Indicators of Traditional Ecological Knowledge and Use of Plant Diversity for Sustainable Development

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1. Introduction

Mexico is a country biologically and culturally diverse, historically linked to peasant and indigenous people who derived livelihood from nature and contributing to generate the traditional ecological knowledge, which leads to sustainable resource management adapted to the availability, needs, and options. Internationally, it has been suggested the involvement of indigenous and local communities to generate plans of social development, biodiversity conservation, environmental impact assessments, enact laws, and for the generation of criteria and useful indicators in the evaluation and monitoring of the utilization of natural resources. The goal of sustainable development is to meet human needs and aspirations through the development of human progress towards protecting the future (ONU, 1992).

Sustainable development indicators used by the international community tend to be based on information available at the official statistics of countries, however, there are elements of each nation that are essential for survival and social development, and are excluded from official assessments. In Mexico, the contribution of indigenous and local communities to national development is not quantified, although these communities protect much of the biological and cultural diversity of the country (Boege, 2009). Biodiversity is essential for the survival of a social sector permanently subjected to exploitation and marginalization, which represents approximately 80% of the population nationwide (Boltvinik & Hernández-Laos, 2000).

Together with the global social development, indicators are required at national level to meet the particularities of countries like Mexico, which account with great cultural and biological heritage, in which social participation has been limited for educational, legal, or lack of access to timely information. Even more difficult, is the acknowledgement of the traditional ecological knowledge and the vision held by people of indigenous and local communities. The generation of environmental indicators and use of biodiversity based on traditional ecological knowledge is an opportunity to learn about cultural diversity, to describe the current health of the ecosystem, and monitoring the changes of this kind of knowledge, since as far as this kind of knowledge maintains its functionality it might meet the needs of the stakeholders. The contribution of the indicators could transcend into the evaluation and follow up of the actions undertaken to achieve social development. This proposal is viable in Mexico because there are numerous research papers on Ethnobiology providing information about the knowledge underlying the utilization of biodiversity. Also it is relevant as long as, it has been probed the economic importance of forest for the people who take advantage of them and utilizing the traditional ecological knowledge.

2. Background

Traditional ecological knowledge has kept for some time and the value of this cumulative and dynamic process, practices, experiences, adaptation to local circumstances, holistic and useful, has taken up to improve the capacity of societies to manage natural resources, especially in changing and uncertain conditions. The value of this knowledge applies to various disciplines including business, such as the search for active ingredients of plants which increases the efficiency of the process 400 times (Reyes-García, 2009). However, according to the author, it is clear that the over-exploitation of common pool resources (Ostrom et al., 1999) is a problem linked to others that they occur in chained form, for example, over-exploitation is the result of open access to resources leading to the collapse of production, erosion of traditional systems of resource management and lost of traditional ecological knowledge, according to the incorporation of indigenous or rural communities into the market economy or school education.

Taxonomic groups as indicators of diversity have become useful in the characterization of certain cases for the identification and resources utilization, however, they reflect snapshot conditions of a situation (Halffter & Moreno, 2005), more than development of spatial and temporary processes. The importance of sustainability in the loss of resources is increasingly, yet, the common contempt for the indigenous communities as sites of consensus when it comes to resource management (Natcher & Hickey, 2002), biased decisions unilaterally in social development programs. Persha et al. (2011) shows that forests tend to be sustainable when users have the right to participate in government programs, formally recognized.

2.1 Traditional ecological knowledge

Traditional ecological knowledge is rooted in the population, emerges as a complex of components such as knowledge, beliefs and practices (Berkes et al., 2000), inherited through generations, and whose significance is denoted by maximizing the diversity of livelihood options that evolve through processes adaptive, encourage diversity to face environmental, social, economic or political, with minimal risk (Toledo et al., 2003). There are synergies of the direct and indirect influences affecting the components of traditional ecological knowledge (Millennium Ecosystem Assessment, 2005; Challenger & Dirzo 2009). Indirect factors include the development models that foster inequality and poverty, discriminatory government policies, and institutions and local knowledge holders, limited participation of citizens and the local population during the implementation and evaluation of development models; in the meantime the direct factors include a lack of consideration for cultural diversity, availability of goods and services more accessible and affordable, health systems predominantly based on allopathic medicine, landscape fragmentation, environmental degradation, and cultural erosion among others.

Traditional ecological knowledge is an expression of cultural diversity which has been instrumental in the conservation of resources and meeting basic social needs, supports the management of natural resources by peasant strategy of appropriation of nature, ability to characterize by maintaining high levels of diversity, to promote the resilience of ecosystems which have been sustainable (Toledo et al., 2003).

Five of the dimensions that conform the peasant strategy to maximize social commodities are: use of families, genera and species, use as many native species, maximizing the number of uses assigned to the species, integral utilization of species, and maximizing use of available species in the wild. Consequently, it is necessary to understand and respect the culture of communities, while protecting the traditional knowledge systems.

Culture is key to achieving sustainable development (UNESCO, 2010). The information generated by ethnobiology, scientific discipline that investigates and systematized traditional ecological knowledge, provides information on the use of the species. The information obtained is adapted to function as indicators of the state of resources and production potential for matters concerning the management of diversity. The Commission on Sustainable Development (CSD, 2000) proposes various indicators related to social, economic, environmental and institutional as well as to specify information that is also comparable between different entities.

So far there are laws, regulations, standards and indicators related to biodiversity, for example, the National Environmental Indicators, which includes among others: the production of timber resources, the number of species found at risk or protected natural areas. However, lacks of instruments to consider the interaction of biological diversity with cultural diversity. One argument in favor of the creation of such legal instruments and environmental planning is the overlapping of priority areas based on their biological characteristics, the territories of indigenous peoples and communities in Mexico. On the other hand, the participation of traditional ecological knowledge in decision making is political and social limited for various reasons, including the ideology held by people of indigenous and local communities.

