Essay

Resilience and sustainability of traditional agroecosystems of Mexico: Totonacapan

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Abstract

In Mexico, traditional agricultural technology, resulting from the thousand-year accumulation of valuable experiences pertinent to the management, exploitation and selection under domestication of a wide range of ethno-resources, continues to be expressed in a wide area. However, due to various negative aspects of the acculturation process, its biological and cultural foundations are at serious risk. Considering the agroecosystem, the integral study unit leading to the understanding of the interrelations involved in the dynamics of its physical, biological and cultural components and having as objective, contribute to the understanding of the ecological and cultural dynamics evidenced in traditional agroecosystems of the Totonacapan. Through experiences derived from more than three decades of work in the region, some distinctive features of these agricultural production systems are described and analyzed, emphasizing the milpa and the mountain as spaces in which knowledge and attitudes related to the production and transmission of knowledge are generated and transmitted. perception, management, use and conservation of ethno-resources inherent to them. Quantitative information linked to the dynamics of this type of agricultural production systems is provided. The applied methods were based on the framework for the evaluation of natural resource management systems incorporating sustainability indicators (MESMIS), life cycle assessment (LCA), ethnobotanical exploration, as well as participatory observation. Based on the definition and evaluation of 15 indexes relevant to their resilience, a transdisciplinary work model is proposed, leading to the measurement of the degree of sustainability evidenced by them. The results indicate that the greater the biocultural legacy transmitted by their ancestors and the attachment of peasant families to it, the greater the ecological and cultural resilience of their agroecosystems and, consequently, the sustainability evidenced by them.

Keywords: agricultural production, conservation, ethno-resources.

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The strategies that led to the emergence, development and consolidation of Mesoamerican civilizations, are correlated -among other aspects- with the perception, management, use and conservation of nature, which made possible the high degree of social evolution that, up to now, evidence this region, which is considered important, not only because of its enormous biodiversity, resulting from the heterogeneity of the ecological environment inherent in the ecosystems in which the taxa have evolved, but because it was one of the independent centers in which it originated agriculture, evidence of the importance of the cultural development of the original peoples that still inhabit this part of the world.

The millenary use of nature by the original peoples, resulted in the identification of a large set of organisms as resources among them plants, some of which were and continue to be used in their wild form, others are tolerated or encouraged, and in some cases, it has been possible to specify the technology conducive to its cultivation and even its domestication. In this millenary process, in addition to the components of the ecological environment, diverse and complex cultural aspects are involved, whose importance is evident both in the management systems, as well as in those related to their use, conservation and selection under domestication.

In Mexico, traditional agricultural technology continues to be expressed over a large area; however, due to various negative aspects of the acculturation process in force, in many rural communities, its ethical and empirical foundations are at serious risk, which is why the registration, understanding and comparison of the criteria involved in this type of agriculture it is urgent to effect.

Considering agroecosystems as one of the most complex anthropogenic expressions, in which, in addition to the multiple interrelationships between the biotope and the biocenosis proper to ecosystems, the inherent culture of the human groups involved in their dynamics greatly increases their complexity, the concepts and methods applied to obtain and analyze the information gathered in this research, required to combine, in addition to those related to agricultural experimentation, others are based on the framework for the evaluation of natural resource management systems incorporating sustainability indicators (MESMIS), criteria derived from the evaluation of the life cycle (LCA), in the postulates established by Hernández (1971) around the ethnobotanical exploration, as well as in the so-called participatory observation.

With the general objective of designing a conceptual method and transdisciplinary work leading to the measurement of sustainability involved in traditional agroecosystems of Mexico, considering them as generators, containers and conservators of agrodiversity, in the present work were generated and applied 15 indices; through, whose application and evaluation was obtained quantitative information linked to the socioeconomic dynamics of two rural families of Totonacapan, based on; the attitudes, the knowledge transmitted, the plots of culture and the vegetal germplasm inherited by their ancestors, manage and take advantage of their agroecosystems of different way.

Considering the importance of knowledge of the cultural variables involved in the understanding of the dynamics of agroecosystems, particularly traditional ones, in this research, as well as defining and measuring variables related to the technology involved in cultivation and other forms of management of existing plant resources in them (eg. those applied to weeds), other variables linked to the selection process under domestication were included, including those related to the use of them.

Being the peasant family an essential component of the traditional agroecosystems of Mexico, the consideration of the attributes of this one is of great importance in the understanding of the dynamics of the traditional agricultural production systems that still exist in the Totonacapan. Within the family nucleus associated with the management of agroecosystems and the use of products derived from them, the influence of women on the criteria applied to the process of phytomedication, as well as on the technology linked to the use of plant resources derived from them, as one of the most important variables in the evaluation of cultural resilience associated with the sustainability of the traditional agroecosystems considered.

