.44
	Completed lower secondary	11	12.22
	Truncated upper secondary	3	3.34
	Completed upper secondary	8	8.88
	Truncated undergraduate	2	
	Completed undergraduate	5	5.56
	Total	90	1
The gender with the highest participation in cocoa farming	Gender	Frequency	
		Absolute	Relative (%)
	Man	83	92.22
	Woman	7	7.78
Total	90	100	
Members of the families of cocoa producers	Number of members	Frequency	
		Absolute	Relative (%)
	45017	23	25.56
	45143	62	68.88
	45269	5	5.56
Total	90		

The population surveyed in the present study had completed at least one grade of formal education, with the 38.89% of respondents presenting a truncated primary education a notable finding (Table 1). The low level of educational attainment has a negative impact on the management and planning of the use of resources (Engler and Toledo, 2010). On the other hand, the producers possess a great wealth of empirical knowledge on the management of polyculture cocoa production, given the years of cocoa farming experience of the majority of producers.

In terms of gender, the majority participation of men in the farming of this crop is notable (Table 1), due to the type of tasks required on a plantation, such as the handling of sharp tools and the high level of physical activity. Women collaborate exclusively on less strenuous tasks, such as the collection of the fruit after it is cut from the tree. While said collaboration is less significant, it remains significant and, moreover, involves other family members, such as children.

The family mostly comprises six members: father; mother; children; and others (grandparents or uncles/aunts) (Table 1). Such large families enable the diversification of tasks, both in the home and those related to farming, although they do increase expenditure on food, clothing, and services. The family is led by the father, who, in 90% of cases, generates his income from the sale of the products obtained from his crop, remuneration for employment outside the community, or both.

Eighty-nine percent of the producers surveyed affirmed that their plantation was over 30 years old and that there are even 100-year-old plantations. The age of the plantation enables both an assessment of the physiological state of the plant and a diagnosis of nutrient (N, P, K) deficiencies or excesses during the development of the plantation. Excess organic matter was found in the study area.

The *cocoa plantations* are considered obsolete 30 years post-planting, given that production begins to decline after this point (Córdova, 2015), with the producer then recommended to implement techniques to counteract the decline in production, especially sectorial renovations, to protect their income (De la Cruz *et al.*, 2015). These improvements are not always carried out, due to a lack of technical knowledge or a sense of cultural attachment.

Institutions such as SADER and the Tabasco Plant Health Committee run projects via their calendar of institutional operations. These calendars, which depend on institutional schedules and resources, do not coincide with the calendars of the producers, as the latter depend on the producers' beliefs, empirical experiences, and the interpretation of lunar phases, around which their cultural practices are organized. A clear example of this is the pruning period, which 90% of the respondents stated was scheduled in the institutional calendar to take place during the *canícula* (the hottest time of the year), which lasts approximately 2.5 months. The producers believe that no type of cutting can be undertaken on the trees during this

period, as the trees suffer "stress" and are apt to develop diseases more quickly, for which reason they do not prune during *canícula*, leading them to consider this situation an example of poor planning by these government institutions.

Given that the values obtained by the present study are below the average national yield (Table 2), the producers receive a very low income from cocoa farming (ENA, 2017). Therefore, producers complement cocoa farming with other income-generating activities, such as livestock (25%), and work in the commercial (13%) and construction sector (10%), while the remaining 52% dedicate themselves exclusively to cocoa farming. Volume of cocoa produced in the study area, producers 90, Hectares/producer 1.9 ha, Total number of hectares 171, Volume/hectares 98.34, Total volume of production for the population surveyed, 16,816.14.

