The "Ejido" as a focal unit for spatial analysis of nature-society relationships

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Abstract. One of the biggest changes in the nature of geographic knowledge over the past fifty years has been the development of relevant spatial theories about the location, the arrangement and distribution of objects and geographical events and space-time interactions between their physical and human components. On the other hand, one of the most pressing needs in territorial planning and the design of public policies at the local level is the availability of spatial information at this level. This study shows how the "Ejido" - the most common land tenure in Mexico - can serve as a focal unit for spatio-temporal analysis of nature-society relationships. As a key concept to analyze these relationships is the "farming system" which corresponds to the modes of agricultural exploitation of space by a society, result of the combination of natural, socio-cultural and economic factors. The ejido/community was considered as part of a self-organized hierarchy where the top level of analysis corresponds to the municipality or watershed units, and the lower level to the plots of the ejidatarios. For the characterization of agrarian systems, 25 communities were interviewed. This information was supplemented with data from the Population Census. Using spatial analysis, a geospatial hierarchical model was built (with geology, geomorphology, climate and vegetation land use attributes), which served as the basis for spatial analysis of agrarian systems and their relationship with environmental characteristics. Based on spatial data analysis a typology of agricultural systems was generated, grouping them in 11 types of systems, for which their spatial distribution and its relationship with environmental characteristics were mapped. Additionally for each one of community/Ejido, it was possible to show the spatial distribution of the status of the different types of capital (natural, social, cultural and economic). In conclusion, the project allows explicitly show and analyze the large spatial heterogeneity that may exist among municipalities entities, their knowledge would allow the design of better public policies, as well as a more realistic approach to local problems, resulting from the interaction of the social actors with the environment.

Keywords: Nature, environment, interactions, spatial analysis, agricultural systems

1. Introduction

The understanding of the nature-society relationship has been a constant theme throughout the history of geography. Today this aspect is becoming more relevant, because the landscapes are increasingly cultural, which has the particularity that the services provided are based less and less in ecosystems not disturbed, but rather a complex and extensive human settlements and land use history (Antrop, 1997). During the last fifty years, one of the biggest changes in the form of geographical knowledge has been the development of relevant spatial theories about the location, the arrangement and distribution of geographical phenomena and the spatial interactions between physical and human components of these phenomena (Golledge, 2002).

Small farmers produce much of the developing world's food. Yet they are generally much poorer than the rest of the population in these countries, and are less food secure than even the urban poor. Therefore, one challenge for developing countries is to identify spatially, specific agricultural and rural development needs and opportunities, and to focus investment in areas where the greatest impact on food insecurity and poverty will be achieved. Investment priorities and policies must take into account the immense diversity of opportunities and problems facing small farmers. This identification and resource allocation process can be facilitated by analyzing farming systems in order to develop an understanding of local factors and linkages. In the course of this analytical process it is also extremely helpful to be able to aggregate locations with similar development constraints and investment opportunities through the application of a farming systems framework.

A farming system (Agrarian Systems, Land use systems, depending on the analysis scale) is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. The Farming System Approach considers both biophysical dimensions (such as soil nutrients and water balances) and socio-economic aspects (such as gender, food security and profitability) at the level of the farm – where most agricultural production and consumption decisions are taken. The power of the approach lies in its ability to integrate multi-disciplinary analyses of production and its relationship to the key biophysical and socio-economic determinants of a farming system (Dixon J. Gulliver A. and Gibbon D., 2001). This approach allows the connection between social and ecological systems, and therefore will allow understanding the key interrelations that exist between these systems.

There are only few studies that analyze farming systems explicitly addressing the spatial context. At a global level, Dixon J. Gulliver A. and Gibbon D., (2001) mapped the major farming systems; Kruska, Reid, Thornton, Henninger, and Kristjanson (2003) and Wint and Robinson (2007) mapped farming systems in the developing world from a livestock perspective using spatial data on agro-climatology (length of growing period), land cover, and human population density.