In the present study, the influence of women on the sustainability associated with the agroecosystems studied, was measured, considering: 1) knowledge about the uses of existing plants in their plots, in their gardens, as well as in their area of daily action (The surface normally involved in their daily activities, including the paths they walk to reach their plots or to move to the market where they buy, sell or exchange); and 2) the skill and experience evidenced around the processes of use of their plant resources, among them the processes of elaboration of some typical dishes, their knowledge about medicinal plants (some species are considered a priority in the health of the children and even are frequently used before, during and after childbirth), those used as firewood, as well as those related to aspects considered of great practical and cultural importance, such as the flavor incorporated into the broth of the beans, as well as the time required for cooking of their seeds, which are incorporated into the selection pressure conducive to the domestication of their food plants.

Empirical knowledge and cultural resilience

Traditional knowledge is defined as ‘the knowledge, innovations and practices of indigenous and local communities around the world that were conceived from the experience gained; through the centuries and adapted to the local culture and environment’ (CBD). Regrettably, such knowledge and practices have not been effectively protected in such a way that both genetic resources and traditional knowledge are exposed to illegal access and use. Around this problem, two aspects must be distinguished: the use of a tangible element, for example, the biological material or genetic resources and the appropriation of an intangible component, the traditional knowledge associated with its management, exploitation and domestication.

The World Organization of Intellectual Property (WIPO), states that: the tangible component of traditional knowledge refers mainly to genetic resources, while the intangible component refers basically to empirical knowledge, generated, transmitted, accumulated and purified by communities’ traditional peasants for millennia (WIPO, 2001). A distinction is also made between traditional knowledge and indigenous knowledge. The latter is a subset within the category of traditional knowledge and is a knowledge conserved and used by the original communities, peoples and nations (WIPO, 2001; Stoll and Von Hahnm, 2004).

In agreement with Vera *et al*. (2013), however, the worldwide consensus regarding the retribution that the indigenous communities involved in knowledge and management of biological resources should receive for the exploitation of their knowledge by third parties, around which in the CBD it is established that ‘in the use of resources, each party must respect, preserve and maintain the knowledge, innovations and practices of indigenous communities that involve traditional lifestyles relevant to the conservation and sustainable use of biological diversity and promote their application broader, with the approval and participation of those who possess such knowledge, innovations and practices and encourage that the benefits derived from its use be shared equitably' in practice, the necessary mechanisms to prevent illegal access and use have not been provided to genetic resources and traditional knowledge and both international proposals and national, have only been of an exhortative nature so that, in practice, the benefits that have reached them are scarce (if not null).

Considering the need to give concrete and fair compensation for the multiple benefits derived not only from the use of plant germplasm associated with traditional agroecosystems prevalent in Mexico, this study aims to generate, apply and evaluate some indicators leading to the measurement of sustainability evidenced in traditional agroecosystems of Totonacapan, for, based on this information, propose a model conducive The above, considering the urgent need to protect not only the germplasm of plant taxa involved in them, but also the millennial knowledge associated with the management and use of this type of agroecosystems, since these are in risk of disappearing before the irrational extension of the agricultural frontier, in which the extension of the monocultures has been the paradigm to follow, being propitious with it severe negative transformations so much ecological as cultural.

The importance of conserving agrobiodiversity generated in agroecosystems, lies in the following reasons:

i) Unlike conventional Germplasm Banks (cold rooms and other alternatives called *ex situ*), the selection process under domestication involved in traditional agroecosystems allows not only the conservation of plant germplasm, but its continuous genetic improvement.

ii) It is in traditional agroecosystems where, through example, the generation and transmission of knowledge and attitudes pertinent to the management of the plant resources existing in them occur, at the same time promoting the evaluation and practical purification of the same.

iii) Because of its location (extremely limited conditions: steep slopes, low seasonal sowing, shallow soils ...), traditional agroecosystems are priority areas of interest for agronomic research, which, unlike the research carried out in the experimental fields allow us to measure the multiple interrelationships between agrobiodiversity, the ecological environment and the culture inherent in the management, use and conservation of plant resources.