Table 2: Products are obtained from the crops associated with the cocoa plantation

Plantation age from a sample of 90 producers	Plantation age	Frequency	
		Absolute	Relative (%)
	<10	2	2.23
20	5	5.56	
30	6	6.66	
40	30	33.34	
50	28	31.12	
60	6	6.66	
70	5	5.55	
80	3	3.33	
90	3	3.33	
100	2	2.22	
Total	90	100	

Crops associated with cocoa and their frequency	Associated crops	Frequency	
		Absolute	Relative (%)
Banana (Musa paradisiaca)	21	23.34	
Orange (Citrus sinensis),	14	15.56	
Mango (Mangifera indica)	18	20	
Black pepper (Piper nigrum L),	13	14.45	
Achiote (Bixa orellana)	6	6.66	
Cedar (Cedrela odorata)	7	7.78	
Mahogany (Swietenia macrophylla)	5	5.55	
Pink poui (Tabebuia rosea)	6	6.66	
Total	90	100	

Products identified and extracted from a cocoa plantations	Products	Frequency	
		Absolute	Relative (100%)
Firewood	25	27.78	
Fruit	16	17.78	
Compost	11	12.22	
Medicinal plants	8	8.89	
Seeds	4	4.44	
Timber	9	10	
Leaves (seasoning)	7	7.78	
Water	10	11.11	
Total	90	100	

Cocoa is considered a noble crop, as it is one of the few that can be developed in association with other crops without any of them being affected by such proximity. The study area is associated with fruit trees, among which banana (*Musa paradisiaca*), orange (*Citrus sinensis*), mango (*Mangifera indica*), and black pepper (*Piper nigrum L*) are notable. However, it also contains timber trees such as cedar, mahogany, and pink poui, and non-timber trees such as the strangler fig (*matapalo* or *Ficus spp*), although these latter trees only cast a lot of shade without providing any economic benefit (Corben, 1987).

A series of products are obtained from the associated crops in the cocoa plantation (Table 2) and cataloged as provisioning ESs. However, the producer does not recognize this categorization of these products, as their perception is limited to tangible goods and, thus, does not allow a holistic view of all the goods obtained from a cocoa plantation. The perception of rural producers with regard to ESs is extremely important and contributes positively to

political discussions and decision-making related to environmental deterioration and the strategies proposed to resolve it (Montes and Sala, 2007).

According to the surveys carried out by the present study, the social representations approach applied revealed that 79% of the producers had not heard of ESs, leading to the conclusion that his general perception of them was nil. This quite an alarming finding, as the perception of rural producers, one of the key tools in relevant political discussions, contributes to making better and more consensual decisions related to environmental deterioration and enables better solution strategies to be devised (Álvarez *et al*, 2016). Nine producers (10%) affirmed that they were aware of the concept of ESs and were able to describe it in their own words (Figure 2), detailing key elements that coincide with that expressed by authors writing on this subject. Some authors point out that the cocoa sector has continued its global efforts to address various environmental and social problems.

Knowledge about the concept of ecosystem service as presented by producers from three communities in the municipality of Cunduacán, Tabasco			
	Do you know what is referred to by the concept of Ecosystem Service?	No. of producers	%
HUIMANGO 1 ST	Yes, and expressed the concept	5	17%
	Yes, but vaguely recalled the concept	3	10%
	Was not aware of the concept	18	60%
	Did not answer	4	13%
		30	100%
CULICO 2 ND	Yes, and expressed the concept	2	7%
	Yes, but vaguely recalled the concept	1	3%
	Was not aware of the concept	26	87%
	Did not answer	1	3%
		30	100%
LA CHONITA	Yes, and expressed the concept	2	7%
	Yes, but vaguely recalled the concept	1	3%
	Was not aware of the concept	27	90%
	Did not answer	0	0%

Figure 2: Number of producers, per community, able to describe the concept of ecosystem service in their own words

After explaining and exchanging experiences during the workshops, they specified their own concept based on their interpretation of ESs: Ecosystem Services “*are all those benefits that we can see and not see, a result of our work with our crop and, for the good of our children, it is necessary to conserve them*” (Cocoa producers, 2018).

Types and importance of ESs identified in the communities sampled

In total, 18 SEs, four regulating, five cultural, and nine provisioning, were identified, with the highest number of services corresponding to provisioning, wherein the three communities sampled concur that their plantations are providers of firewood, water, timber, fruit, and leaves

(condiments) (Figure 3). These benefits are characterized by being those most appreciated by society, because they satisfy basic needs such as subsistence and shelter (Camacho-Valdez y Ruíz-Luna, 2012).

Pozol was one of the most recognized products and was identified by respondents as being extracted from the *madreaos*. Although this product is subject to a manufacturing process, its main ingredients are cocoa beans and corn kernels. This beverage, known in the region as *chorote* or *pozol*, represents identity and tradition for the people of Tabasco, making it a cultural ecosystem service.