Actually there are technical and financial difficulties to obtain information on the interaction between biological and cultural diversity throughout the country. Meanwhile numerous research papers have documented traditional ecological knowledge that underpins the use and benefits of diversity in rural communities, towns and biogeographic regions. Therefore, these works have the potential to clarify or modify laws, regulations and rules in light of the conditions of biological diversity and cultural knowledge available. One area of opportunity for the incorporation of traditional ecological knowledge in planning instruments is the generation of Environmental Indicators and Use of Biodiversity, inclusive of the needs and characteristics of the cultures involved, so that, having this type of indicators is possible: a) a description of current state and the transformation of traditional ecological knowledge on natural resources, and b) knowledge of the biodiversity that is being used for self-support (needs of the community without marketing purposes). This type of information accumulated historically and of intangible value, goes unnoticed in the statistics on domestic natural resources, like medicinal plants.

2.2 Indicators

One way to enhance the contribution of traditional ecological knowledge for subsistence, conservation and sustainable use of biodiversity, is the generation of indicators. There are instruments to assist decision making for the planning of sustainable development (UN, 2009). The indicators vary according to the definition of purpose, are descriptive, based on components, objects or processes, normative (prescriptive and assessed for changes in condition or efficiency of management), or hybrids (descriptive and normative) (Heink & Kowarik, 2010). In general, indicators should be useful to diagnose an environmental situation, to evaluate the condition or state of the environment or to provide early signals of change. Therefore, should include attributes that would inform the structure, function and composition of ecological systems (Dale & Beyeler, 2001). The scale at which indicators should be generated varies from small local to larger scales, inclusive of provinces, regions and countries. Indicators should also consider an interaction of both development elements: environmental and social, and should link culture with nature.

Internationally there are successful experiences around the participatory generation of indicators in the conservation, management and evaluation of action research for agriculture, the quality of water bodies, local coastal management and environmental degradation. As an example, Munis de Medeiros et al. (2011) used five indicators picking patterns and perception, to estimate the pressure of use, and three categories of impact, due to timber harvest in northeastern Brazil. The indicators are related to the volume of wood consumption, indices of diversity and equity. The conclusion points out that the use of wood energy facilitates the use of greater importance and recommends to specify which species are the highest quality fuel, taking into account the preference of consumers, ecological information in plants, forest seral stage, and post-disturbance regenerative capacity.

It should also be considered under the concept of perception, and what importance do people give to plants or plant uses. In ethnobotany, number of mentions of a plant by the respondents, is an indicator of the intensity of use of a species (Muthcnick & McCarthy, 1997; Begossi et al., 2002). We believe that linking culture with nature through traditional ecological knowledge could be useful for decision-making in the development of policies, plans and development programs.

2.3 Sustainability

In the case of the sustainability of resources, it is important to consider the role of local community initiatives, as in the case of Belize where maintenance of wildlife depends largely on the protection of land through patrolling and systematic evaluation by local users who own the land and operators of resources, including protected areas by the government (Horwich et al., 2011). Sustainability indicators are used in different ways, also in terms of objectives, some of which are only environmental, social or financial, while some are multi-scale, hierarchical, and in other cases, are specific inputs for political reasons aimed at sustainable practices, viewed through systematic observation of changes in holdings (Caceres, 2009). The Framework for the Evaluation of Systems Management of natural resources through Sustainability Indicators (MESMIS) has excelled in Latin America and especially Mexico, as it proposes a systematic framework, participatory, interdisciplinary and flexible approach to assessing the sustainability of agricultural systems. Some of the rates quoted by the author are

EI: ecological index based on physiognomy, erosion and vegetation covers; SI: socioeconomic index based on family income and food security; and LSI: land sustainability index supported by the articulation factor of socioeconomic index plus the ecological index based on specific variables. It has been suggested that achieving a positive impact on biodiversity must be considered as the aggregation of variables and temporal scales of study. To Heink & Kowarik (2010), sustainability is a complex indicandum because it is additive composed of a set of indicators, as outlined in the previous reference in the operation of the term which depends on its original conceptualization. They reiterated that sustainability is a multidimensional indicandum including environmental compatibility, social acceptability, justice and economic development.

Natcher & Hickey (2002) have included in a small area near Alberta, systematic recording of changes in management plans based on objectives, criteria, indicators and actions. In the case of forest management, they consider that the native community should be helped to access to land and resources, protection of the areas identified by members of the community, as important, meaningful historical, biological, cultural, and protection rights to perform various activities in the forest, promote economic opportunities for members of the community, and enabling their participation in the decision-making processes.

3. Contributions based on traditional ecological knowledge and indicators

Due to the rapid transformation of the natural environment in the state of Morelos, Mexico, we need indicators based on the potential of biological and cultural diversity, to generate sustainable development decisions. In this chapter we contribute with some useful indicators for assessing the status of traditional ecological knowledge and the use of biodiversity by rural communities of the state of Morelos (1.7×10^6 inhabitants in an area of 4893 km^2), Mexico. This region occupies 0.2% of the area of Mexico and has tropical deciduous forest in the warm zone, where we have research on the traditional ecological knowledge generated by the local people. The indicators studied were based on the strategies for local use. We pretend that the cultural value and the intangible and implicit traditional ecological knowledge should be known, capitalize and transform in cultural, ecological, economic, and social value useful for sustainable social development, and also serve as an instrument to regulate public policy of utilization of resources.

Should be mentioned as background that we have worked with local traditional knowledge for sustainable non-timber forest species, assuming that traditional knowledge related to using a group of plant species is widely known among local people. We got ethnobiological information from 1979 up to now, based on structured interviews and participatory workshops, to learn about traditional ecological knowledge and non-timber forest species of local importance for use and conservation purposes. Also, we have studied the multiple and comprehensive utilization of resources for firewood (Monroy & Monroy-Ortiz, 2003), charcoal and orchards. As a result, 24 Ethnobiological reports concluded up to 2001 which were systematized (Monroy-Ortiz & Monroy, 2006). Likewise, we used bibliographic information to elaborate databases for medicinal plants (Monroy-Ortiz & Castillo, 2007). For the analysis of local knowledge and indicators using descriptive and multivariate statistics, fieldwork as check up applying the scientific method coupled with demographic assessment of floristic resources and uses (Monroy-Ortiz et al., 2009). In the next lines we mention the wealth of plants used some of the general traits of traditional ecological knowledge registered; we discussed briefly the importance of medicinal plants and also the form of supply of firewood.