The foregoing, refers to the importance of plant resources for humans must consider, in addition to their production and consumption, many other aspects related to genetic properties that through their evolution, allows them to perform different functions within the ecosystems located in the mountains, as well as in the interior of agroecosystems, among which the milpa stands out, generating multiple indispensable services in the life of human beings (regulation of temperature, carbon capture, regulation of the water cycle, etc.), levels that are identified in the definition of biodiversity and agrodiversity, indicated in the convention on biological diversity.

Agroecosystems are ecosystems that have been deliberately transformed (often simplified) by man for the production of goods of value to humans (Swift *et al*., 2004), from plants, animals and microorganisms. In agreement with Cuevas (2001), the simplification of the management of modern agroecosystems has frequently led to: 1) the reduction in the number and variability of cultivated plant species and genotypes, often restricted to monocultures of commercial importance; 2) the reduction in the members of the family that intervene directly in the production process; 3) interest in productivity and competitiveness often ignores sustainability in the analysis of its efficiency; and 4) the irrational expansion of the agricultural frontier, an aspect that, in turn, has led to the extinction or underutilization of a wide range of plant *taxa*.

Understanding the dynamics of agroecosystems involves a complex set of variables and interactions, among which are those related to the energy invested in each stage of food production by said human group, which, unfortunately, are still ignored in the official education of agronomists in general and in particular of the specialists in plant breeding. Regarding the energy efficiency involved in the traditional agroecosystems Rappaport (1978), in his classic work on the flow of energy in an agricultural society, he demonstrates the rationality in the management of the resources used by the Tsembaga group of New Guinea, after a meticulous calculation of the energy invested in each phase of the management under slash-burn of their agroecosystems, finds that, on average, for each kilocalorie invested in their agroecosystems, there is a gain of up to 20.1 kilocalories, a figure hardly found in agroecosystems modern, in which, the use of fossil fuels frequently registers an inverse relationship.

With regard to the reduction of specific and genetic diversity increasingly evident in modern agroecosystems, Pernes (1973) indicates: the modern improvement of plants, by means of elaborate genetic techniques, is a tributary of the gene diversity maintained without ceasing within the natural populations (La Recherche, 1973). Inversely, this shows how necessary it is to maintain the genetic diversity present in these populations and that the traditional farmer takes care intuitively when he watches over his field and chooses his seeds. ‘If we want to avoid agronomic catastrophes in the future it is necessary to lovingly preserve both the populations of the wild forms and those of the traditional varieties’.

However, the importance of wild plant populations, many of which, in addition to containing genetic information for the improvement of a wide range of cultivated plants, have attributes of anthropocentric interest that show their potential to develop new plant resources. Unfortunately, in agreement with Cuevas (2013). ‘Since its consolidation as a branch of science, agronomic research has been carried out mainly at the species level, involving in many cases only the statistical evaluation of the yield expressed by a few varieties or genotypes domesticated in the remote past. With the exception of some brilliant works for their integrating effort, most of the agronomic works have not taken into account the complex set of interactions that, objectively, evidence the biocoenosis, the biotope and the culture of the human groups involved in agroecosystems. Accustomed to judging the benefits derived from plants almost always from the partial perspective of economic gain, the ecological or cultural functions that a large number of wild plant resources perform, have not been sufficiently valued’.

Being the genetic resources (plants, animals and microorganisms) part of the most important materials on which the life and development of humanity is based and considering the agroecosystems the scenario where the complex set of interactions related to agriculture is manifested, in this research demonstrates the urgent need to analyze the path to follow for the protection of the biocultural heritage involved in the dynamics of the agroecosystems of Mexico.

Mexico is amply recognized as one of the countries with the greatest biological, ecological and cultural diversity of the planet because of the species and ecosystems it has, even with wild populations of several *taxa* of diverse organisms of anthropocentric interest. In addition, for its ethnic richness and cultural development, our country stands out as one of the centers of origin of agriculture. Unfortunately, due to the irrational expansion of the agricultural frontier, many of these resources of current or potential use are at serious risk of extinction.

However, the privileged situation referred to above, we have done little to have public policies, the legal framework and scientific strategies to sustainably benefit from such immense wealth. Efforts made by national institutions are acknowledged, as well as by some of the international sphere, which, for the most part, have been carried out in a dispersed manner, with different motivations and, in many cases, following specific objectives, generally circumscribed to the institutional sphere. This has irremediably led to the duplication of efforts in all the activities associated with the study of biodiversity in general and in particular of that involved in agricultural activities; that is, agrodiversity.