Seventy-five percent of the homes of cocoa producers are found on the edges of the plantations, while others are located in the center of the plantation, wherein the *madreao* serves as a buffer against the high temperatures currently

recorded in the state of Tabasco. The coolness provided by a cocoa plantation was one of the services that most producers described as regulating services.

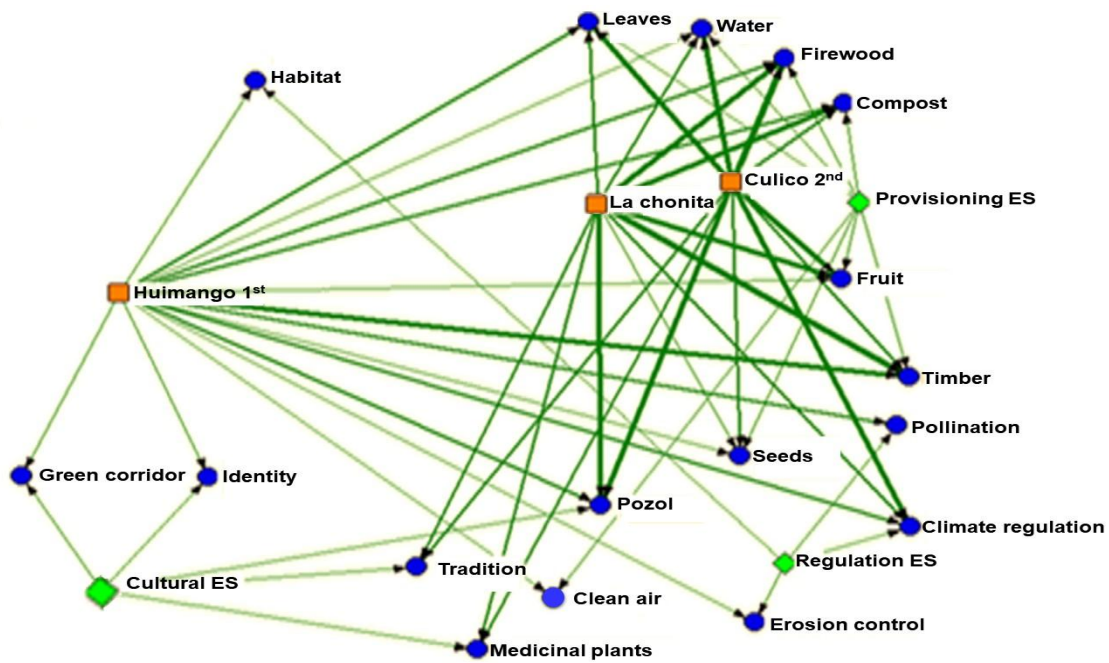


Figure 3: The blue circles represent, by community (brown box), the ESs that the producers obtain directly and indirectly from their cocoa plantation, while the green figure indicate the group to which each of the ESs identified pertains

According to the perception of the cocoa producers, firewood and timber were the services of the most importance based on the generation of monetary resources (Figure 4).

In the communities of Cúlico 2nd and La Chonita, a greater cultural attachment to the plantations was identified, with *pozol* being the product perceived as having the greatest cultural importance. This refreshing beverage, consumed traditionally in the region, has a high calorie content, providing producers with sufficient energy to carry out work in the field. The community of Huimango 1st identified various ESs generated by its *madreaos*, but gave little importance to them, contrasting them with land use changes and day-by-day population growth. As well as Santana-Santana and collaborators 2022, finally, it is necessary to raise the need for good management of cultural ecosystem services because it could generate benefits for regulating services.

Existing *cocoa plantation* shad been transformed into pasture, or the land had been used by the producer's children to construct their own houses or condominiums, thus giving way to human settlements, in response to processes of urbanization.