3.1 Richness of medicinal plants used

We recorded 581 species belonging to 402 families used and 130 botanical families. The absolute values of the services registered (Figure 1) include different plant parts that meet the various needs of society, so that traditional ecological knowledge held by people in the communities studied, allow them to obtain a wide range of provision, regulation, supporting and cultural services.

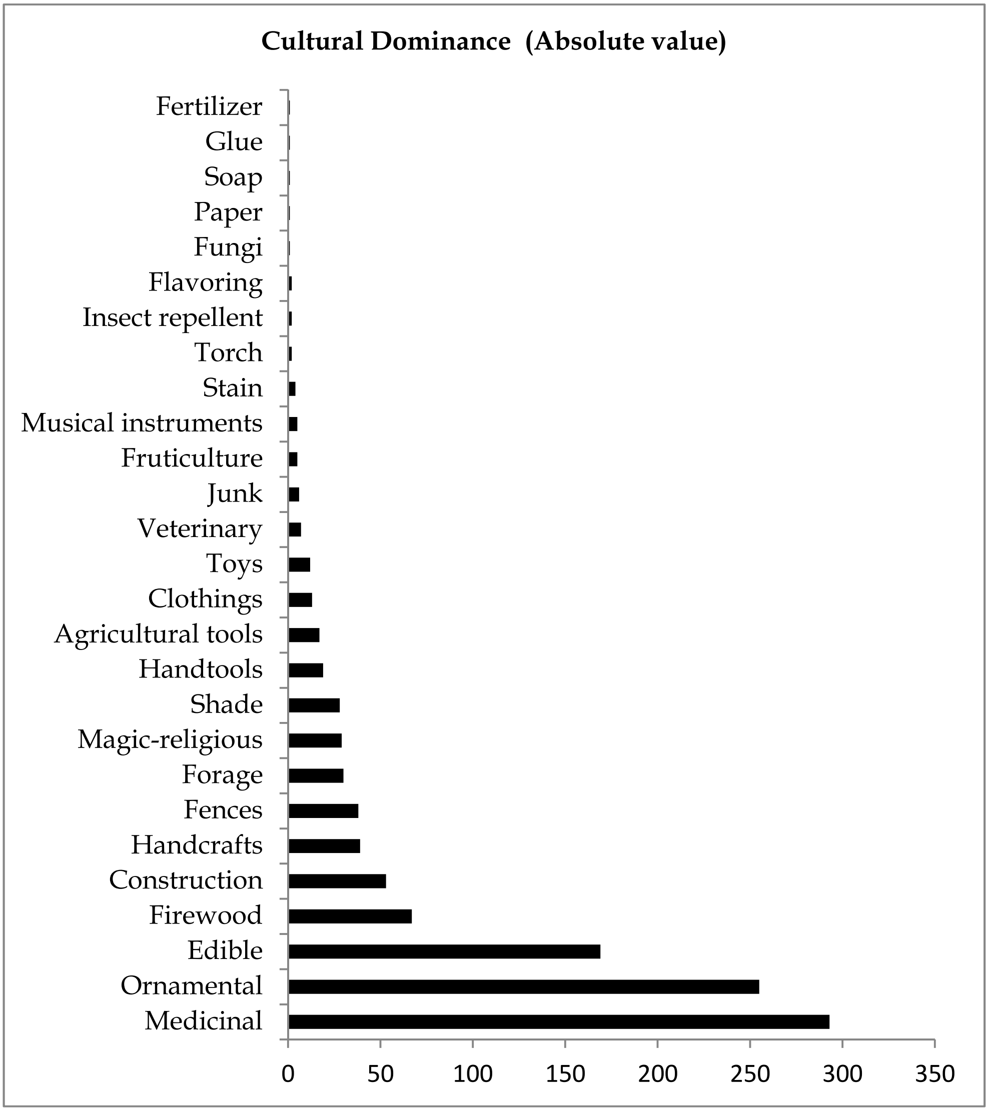

Fig. 1. Provision, regulation and cultural services of the tropical deciduous forests of the State of Morelos.

Highlights the medicinal, ornamental and edible uses, the first two are essential for survival and reproduction of society (Gispert & Rodriguez, 1998). Medicinal and edible uses are closely related to each other by facilitating the free flow of species. The ornamental use is related to the favorable climate for cultivation, making it economically productive. It is interesting that in the group of ornamental plants there is a notable tendency toward homogenization of diversity and the replacement of native flora by introduced species such as *Ficus benjamina* L., which replaces to the native urban woodland of *Plumeria rubra* L. or *Tabebuia rosea* (Bertol.) DC., two trees noted for its beautiful flowers. It should be mention that there is a transition in the use of an ornamental species for medicinal including exotic species that are empirically evaluated by their medicinal potential (Bennett & Prance, 2000). This is the case of *Ricinus communis* L. a plant native to Africa that is used in Morelos to elaborate a poultice that is applied on the feet and abdomen to reduce fever. The transition from the ornamental to medicinal demonstrates the importance of underestimating the types of use considered non-dominant and expendable.

We think it is necessary to examine whether the transition of uses due to losing a plant resource or traditional knowledge associated with it, it would encourage a multiplier effect of cultural erosion.

3.2 Importance of using medicinal plants in Morelos State

A total of 821 species of medicinal plants are used to cure diseases of 22 kinds of systems and apparatus (Monroy-Ortiz & Castillo 2007). Just for the digestive system there are 453 plant species, 54% of the 842 species. For trauma treatments the people use 224 species (27%). The prevalence of digestive illness is probably related to poverty and extreme poverty in which they live 80% of Mexicans. Other illnesses treated with plants, according to traditional knowledge, for the state of Morelos are shown in Figure 2.