Evaluation of the sustainability of agroecosystems

Several authors agree that sustainability involves ecological, social and economic problems and when trying to study each of them separately, the rest is subtracted. That is why, as mentioned, it is important to study and propose models that allow analyzing the sustainability of an agroecosystem as a whole, with its relevant amplitudes and limitations. On the other hand, there are still policies that consider only one of the aspects, leaving out the importance of the environment or economic development, or thinking that social participation is the remedy for all problems. The theoretical framework that supports each of these policies is adequate, for a part of reality. However, given their bias, they are not enough. Unfortunately, scientific research has not yet been able to develop integral theories that can recognize the synergies and limitations between nature, economic activities and people.

It is for the foregoing that, in the present work, as well as in other similar works, the use of the so-called indicators is used, which will help us to determine which are the aspects that make up an agroecosystem and that do it, as a whole, a true image of the state of it. Thus, the indicators will have to derive in a numerical value, a synthesis of information of a social, economic and environmental nature. With more information, we seek to minimize the probability of policy failures tending to promote the sustainable management of the environment.

Sustainability is part of the subset derived from the intersection of the three components of study, society, economy and the ecological environment. As can be seen in Figure 1, the subset resulting from the intersection of society and the economy is equitable the intersections between the ecological environment, and separately, with the economy are viable.

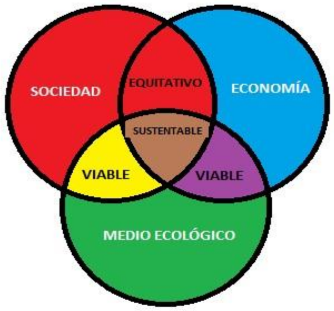

Figure 1. Interactions between the ecological environment, the economy and society.

In the analysis of the dynamics of agroecosystems, different methodologies have been used to evaluate sustainability, from very detailed ones, only applicable to experimental conditions, to other very general ones, going from the simple taking of data to the field, by surveys and interviews and reaching until the prediction by means of regression equations and simulation models.

In this work, it is intended to contribute to the design of a sustainability assessment model associated with the traditional agroecosystems of Mexico that, based on a conceptual framework that includes the scope of the different branches of science involved, allows the measurement of resilience ecological and cultural on which the degree of sustainability evidenced by them depends to a great extent.

Indicators of sustainability

The indicators are variables or a set of variables in a simplified model of the system under study. In this process of dimensioning the indicators, two models were managed, the inductive and the deductive. The first refers to thoughts that start from particular facts to general statements, which implies, for example, moving from the results obtained in an experiment to the hypothesis, laws or theories. The deduction, on the other hand, part of general statements to particular facts, this allows us, for example, that from the use of certain premises we can draw conclusions.

Resilience as an indicator of sustainable development

From the ecological point of view, 'sustainability requires the establishment of dynamic and larger-scale relations between economic and ecological systems, in order to ensure that human life continues on a permanent basis and according to the diversity of cultures that exist, and where , therefore, the effects of human activities do not exceed environmental limits that destroy or minimize the diversity, complexity and functions of ecosystems', Castiblanco (2002) [which are precisely those that support the life of the different organisms]. We emphasize that this criterion of sustainability should guide policies, strategies and concrete actions leading towards its greater purpose: sustainable development. In this regard, Castiblanco cites Common and Perrings (Correa, 2003), who affirm 'ecological sustainability is not a state that can be defined by simple rules. It can be said that it is rather the resilience of the system that must be maintained over time'. That is to say, in a sense similar to that indicated by Leff in the previous paragraph, they refer to the stability and equilibrium capacity of ecosystems in a time horizon.

'Stability refers to the ability of populations to return to equilibrium, after any disturbance or alteration of ecosystems has occurred. Resilience is a broader concept that measures the propensity of ecosystems to maintain their main features after an alteration' (Castiblanco, 2002).

Therefore, we must assume that to apply the criterion of sustainability to development, it is necessary to consider, in the first place, the degree of resilience and stability of agroecosystems, in order to finally be clear that certain development models may be contrary to the possibility of sustainability of the same if there are no criteria of environmental rationality in the use of natural resources and reasonable thresholds of extraction of the natural stock available in the intervention spaces (i. e., considering its temporality and replacement costs if they are renewable resources or non-renewable).

In this work, as in some others shown by the aforementioned authors, not only economic growth *per se* is privileged but also in relation to its interaction with the other variables of the ecological and social environment.

Objectives of sustainability indicators

1. Measure the distance and direction of the variation of an environmental system between: the initial state of the system (reality data) and the state of transition of the system towards a sustainable performance scenario of society; and 2. Provide an empirical and numerical basis to know the problems, calculate the impact of our activities on the environment and to evaluate the performance of public policies. Indicators make communication easier by simplifying complex phenomena and translating them into numerical terms. Measurements help decision makers and society define goals and objectives. When observed over time, they should be able to communicate specific information about progress and indirectly demonstrate the efficiency of programs and policies designed to promote sustainability.