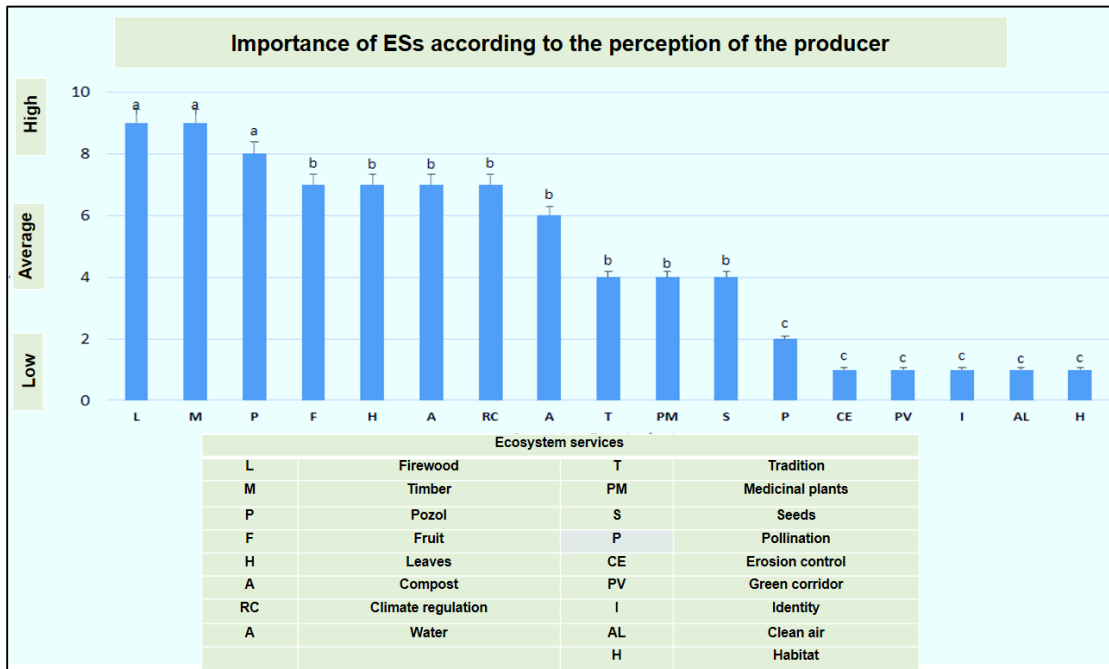


Figure 4: Perception of cocoa producers, in three communities of the municipality of Cunduacán, on the importance of ESs

The different letters indicate the significant differences ($P < 0.05$) according to the perception of the producer.

The lack of knowledge on the importance of ESs in the cocoa agroecosystem and the lack of interest of new generations in preserving this crop exacerbate the financial problems faced by families. This dynamic directly influences the decisions of the producer over the use of their plantation’s resources, decisions which are, at the same time, directly related to the way of life for families in rural communities (FAO, 2016).

Analysis of the indicators established in the network: Density and degree centrality

Every social network is defined by the links formed by the actors it comprises. The present study sought to explore the relationship between the main actors, represented by producers from three communities in the municipality of Cunduacán (Huimango 1st, Cúlico 2nd, and La Chonita), with the ecosystem services provided by their *cocoa plantations* (Figure 5).