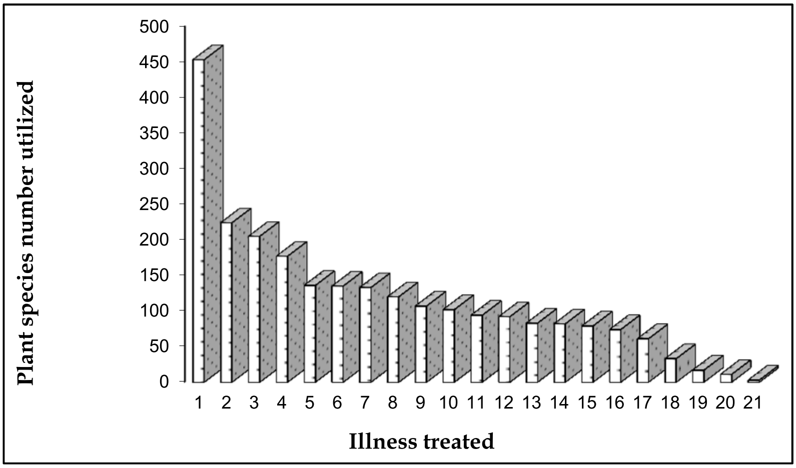

Fig. 2. Species number used to treat different illness: 1 digestive, 2 trauma, 3 symptomatic, 4 respiratory, 5 female sex, 6 urinary, 7 muscle-skeletal, 8 nerve, 9 circulatory, 10 metabolic, 11 nonspecific, 12 "cultural" cold or fright, 13 children, 14 poisoning, 15 infectious, 16 treatment, 17 malignancies, 18 eye, 19 ear, 20 male sex, 21 psychiatric.

It should be noted that acute respiratory illnesses were the leading cause of morbidity in people of Morelos between 2000 and 2009. During the same period intestinal infections occupied the 2nd place of morbidity (SSM 2011). People interviewed on the use of plants have traditional knowledge that allows them to use a more accessible and less expensive to address two of the leading causes of illness. Therefore, it is important to spread knowledge and use of such species. The identity of the species and medicinal plants represent the indicators that explain the most frequent morbidity and mortality in the population. We reiterate the importance to spread knowledge and use of native species which are also useful to many people. We recorded a few plants for the treatment of diseases of the circulatory system, diabetes or malignancy. This situation is related to the recent evolution of these diseases in the communities.

3.3 Use of firewood

Obtaining energy from wood is still a key activity for family subsistence. In Mexico, 80% of the inhabitants of rural communities generate energy from the firewood (Balvanera et al., 2009). In addition, extraction of firewood is a source of income for people living in areas with a climate that has a markedly seasonal rainfall, as in the dry season cannot cultivate the land. This activity is the only source of income for Cuauchichinola Limón households. This community lives in poverty and the collection of firewood is the only source of income for families, for a period of 5 to 7 months, each year. To evaluate the effect of the removal of wood on the tree community, it was assumed a gradient of extraction, which would increase the intensity of collection of firewood with closeness to the households. We worked with randomized blocks in a pseudo-replication. The distance for each block is delimited depending on the frequency distribution of the extraction trips. We counted in blocks and measured for diameter stumps and the same procedure was applied to the tree community to have an area index in both cases. Extraction variables were the number of stumps, and the number of standing trees plus the number of stumps. The indicator of disturbance caused by the extraction equals the number and area of the stumps in relation to the total recorded in the tree community.

The collectors selected 18 of the 47 tree species recorded for use as firewood, based on criteria such as hardness when cutting and burning characteristics. Disturbance indices show a gradient in the density of the tree community concentrating higher density in the far side of the community. Five species density changed on this gradient. Firewood extraction implies a possible conservation value supported by the lore, for biological reasons: using the species and plant stage development with the best quality for combustion, plants of seed dispersal anemocorous and without dormancy, to ensure prompt germination, development and recovery of the trees felled. Another good response of traditional knowledge is timely and not causes disturbance or riot-fell catastrophic, which minimally impacts, similar to a falling tree in the forest, which retains the seral stage of vegetation, and finally, with leading order of collection which begins with the branches before proceeding to the whole tree logs, and branches includes half of the tree biomass. In this way, the community is provided with firewood but the tree has opportunity to re-growth and recovering its structure. The benefits referred to as selective logging, promote density (Bruenig, 1991) and dominance of certain tree species. In conclusion, the appropriation of firewood is an activity that reveals the lore of the inhabitants of “El Limón” on the tree community around them. This knowledge translates into conservation management practices that could be incorporated into a plan for sustainable forestry, based on the active participation of the inhabitants of this community.

4. Studies at local-regional scale

4.1 Method

Indicators of current status of traditional ecological knowledge were estimated indirectly, to investigate how people maximize the utilization of biodiversity and the number of options for attaining survival, from plant resources availability. For the development of the indicators we elaborated a database of plants used traditionally consulting bibliographic information about six case studies that describe the traditional use of plants from the viewpoint of resource inventory. We selected these dimensions in order to homogenize and compare the six selected cases since there are some differences in the kind of traditional ecological knowledge registered by each author. Although sometimes was possible search complementary dates to homogenize information using the floristic list of plant used, such is the case of the origin of the plants, we thought that not always is correct. For example, some authors give information about the distribution of the use of the different plant species during a year; another describes the status of conservation of the vegetation where the plants are collected or classify the management degree of the plants used as cultivated, tolerated, or promoted. In these examples, we have some of the specific characteristics of local management which corresponds to a particular cultural, environmental and technological development framework and should not be inferred from a different local framework. The ethnobotanical information was classified based on the next five dimensions designed to describe the maximization of the diversity and number of options for the use of plant resources (see Equation 1-13):

Dimension 1. Use of families, genera and species of useful plants

Indicators estimated based on the territorial extension.