At regional level, Verburg and van Keulen (1999) analyze the spatial distribution of livestock in relation to land use change in China. A more detailed mapping of farming systems for a region in Northern Argentina was presented by Duvernoy (2000). In Mexico, only one study is known about mapping farming systems, at local scale (centroGeo, 2002)

The objective of this study was shows how the "Ejido" - one of the most common land tenure in Mexico - can serve as a focal unit for spatial analysis of nature-society relationships and accounts for spatial variation in environmental and socio-economic conditions to explain differences in farming systems across a region. The ejido/community was considered as part of a self-organized hierarchy where the top level of analysis corresponds to the municipality or watershed units, and the lower level to the plots of the ejidatarios.

The purpose of this geographical perspective of the agrarian systems analysis is increase our understanding of the relationships and variations of those systems and obtain a more complete knowledgebase for interpreting human–nature relations, in aspects such as the vulnerability of agricultural systems to global environmental change, at scales ranging from local to the global and contribute to design of better public policies, as well as a more realistic approach to local problems, resulting from the interaction of the social actors with the environment.

2. Methods

The study area is located in Santo Domingo watershed, which comprises the greater part of the Las Margaritas municipality and a small sector of the Independencia municipality. The Santo Domingo watershed is part of the great Usumacinta River basin (see Figure 1). The selection of the ejidos/communities to study was based on the following criteria: accessibility of services by communities (based on its geographical location with respect to the municipality settlement or the presence of services within or near community) and the knowledge about some communities concern with their farming systems. According to these criteria 4 zones were selected, namely (see Figure 1): a) San Juan Chamula, b) Vicente Guerrero - Rosario Buenavista, c) Las margaritas – Yasha, and d) Los Ranchos. The communities studied in each sector are listed in table 1.

To characterize the study area and define the biophysical characteristics associated with each ejido/community, through spatial analysis, a geospatial model was built based on the following information: physiographic landscapes (Saavedra A. and Castellanos L., 2012), slopes (calculated from Shuttle Radar Topographic Mission elevation model – SRTM), land use – land cover (supervised classification based on SPOT image, 2008), soil map (series II, INEGI, 2009).