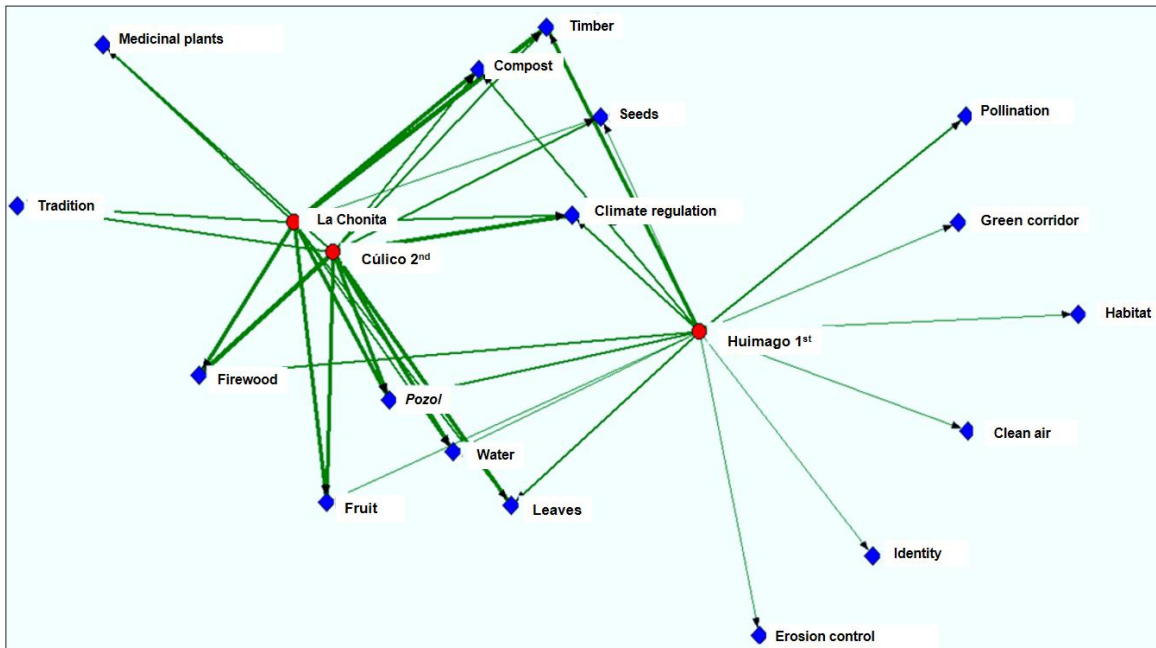


Figure 5: Network of ecosystem services as identified by members of three rural communities (prepared by the authors)

A measure of the number of existing links in the network, which itself is presented as a proportion of the number of possible links, density is considered a measure of cohesion between actors in a network (Borgatti et al. 2013). If density means cohesion in a network, then the higher the density, the greater the cohesion and, therefore, the greater number of links between the actors that form the network (De Nooy et al., 2005). Cultural attachment was one of the qualities of cohesion reported between the producers and their *madreao*, with Cúllico and La Chonita highlighted as the communities with greater cohesion among the services identified.

A cocoa plantation represents the heritage and the main source of income of the producers, who demonstrate a gradient in the intensity of management which determines the sustainability of the plantations, while their scant use of technology provides a more balanced option in terms of the offer of ESs.

While the producers of Huimango 1st section describe the various services provided by their *madreao*, they attribute less importance to it than respondents from the other two communities sampled, as seen in the land use changes, they have undertaken to the due to the growth of their population. Commonly, the producer allocates part of their property for the construction of houses for their children, a practice common in the region, with entire cocoa farms destroyed by the construction of condominiums to meet the demands of the great urban sprawl, the ravages of which are increasingly notable.

The results obtained show that the density of the network is 0.2078, which, expressed as a percentage would be 20.78%, with the 79 links observed representing 20.78% of

the possible links in the entire network (size $n = 20$). In this same calculation, the results obtained show that the density of the network is 0.2078, which, expressed as a percentage would be 20.78%, with the 79 links observed representing 20.78% of the possible links in the entire network (size $n = 20$).

In this same calculation, the indicator of the average degree centrality for the network can also be seen and was, in the present study, 2.0789. Each of the 20 actors that form the network have, on average, 2.0 links, which refers to the number of connections between actors as identified by calculating how adjacent they are to each other (Figure 6).

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DENSITY / AVERAGE MATRIX VALUE
-----
                1      2      3      4
              Avg Va  N° of  Std De  Avg
              lue   ties   v       Degr
              -----
1ReddecomunidadesySE 0.2078 79    1.193  2.0789
1 rows, 4 columns, 1 levels.
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Figure 6: Calculation, using the UCINET program, of the density of the three communities in terms of the ESs provided by their cocoa plantations

Centralization: Degree centrality

The level of centralization of a network is an indicator that measures the difference between the levels of centrality of the actors and provides an idea as to whether dominant nodes are present (Freeman et al., 2007).

Given that centralization measures the degree to which an actor is dominant in the network, the present study solely emphasized the centralization of the network based on degree centrality. Therefore, the centralization of a network can be understood as the degree to which a network is dominated by a single node (Borgatti et al., 2013).

The indicators obtained show that our network is more centralized in degrees of output (0.13 = 13.0%) than input

(0.11 = 11.0%), meaning that there are one or more nodes in the network that are dominant in the establishment of output links.