These indicators will provide a measure of the availability of useful resources per unit area, which allows comparisons with other studies and at different geographical scales (local, municipal, state, national). It is also an indirect measure of the potential of traditional ecological knowledge to generate goods and services and its condition. A higher value would indicate a greater availability of useful resources.

$$\frac{\text{Number of botanical families with wild and cultivated useful species}}{\text{Municipal area}} \tag{1}$$

$$\frac{\text{Number of genera with wild and cultivated useful species}}{\text{Municipal area}} \tag{2}$$

$$\frac{\text{Number of wild and cultivated useful species}}{\text{Municipal area}} \tag{3}$$

$$\frac{\text{Number of plant families with wild useful species}}{\text{Municipal area}} \tag{4}$$

$$\frac{\text{Number of botanical genera with wild useful species}}{\text{Municipal area}} \tag{5}$$

$$\frac{\text{Number of botanical wild useful species}}{\text{Municipal area}} \tag{6}$$

Indicators estimated based on the botanical richness

These indicators give us a measure of the richness of families, genera and plant species, which is being used locally. This scale is used for comparison because it is more likely to use the resources in the locality. A greater tendency to use diversity could be a proxy for the state of conservation of traditional ecological knowledge, as when resources are best known to have the potential for exploitation. Consider that among the limitations of these studies, nor floristic inventories, nor can ethnobotanical be fully known.

$$\frac{\text{Number of botanical families with wild and cultivated useful species}}{\text{Number of inhabitants in the community}} \tag{7}$$

$$\frac{\text{Number of botanical genera with wild and cultivated useful species}}{\text{Number of inhabitants in the community}} \tag{8}$$

$$\frac{\text{Number of wild and cultivated useful species}}{\text{Number of inhabitants in the community}} \tag{9}$$

$$\text{Ratio of plant families used} = \frac{\text{Number of botanical families with wild useful species per location}}{\text{Number of families with wild plants registered in the Morelos state}} \times 100 \tag{10}$$

$$\text{Ratio of botanical genera used} = \frac{\text{Number of botanical genera with wild useful species per location}}{\text{Number of genera with wild plants registered in the Morelos state}} \times 100 \tag{11}$$

$$\text{Ratio of plants used} = \frac{\text{Number of wild useful species per location}}{\text{Number of wild plants registered in the Morelos state}} \times 100 \tag{12}$$

Dimension 2. Use as many native species

Proportion of native useful species

Proportion of useful introduced species

The use of a greater proportion of useful species would show that the introduced species replace the use of local flora. The value from the relationship between native and wild shows how many wild plants are used for each one introduced species. Therefore, if we obtain greater numbers, the relevance of native plants is greater. The replacement of native species by introduced species is interpreted as a proxy for the replacement of local traditional ecological knowledge and the reduction of plant resources available. If this were the case, the generation of options to satisfy the necessities for survival of the community will be diminishes.

$$\frac{\text{Number of useful native species}}{\text{Number of useful introduced species}}$$

Dimension 3. Maximizing the number of uses assigned to the species

Proportion of useful species by number of uses.

This indicator is an indirect measure of the conservation status about traditional ecological knowledge. It is expected that the number of useful plants was greater where there is greater preservation of knowledge. In areas where there is less conservation of traditional ecological knowledge we would expect the absence of species with numerous uses. Therefore, this is an indicator of the state of conservation of traditional ecological knowledge. The same indicator shows the potential of traditional ecological knowledge to solve more than a basic need.

Dimension 4. Integral utilization of species

Proportion of useful species by the number of plant structures used.

Integral use will be achieved if we know the morphology of the plant, and the uses of each part. In this sense, the presence of plants from which it takes more than one part indirectly indicates a certain level of conservation of traditional ecological knowledge.

Dimension 5. Maximizing use of available species in the wild

Proportion of botanical families with useful species wild and cultivated

Ratio of botanical genera with useful species wild and cultivated

Proportion of wild and cultivated species useful

These indicators show a greater reliance on indirect natural environment for goods and services. A greater number of goods and services would be a good indicator of the state of conservation of traditional ecological knowledge. Obtaining goods and services should be persistent throughout the year. The trend towards temporary lack of goods and services is likely to involve loss of traditional knowledge.

Some of the dimensions included are related with the diversity of plants distributed in the communities selected (use of families, genera and species of useful plants; use as many native species; maximizing use of available species in the wild). Actions should be taken to control the direct and indirect factors that affect the preservation of diversity and its sustainable use (Millennium Ecosystem Assessment, 2005; Challenger & Dirzo, 2009). For example, the social-political factors should be implemented in order to avoid the replacement of forest with urban colonization and/or the economic incentives that promote the establishment of monocultures. The highest value of these dimensions shows indirectly that authorities of a community, region or country are been conducted towards sustainable development. Biophysical, social, and economic variables can influence on the indicators (Figure 3). Thus, the six case studies were selected based on the differences of the