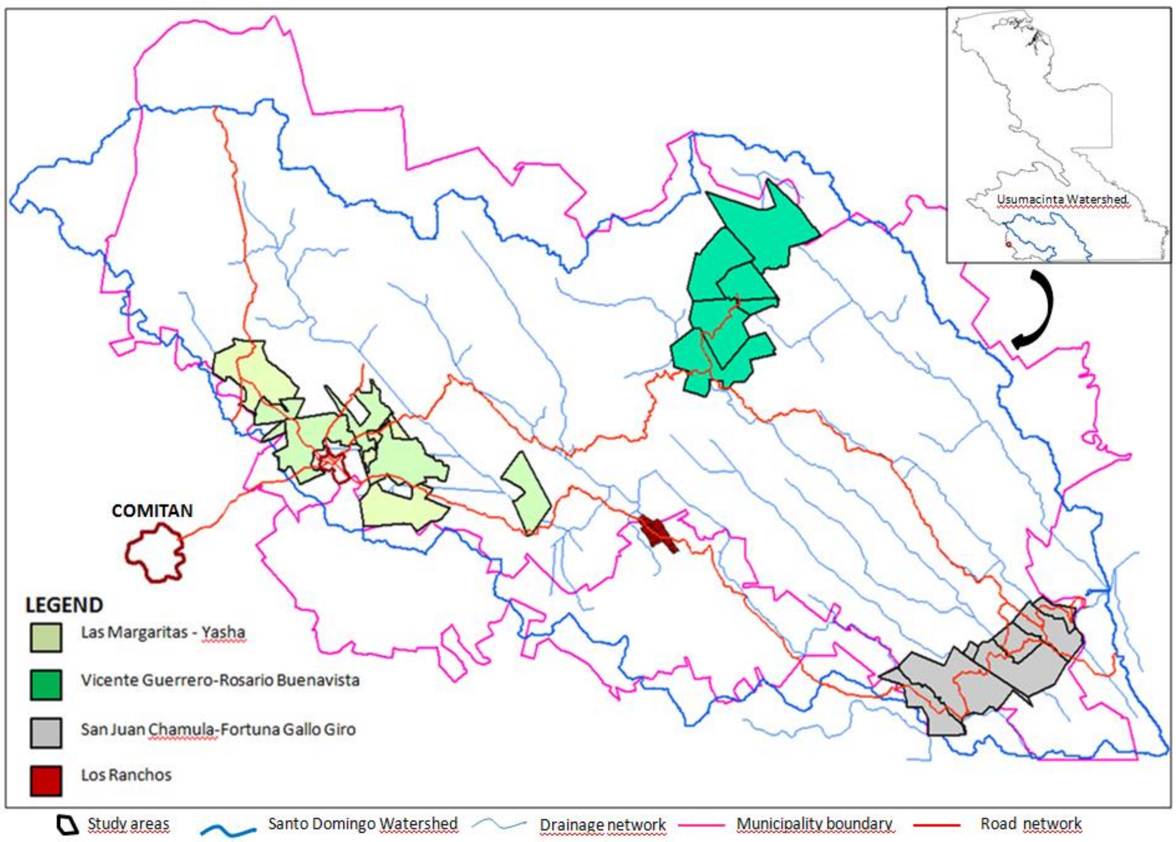

Figure1. Location of the study areas

Zone o sector	Communities/Ejidos
San Juan Chamula	Amparo Agua Tinta, Nuevo San Juan Chamula, Linda Vista, Nuevo Huixtan, Nueva Poza Rica, Jerusalén y La Fortuna Gallo Giro
Vicente Guerrero/ Rosario Buenavista	Vicente Guerrero, Santa Ana La Laguna, San Vicente, San Juan Bautista, La Candelaria y Rosario Buenavista
Las margaritas/ Yasxa	Las margaritas, Francisco I. madero, Bello Paisaje, Plan de Agua Prieta, Yasha y San Sebastián
Los ranchos	Santa María, San Jacinto, Guadalupe, San Francisco, San Jose Liquidambar, El Rosario, La reforma, San Caralampio, Las delicias y Fracción Trine

Table1. Communities/Ejidos studied in each zone

In order to understand the social, demographic, cultural and economic characteristics that frame the agricultural systems in each community as well as the agronomic characteristics and forest and animal management associated with existing farming systems, 25 communities were interviewed. The interviewed were conducted, either to the Ejido Commissioner or an ejidatario with a long tradition and knowledge of the ejido, or to the owners of each one of the ranches. For some communities, this information was supplemented by information contained in "notes about alternative development and challenges of agrarian units" prepared by the Inter-American Institute for cooperation on Agriculture (IICA).

Based on the information acquired through surveys, the communities were grouped in 11 agricultural systems according to the following criteria:
(a) The type of main activity which is carried out in the community, namely: agricultural, livestock and/or a combination of them.
(b) The combination of the cultivated species
(c) The type of land tenure: private property and Ejido.
(d) The accessibility of services by communities (health, education, market) based on its geographical location with respect to the municipal settlement and the connectivity.

3. Results and discussion

3.1 Geospatial Model

Figure 2 shows the landscape units resulting from the integration of the geology, geomorphology and climate variables; based on average annual rainfall the landscape units of Santo Domingo Watershed can be grouped in three landscapes classes as follow: Sub-humid landscapes with an average annual rainfall less than 1,500 millimeters, humid landscapes with average rainfall between 1500 and 3000 millimeters and very humid landscapes with an annual average rainfall greater than 3000 millimeters. In each of these groups of landscapes one zone of the studied communities is located respectively, as well: the zone known as Las Margaritas is located in the sub-humid landscapes namely as crest, gently sloping karstic hills and flat Valley, in these landscapes most representative soils are vertisols and luvisols. The zone of Vicente Guerrero-Rosario Buenavista is located in the humid landscapes namely as ridges and gently sloping karstic hills, being the leptosols and to a lesser extent luvisols the dominant soils. Finally, the zone of San Juan Chamula is located in the very humid landscapes called as cuesta-creston, karstic hills and Valley flat, the dominant soils correspond to the luvisols and leptosols and to a lesser extent cambisols.