The design of a good indicator of sustainability is a difficult task, involves the challenge of combining social, economic and ecological aspects, as well as explaining the relationships between these three factors. An integral and reliable indicator will be useful to eventually be able to place the evaluation of sustainable development at the same level as the evaluation of GDP. This will earn and maintain a place in the political and economic agenda.

Definition of sustainability indicators

In agreement with Achkar (1999), sustainability indicators are variables that represent another variable or a set of variables in a simplified model of the system under study and whose main objective is to measure the distance and direction of variation of a system environmental between: 'the initial state of the system (data of reality) and the state of transition of the system towards a sustainable performance scenario of society'.

For this study and taking into account other models proposed for the measurement of sustainability, we must first answer some questions: Are the traditional indicators used to measure the performance of an agroecosystem adequate to monitor different levels of sustainability?, The sustainability indicators of an agroecosystem should be oriented, only, in the economic sense?, Is it possible to construct indicators that make possible the comparison in different situations, such as ecological and cultural?

In this sense, this work proposes the construction of sustainability indicators that allow obtaining an overview of the real situation of a particular agroecosystem. Thus, the three initial questions form the basis of the discussion, how to measure the distance that a determined agroecosystem finds itself in, in sustainable development? The answers that can be constructed constitute the fundamental tools to implement and adjust the policies that should lead to the designed sustainability scenario.

Location of area of study

It is important to delimit the area of study, because, to a large extent, it depends on the measurement of the degree of sustainability associated with the management of agroecosystems. The two agroecosystems selected for the realization of this study are located in the community of Ecatlan, located at 20° 03’ 11.66’’ North latitude and 97° 33’ 25.59’’ West longitude in the Sierra Norte of Puebla, whose climate is A (C) (w) I g; that is, it is a transitional climate, tropical but with a tendency to be temperate, with an average annual temperature of 21.4 °C and that of the coldest month >18°, with an annual average precipitation of 2 845 mm, isothermal (<5 °C), and an annual March of the Ganges-type temperature, at an average elevation of 630 meters above sea level. The Andosols, are the predominant types of soil on the hills that show strong slopes, which sometimes reach >30°, presenting few relicts of Medium Perennifolia Jungle.

The forest and its plant resources: forest subsystem

The mountain, is a term that the country people use to refer to the hills, rivers and little-traveled trails from which, often also obtains diverse satisfiers both vegetables (firewood, materials for construction, food, medicine and even ceremonial plants) and animals (hunting continues to be important in many communities). Of the different types of existing vegetation (forests, jungles, bushes ...) in the forest, the wood that will be used for the construction of houses, corrals, tools, cooking utensils, handicrafts and firewood is extracted, this being one of the most important given its indispensable presence in most homes of indigenous families.

Integration of indicators

After the determination and differentiation of the criteria leading to the selection of the indicators, we proceeded to its analysis for the standardization of the results. For its sustainability, and to determine the maximum and minimum values that allow us to establish a point of reference in order to determine the performance of each of the agroecosystems in each indicator (Table 1).

Table 1. Standardized value of the indicators.

Proposed indicator	Traditional	Reference	Minimum value	Maximum value
Family participation	1	0	0	1
B/C ratio	1.5	3.1	1	4
Energy efficiency	8.4	2.8	1	10
Erosion	1	2	0	3
Fertility	1.6	1.9	1	2
Plant diversity	21	1	1	30
Animal diversity	9	0	0	9
Microbial diversity (%)	90	10	0	100
(%) of beneficiaries of government programs	40	86	0	100
Access to technological innovation	0.37	1	0	1
Input dependency (%)	6.8	84.5	0	100
(%) of farmers in production associations	80	20	0	100
Knowledge inherent to the environment and to the use of its	1	0.2	0	1
Biodiversity loss	1	0.2	0	1

Once the reference values are established, the data is standardized with the following equation:

$$IS=\frac{V_o-V_{min}}{V_{max}-V_{min}}*100$$

Where: IS= standardized indicator; V_o= value obtained; $V_{mín}$= minimum value; $V_{máx}$= maximum value.

Conclusions

The greater the biocultural legacy transmitted by their ancestors and the attachment of peasant families to it, the greater the ecological and cultural resilience of their agroecosystems and, consequently, the sustainability evidenced by them.

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