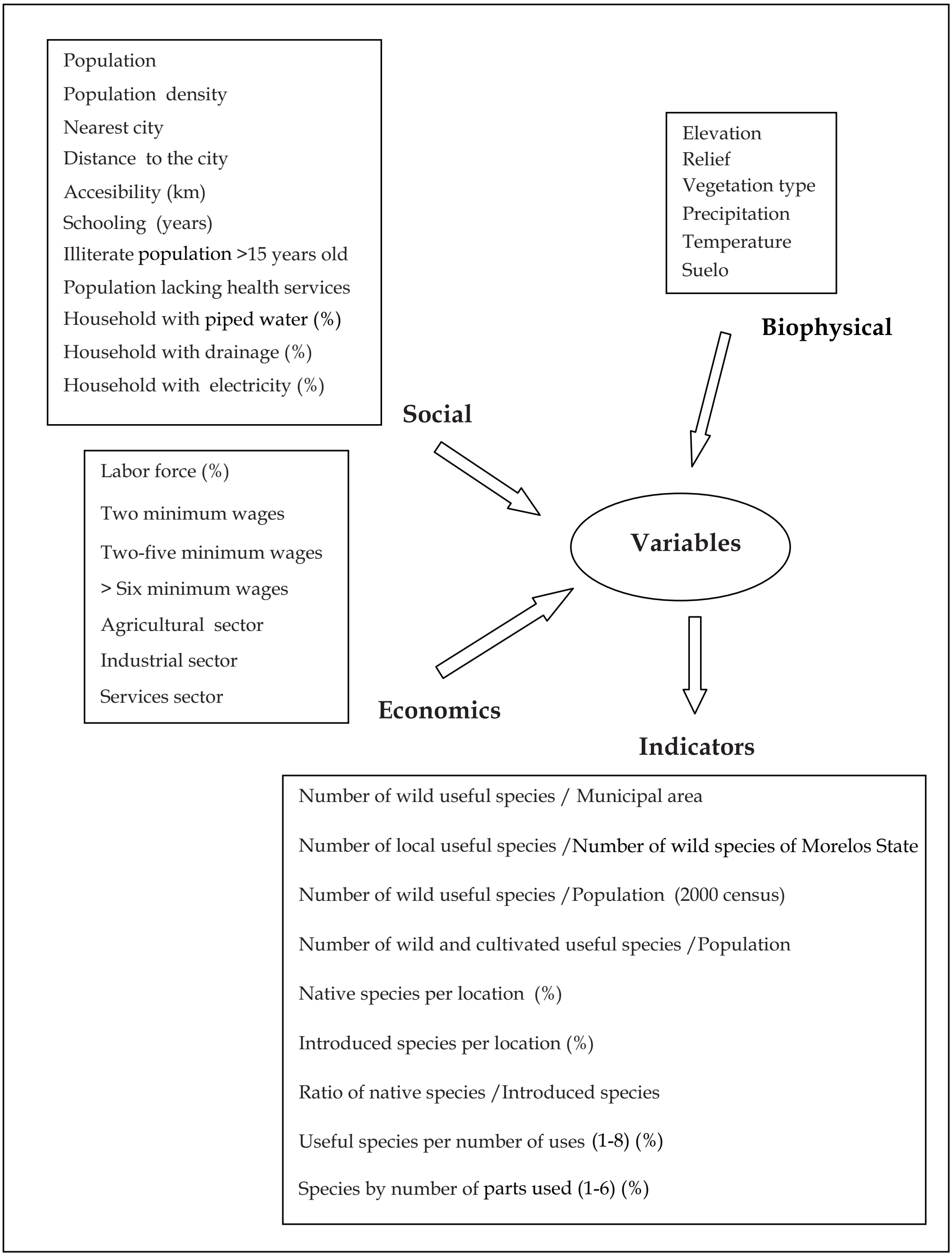

Fig. 3. Quantified variables and estimated indicators.

communities in the physical and biological attributes related to human activity such as accessibility, proximity to urban centers or different socioeconomic characteristics. The socioeconomic characterization of the population was done based on data recorded in the censuses of population and housing from which we obtained information on economically active population occupied in agriculture, livestock and forestry, as well as industrial and services; income, illiterate population, lacking health services, availability of electricity, piped water and drainage in the household. The official census do not include information on the contribution of traditional ecological knowledge to meet essential needs or medicinal, food, implicit in the welfare of low income families.

The relation between the indicators and the physical and socioeconomic variables was established using multivariate statistics. The indicators useful to use multivariate statistics, pre-selected from a correlation analysis between variables to avoid co-linearity, are listed below:

Indicators to maximize the diversity and number of options.

Number of families, genera and species per unit area.

Number of families, genera and species used in relation to the number of families, genera and species of flora recorded in the state.

Indicators of utilization of as many native species as possible.

Number of native species useful in relation to the number of useful introduced species.

Native wild species used

Indicators to maximize the number of uses assigned to species.

Number of uses per species.

Distribution of the number of species per number of uses.

Indicators of the total utilization of the species

Number of plant structures used.

Distribution of the number of species in relation to the number of plant parts used.

Indicators to maximize use of available species in the wild.

Proportion of botanical families with useful species wild and cultivated

Ratio of botanical genera with useful wild and cultivated species

Proportion of wild and cultivated useful species

Indicators to maximize the number of uses assigned to species.

Number of uses per species.

Distribution of the number of species per number of uses.

Indicators of total utilize the species

Number of plant parts used.

Distribution of the number of species in relation to the number of number of plant parts used.

Indicators to maximize use of available species in the wild.

Number of species that produce goods and services per month of the year.

Goods and services type produced by species and month of the year.

4.2 Results. Plant biodiversity maximization and the number of options

We will address the study related to the maximization of plant biodiversity and the number of options to ensure minimum subsistence risk. The information corresponds to six different locations of the state of Morelos, Mexico, with different biophysical attributes, in relation to human activity such as accessibility, proximity to urban centers, or other socio-economical traits (Figure 3). We analyzed them using multivariate methods (ordination and clustering), following Rohlf (2000).

The principal component analysis (Figure 4) explained 90% of the total variation for the first three components. The variables contributing the most in principal component 1 were among the socio-economic: the level of schooling of the population, people lacking access to health care, population density, and the mean wage of 2-5 per inhabitant. The most relevant

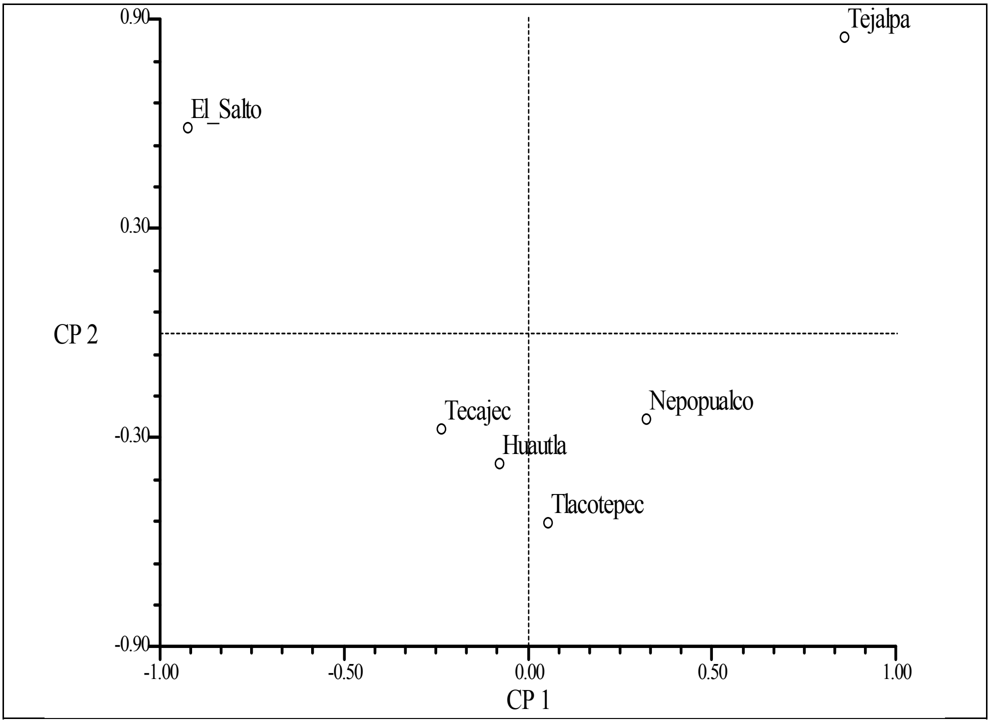

Fig. 4. Ordination of the rural communities based on plant utilization and socio-economical attributes.