3.2 Farming systems

In accordance with the level of detail of the survey used in this research the concept of agrarian system was applied. The studied communities, according to the land use and management characteristics, were grouped in 11 agricultural systems, for which the principal characteristics are describe in table 2. Its location in the study area is shown in Figure 3.

The agrarian system described in table 3, according to their location with respect to services supply and its connectivity (based on road network and transportation facilities), can be regrouped into four classes as follow: a) a first group consisting of mixed private, livestock private and mixed ejidal3 systems, which are located very near the municipal settlement or have own transport, and therefore can have access the all services available in the municipality: financial, education (primary, secondary and technical), health (hospital services), transport, market); in addition these communities have a high connectivity; b) a second group with intermediate conditions of accessibility to services, and of connectivity, include the systems: mixed ejidal1, mixed ejidal2, maize-beans-coffe-private, maize-beans- coffee ejidal and livestock-Ejidal; these communities have access to primary and secondary education, health center, and local market, and (c) a third group that has very little access to services as well as a poor connectivity, include the system mixed Ejidla4 and, finally the Mixed Ejidal5 systems that has a very little access to services as well as a very poor connectivity. The last two groups only have access to primary education.

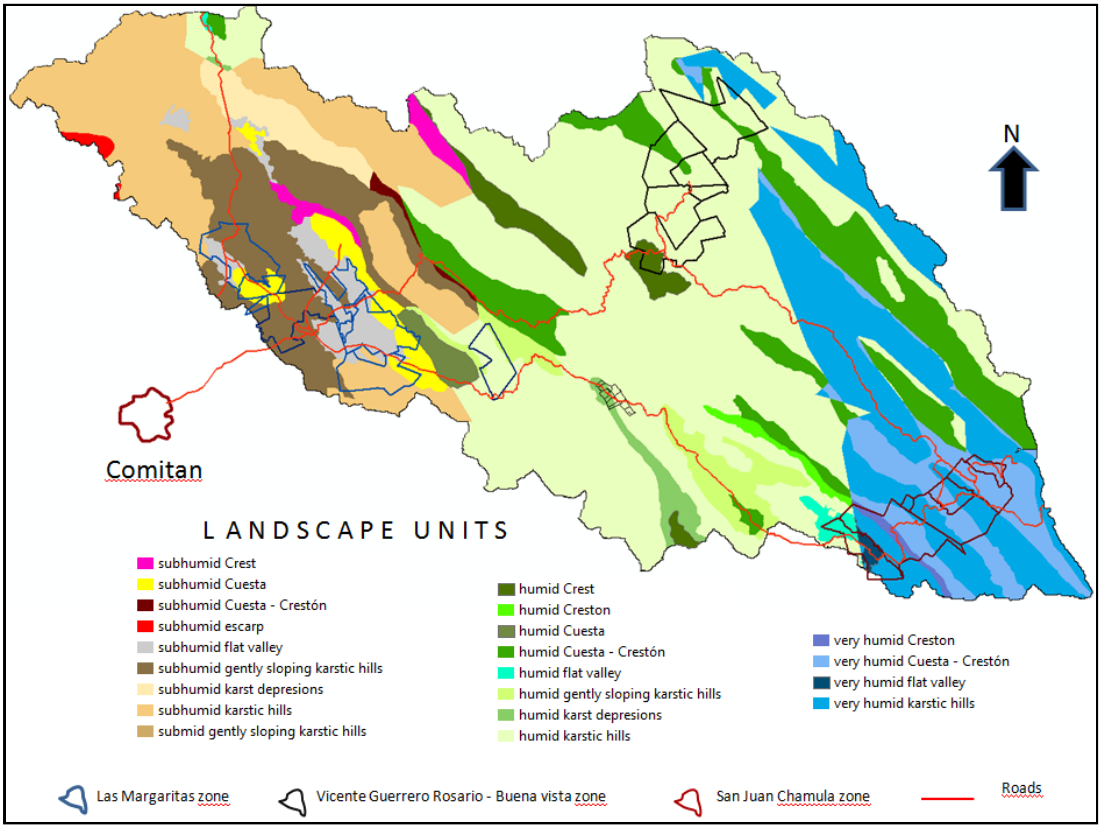

Figure 2. Landscape Units map of Santo Domingo watershed

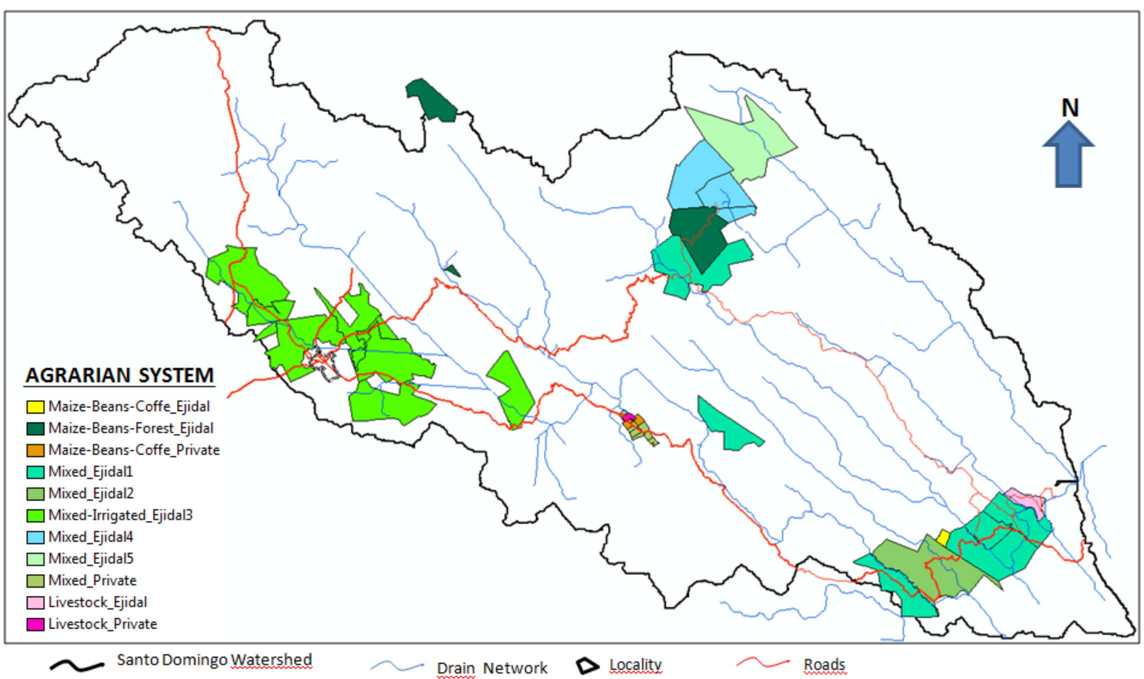

Figure 3. Agricultural system Map of three sectors of the Santo Domingo watershed

KIND OF SISTEM	COMMUNITIES	MAIN CHARACTERISTICS