The community of Cúlico 2nd, therefore, represents the sector of the sample population that is mostly dedicated to cocoa production and is, of the three sampled, the community with more rural characteristics. The producers of this specific community maintain a close relationship with their plantations as they are the only source of income for their families. Given their experiences of cocoa farming, they demonstrated greater cultural attachment than the other two communities studied (Figure 7).

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Graph Centralization -- as proportion, not percentage
                1      2
              Out-Ce In-Cen
              ntrali traliz
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Figure 7: Result of the centralization index (output and input) for the network, comprising 20 nodes and 79 links

The other two communities present a lower degree of dominance in terms of the degrees of input and output, thus indicating a limitation in the social structure studied (Figure 8), given that the nodes (communities) with fewer interactions represent disinterest in the care and preservation of ESs. This, thus, gives them a lower social value, as they are considered unimportant, in the perception of the producers, given that social values are the

sociocultural perception of the human well-being provided by ecosystems (MA, 2005). The lack of value attributed to the services provided by these plantations exacerbates the problem of emphasizing the recovery of a crop that represents culture and identity for the people of Tabasco and, above all, is of such importance to the environment in terms of the preservation of ecosystem services in the region.

FREEMAN'S DEGREE CENTRALITY MEASURES					
		1	2	3	4
		OutDegree	InDegree	NrmOutDeg	NrmInDeg
2	Cúlico 2da	3.000	1.000	50.000	16.667
3	La Chonita	0.000	3.000	0.000	50.000
1	Huimango 1ra	1.000	0.000	16.667	0.000

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Figure 8: Degrees of input and output by community, calculated using the UCINET 6.6 program

The vulnerability of the producer due to the reduction in ESs

There is an inversely proportional relationship between the vulnerability of the producers and the vegetation provided by the cocoa plantations for each community, given that the more cover provided by cocoa plantations, the lower the vulnerability to secondary effects, such as droughts, air pollution, and erosion etc.

In accordance with the levels of cultural attachment and importance they attribute to their plantation, the community of Cúlico 2nd presents a traditional technological system or local complex system and is less vulnerable to negative effects such as droughts, air pollution, and erosion etc. This is manifested by the producers, who express interest in preserving their plantations, particularly because they are where they have made their homes, which provide them comfort and the ability to generate monetary resources in order to survive.

The producers of Huimango 1st section perceive greater vulnerability, which corresponds to the lower coverage provided by their plantations (<115ha) than that provided for the other communities (297ha) sampled, a finding which coincides with prior estimates made in the region (De La Cruz *et al.*, 2015). Cocoa groves are being cleared in the community of Huimango 1st and transformed into pasture for grazing cattle or to be used for the construction of new neighbourhoods to meet the demand for housing due to excessive population growth (INEGI, 2010). Finally, the community of La Chonita presents greater opportunities for the producer to reassess the value of their *cocoa plantations* and work to conserve them. To this end, priority must be given, not only to seed production but also to the value of all the ESs obtained from these forests, which are currently undervalued due to the lack of information on the importance of these resources and the negative effects caused by this undervaluation. These negative effects include a decrease in both carbon sequestration (Balvanera *et al.*, 2011) and the provision of resources for hosting biodiversity (Feijoo *et al.*, 2011), severely affecting all soil regulation services (Marichal *et al.*, 2014) and reducing quality of life for future generations.

Conclusion

The conservation of the cocoa agroecosystem and the ecosystem services it offers is conditioned on the recovery and preservation of local knowledge and know-how. Its social value must be identified and attributed by the producer and their community through the rational use and exploitation of resources, while, at the same time, recognizing the importance of this agroecosystem for current socioeconomic activities.

The training of producers and their families is required to increase the perception of everything that cocoa farming represents in order to trigger conservation efforts and increase the offer of all ecosystem services. This, coupled with the use of innovative technical resources and the resolute participation of the whole community, would make a great contribution to achieving sustainable local development. Field research on traditional crops such as cocoa will serve as a reference framework, enabling sustainable development to be consolidated in rural communities under the new living conditions currently imposed by the SARS-CoV-2 (*severe acute respiratory syndrome coronavirus 2*) pandemic.

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