variables pertaining to plant use were: species of plants with two types of use, number of plant parts used, ratio between the number of useful wild species and the number of inhabitants, and the ratio between the number of useful wild and cultivated species and the number of inhabitants. The communities are arranged in a gradient defined by the level of development, where El Salto and Tejalpa correspond to the least and the highest socio-economic development. The latter has been an urban area near by the state capital, having the largest population, access to health systems and higher rates of education. In contrast, El Salto has the highest number of useful wild species in relation to population, and where the wild plants have a greater number of uses. The importance of using native species in the El Salto and Tejalpa relates primarily to the existence of Natural Protected Areas in their vicinity. El Salto is immersed in the Reserve Biosphere Sierra de Huautla, while Tejalpa borders the State Protected Natural Area "The Texcal." The importance of using native plants in Tejalpa is also related to the origin of its inhabitants, as though there are many immigrants, whose origin for most of them is Tlapa, Guerrero, a community that has the same type of vegetation (tropical deciduous forest) as the one in the Texcal (Monroy & Ayala 2003). It also has pre-Hispanic cultural roots.

For the Principal Component 2, the most relevant variables of the socio-economic group were: households with electricity and distance to the nearest city, while in the group of variables of use highlighted: the relationship between native and introduced species, the percentage of native species per location, and the percentage of introduced species per location. In the second axis, the communities were arranged in a gradient that primarily involves attributes related to the knowledge of plants, since towards the upper end of axis 2 are located communities with the greatest percentage of native species per location, in contrast , they contain the lowest percentage of introduced species. Tejalpa has the largest population, percentage of population with income from 2 to 5 minimum wages and access to health services (53%). In contrast, El Salto had only 5% of the population which earns more than minimum wage.

Figure 5 shows a grouping formed by Tlacotepec, Nepopualco, Tecajec and Huautla, having a higher similarity in both, socioeconomic and the use of wild plants. In the latter case highlights the fact that they have similar values in the number of useful species used, the percentage of native species per location, and the higher rates of introduced species. On the other hand, El Salto and Tejalpa are distantly related to the previous group, which may influence mainly the socio-economic traits.

It should be noted, that the contribution of the indicators to characterize the situation of utilization of resources based on traditional knowledge. Is very clear and reflects the social situation that influences on the use of plants to satisfy their needs. It also shows the inverse relationship between acculturation and knowledge of plant biodiversity, environment or the use of adaptive management of resources.

From the sustainability of the resources, joint analysis of economic factors and indices on the traditional ecological knowledge, we might suggest the relevance of the islands of vegetation, in the wild and urban, for the people of the communities having traditional ecological knowledge on the use of plants. It seems important the access that people should have to these islands of vegetation since they will continue using the existing resources even on protected natural areas.

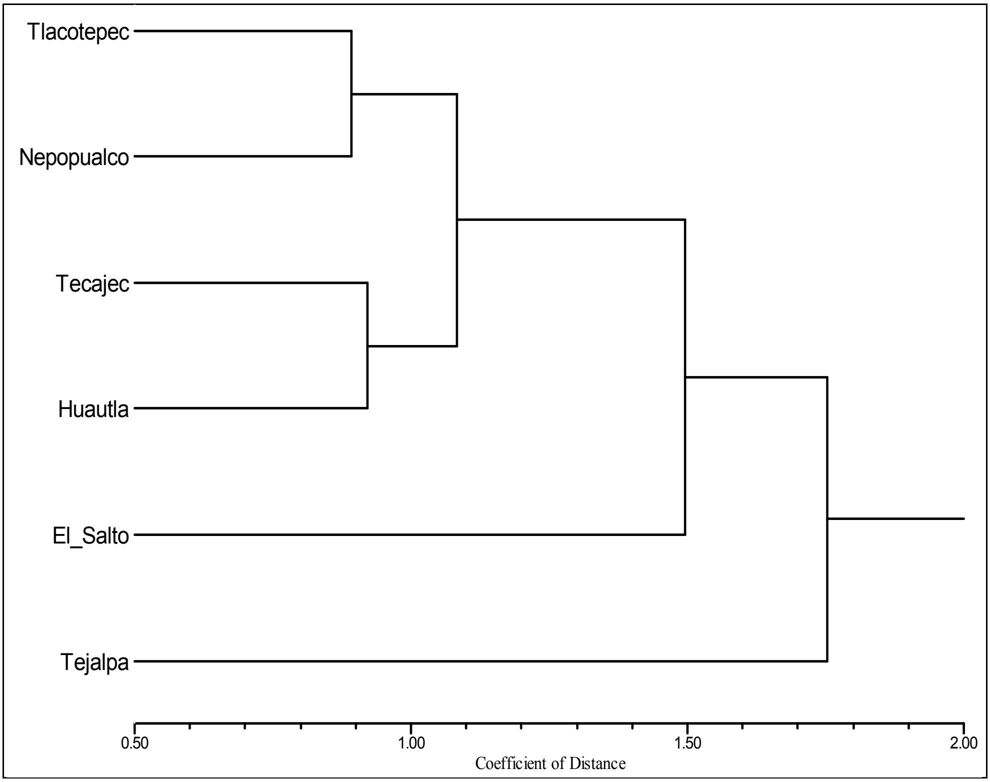

Fig. 5. Grouping of the communities studied in terms of socio-economic and utilization of wild plant species.