Mixed Private	Santa Maria Guadalupe San José Liquidámbar La reforma, El Rosario Las Delicias, San Luis	*Livestock Subsystem* Breeding Beef (Zebu, Swiss, Charolay), sale of calves. *Crops Subsystem*: Coffee, banana, Hired labor, Direct marketing
Mixed Ejidal-1	Jerusalén, Nueva Poza Rica Nuevo Huixtan Amparo Agua Tinta, Laguna Las Delicias Santa Ana La Laguna Vicente guerrero	*Livestock Subsystem* Breeding Beef (Zebu, Swiss, Charolay), sale of calves. *Crops Subsystem*: Maize, beans, coffee Family labor, indirect marketing
Mixed Ejidal-2	Nuevo San Juan Chamula	*Livestock Subsystem*: Breeding Beef (Zebu, Swiss), sale of calves. *Crops Subsystem*: Maize, beans, coffee, Pineapple Family labor, indirect marketing
Mixed Ejidal-3	Yaxha Las Margaritas San Sebastián Francisco y Madero Plan Agua Prieta, San Mateo	*Livestock Subsystem*: Raise livestock (Zebu and Swiss) *Crops Subsystem*: Maize, beans with fertilization Family labor, direct marketing
Mixed Ejidal-4	San Vicente San Juan Bautista La Candelaria	*Livestock Subsystem* : Raise livestock (ZeBu) *Crops Subsystem*: Maize, beans, without fertilization, Family labor
Mixed Ejidal-5	Rosario Buenavista Rio Corozal	*Livestock SubSystem*: Meat purpose cattle (zebu) Family labor *Crops Subsystem* : Maize, beans: without fertilization, Family labor,
Maize- beans-coffee Private	San Francisco San Jacinto Fraccion Trine	*Crops Subsystem :* Maize, beans, coffee, without fertilization, Family labor
Maize-Beans-Coffee Ejidal	Linda Vista	*Crops Subsystem*: Maize, beans, coffee; without fertilization, Family labor, indirect marketing
Maize-Beans-Forest Ejidal	Carmen Chiquito Ninguan Limón	*Crops Subsystem:* Maize, beans – Forest, with fertilization, Family labor
Livestock Private	San Caralampio	*Livestock System:* Raise livestock (ZeBu). Hired labor, direct marketing
Livestock Ejidal	La Fortuna Gallo Giro	*Livestock System:* Dual purpose catlle (Zebu). Family labor, indirect marketing

Tabla 2. Agrarian Systems Characteristics of the study area

3.3 Capital Social

According with Matthews and Selman (2006) social/human capital – include the networks and institutions that underlie trust and civicness, the potential for social learning within familiar and tangible settings, and levels of education and skills. Whether at the micro, meso, or macro level, social capital exerts its influence on development as a result of the interactions between two distinct types of social capital—structural and cognitive. Structural social capital facilitates information sharing, and collective action and decision making through established roles, social networks and other social structures supplemented by rules, procedures, and precedents. As such, it is a relatively objective and externally observable construct. Cognitive social capital refers to shared norms, values, trust, attitudes, and beliefs. It is therefore a more subjective and intangible concept (Uphoff 2000 after Grootaert and van Bastelaer. 2002). From social capital point of view

According with the presence o absence of social capital the studied communities were classified in two groups:
(a) Communities without social capital: Conform these group communities or families whose land tenure form is private and do not have any kind of social organization. If it is considered that the absence of social capital can become a limiting factor for access to services and/or Government subsidies, this group in turn is divided into two sub-groups. A first subgroup consisting of the communities/families of Santa María, San Jacinto, Guadalupe, San Luis, San Francisco and fraction trine, which due to their low incomes, deficiency in services of education, health and market, the absence of social capital can be a determining factor that contributes to a greater marginalization. The second subgroup, consisting of the families of San Caralampio, San Jose Liquidambar, El Rosario, La Reforma and Las Delicias, since they have a medium level of income and also living in the urban area of Las Margaritas or Comitán, therefore have better access to services, therefore, the absence of social capital is not a determinant factor of the living conditions of these families.
(b) Communities with some form of social capital: this group make up the rest of communities studied, whose form of land tenure is the Ejido. These communities have an internal regulation; it is a policy document that describes the General bases for the economic and social organization, the rules for admitting new ejidatarios, and for use of the common use land. This document is known and respected by a good portion of its inhabitants. Each community makes ejidal assemblies with some frequency, involving landowners, residents and the neighborhoods; this Assembly is the channel for the resolution of disputes or to inform about issues important to the life of the ejido. In general, each community has an Ejido Commissioner, a Secretary and a Treasurer.

3.4 Capital Natural

The spatial properties of the environment can influence the trajectory of change within a landscape (Iverson, 1988; Mertens & Lambin, 2000), the kind and magnitude of social ecological transformation (e.g., Gonzalez, 2001), the ability of the system to respond and adapt to transformative processes as they occur, and the regeneration of post-disturbance landscapes (Bengtsson et al., 2003; Lugo & Helmer, 2004).

According with Matthews and Selman (2006) the ecological/natural capital – is considered as the 'life support systems' underlying biodiversity and natural resources. The natural capital is a good indicator of both the grade of disturbance as well as the health of the systems and therefore of the capacity of the system to provide environmental services. An ecosystem is healthy if it still provides primary production, nutrient retention and cycling, nitrogen fixing, soil stabilizing, water purification and other functions. An ecosystem that provides at least a substantial proportion of ecosystem services may be considered healthy, although it may not have
integrity. In this research, the analysis of natural capital was made based on two criteria: the availability of lands with natural forest, which was evaluated base on a land cover-use classification and the availability of suitable land for agriculture, which was assessed based on the slope and soil type.