5. News pertaining to traditional knowledge

It is necessary for the planning of urban development to consider the need for islands of wild vegetation, either as a source of goods and services or teaching space on the uses and forms of exploitation of resources. Also is required to keep the cover in rural areas. As well as protect and promote traditional knowledge in different areas, e.g., in the education sector should ensure the exchange of knowledge on the resources at the classroom level. In the urban environment field, should be consider the use and practices of resource use of the migrants when planning and design management of existing vegetation islands, as well as other green spaces such as public parks and bed of flowers. Whereas in urban areas is still preserved traditional knowledge about plants, it is necessary to protect and promote this kind of knowledge in education, environment and health sectors, which is necessary, to promote the informed participation of the population in decision-making in these areas. What is new with respect to traditional knowledge is currently being recognized the benefit of traditional ecological knowledge and thought in their legal protection, based on the agreed Nagoya Protocol in Japan October 29, 2010, which has a binding implications and aims at equitable sharing of benefits arising from genetic resources for communities to conserve their resources based on community standards and participate in innovative features (compartiendosaberes.org, 2011).

6. Limitations of the studies based on traditional knowledge

One of the drawbacks in treating ecological data supported by traditional knowledge is empiricism that fall into subjectivity, which is true for ethnic and rural populations. Scientist rely on concepts like adaptive management that validates a coordinated use between the production process and environmental conditions. An integrated view about the three concepts used in this paper: traditional ecological knowledge, indicators, and sustainability, anticipates that the information is still partial, requiring a participatory process, from diagnosis through the indicators, and systematic monitoring of the processes change in both plant communities and in the forms of appropriation of species, in order to maintain the desired productivity. On the research side, another of the limitations of the proposed indicators is the lack of available information for their estimation, or the time required to conduct the study that may lead to determine the useful plants of any community. However, there are inventories of the plants used in develop and under develop countries; in addition, there are methods of inventorying relatively fast.

An additional limitation may arise from the variability in selected information sources, by the method of obtaining and recording of traditional ecological knowledge in each of the case studies. For example, in some studies were selected informants according to their degree of knowledge, sometimes the researcher lived in the community while doing their job, but there are those who planned a series of visits over a period of time, and so on. These variations affect the quality and quantity of ethnobotanical information that could gather and therefore, the estimated indexes and their subsequent analysis.

Likewise, we must consider that due to economic constraints and time, inventories of useful plants are not necessarily complete. In the same vein, we note the lack of local floristic inventories which could make a better comparison of the potential of the resources utilized.

7. Future research

Traditional knowledge necessarily requires scientific validation, since there is a tendency to give importance to the potential to combine both approaches to the same problem, to highlight and protect cultural and biological diversity.

The breadth of topics related to traditional knowledge provides the opportunity to have more indicators; for example, those directly related to the use of such plants as the best time for a medicinal use, the criteria for selecting the best type of wood, the characteristics of wood to use in making a chair, and so on. This variety of indicators could be related to different areas of government policy. Example, traditional knowledge related to the use and enjoyment of food and medicinal plants would be linked to the health sector to propose, promote and regulate the consumption of those nutritious vegetables or effective in the treatment of illness. Also, it is required to investigate the potential of this information provided by the indigenous and rural people to be incorporated into formal education (Figure 6), so that helps students to have better nutrition and health care. Similarly, it is necessary to review the legal framework for considering the inclusion of these foods and medicines, utilized traditionally.

Fig. 6. School education children learning about the importance of traditional ecological knowledge.

Future research must be supported in objectives to reach the desired achievement of certain events, including modernity without losing traditions, out of the discourse and influence the sustainability of resources as a means of maintaining ecosystem health and continuity of productive resources, integrating the communities that really have the traditional ecological knowledge. Ensure that economic activities do not exceed the carrying capacity, or social events such as migration, which contribute to the loss of ecological knowledge of ancient tradition and the cultural erosion. Encouraging multilateral political and social decisions based on cultural diversity. Legally protect traditional knowledge for communities to achieve benefits, as recently discussed by the FONCICYT Consortium (compartiendosaberes.org), which also proposed to strengthen and building capacity to articulate traditional and scientific knowledge in innovation processes and resolution of conflicts associated with the management, ownership and use of resources.

8. Conclusion

The maintenance of productive and healthy natural processes emphasizes the value of sustainability, which, if based on traditional ecological knowledge of those communities, processes and experiences through various measures and indicators of performance , would help to better comprehension of the differences of multiple community expectations pertaining to the management systems, in our case, forestry. The synergy of activities between ethnic groups and rural population, as conservationist of the traditional ecological knowledge and the scientific community as adviser in the current situation of resources and proposing solutions, facilitating a practical impact on the utilization and conservation of resources, and the continuity of productive and healthy ecosystem, ensuring to sustainability.

In Morelos, it is undeniable that there is a wealth of plant species and traditional ecological knowledge still exists, which supports forms of appropriation of resources that contribute to the sustainable production, conservation and maintenance of ecosystem integrity, providing good and services to society over time. The indicators derived from the traditional ecological knowledge show convergence and complementarities with the scientific knowledge. There is also the potential of biodiversity and traditional ecological knowledge, to consider the active participation of local people in the generation, implementation and monitoring of development proposals that seek sustainability and social welfare. Lacks enhance these convergences of knowledges into actions for sustainable development.

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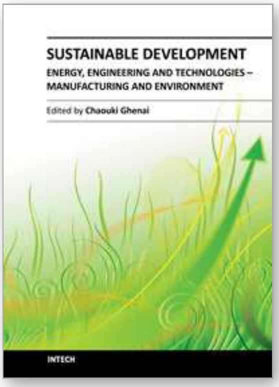

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The technological advancement of our civilization has created a consumer society expanding faster than the planet's resources allow, with our resource and energy needs rising exponentially in the past century. Securing the future of the human race will require an improved understanding of the environment as well as of technological solutions, mindsets and behaviors in line with modes of development that the ecosphere of our planet can support. Some experts see the only solution in a global deflation of the currently unsustainable exploitation of resources. However, sustainable development offers an approach that would be practical to fuse with the managerial strategies and assessment tools for policy and decision makers at the regional planning level. Environmentalists, architects, engineers, policy makers and economists will have to work together in order to ensure that planning and development can meet our society's present needs without compromising the security of future generations.

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