3.4.1 Availability of land with forest cover

The figure 5 and table 3 show the percentage of forested land for each community. Having account the percentage of area under forest cover available in each community three groups were established: a) communities with a very low percentage (less than 5%of forest cover) included the communities of Fortune Gallo Giro, Nueva. Poza Rica, Las Margaritas; b) communities with a percentage between 10 and 50% of forest cover, included Jerusalem, N. Poza Rica N. Huixtán, N.S.J Chamula, Amparo Agua Tinta, Candelaria, Rosario Buenavista, S. Vicente, Vicente Guerrero, S. Ana Laguna, Francisco I. Madero, S. Sebastian; and (c) include communities that have more than 50% of forested land, Espiritu Santo, Yaxhá and Linda Vista.

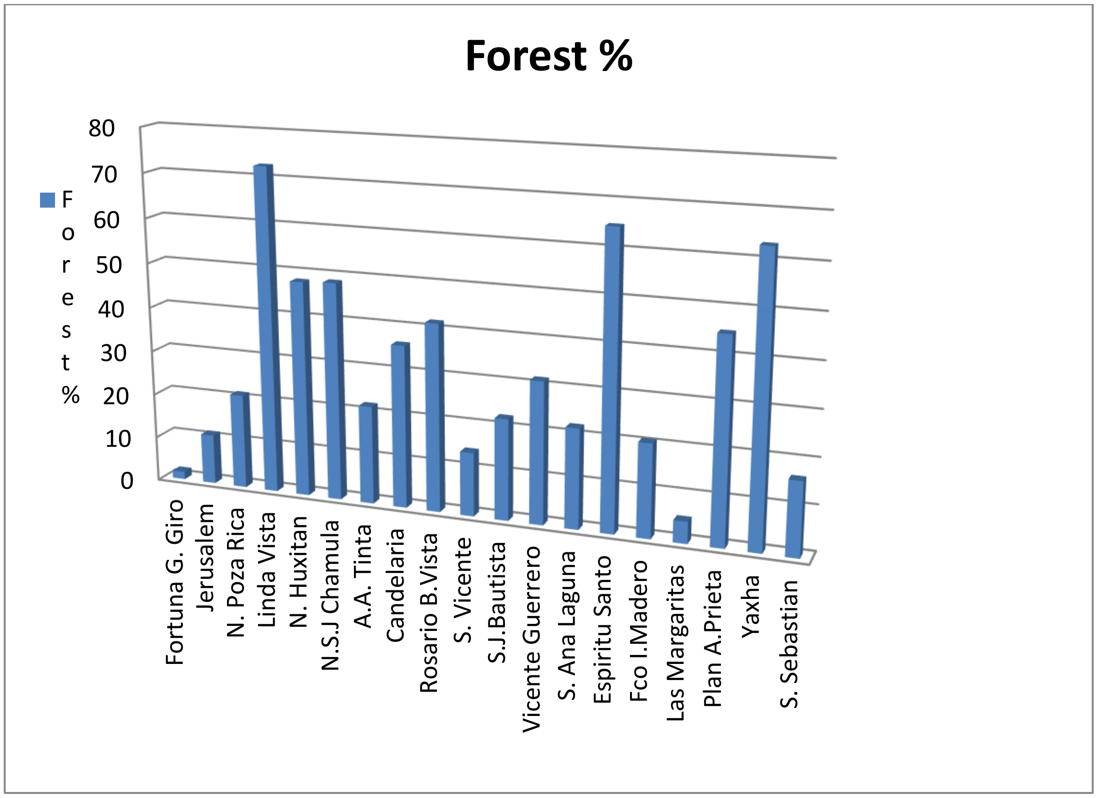

Figure 4. Percentages of lands with forest land cover in each community

EJIDO	Total Area_Ha	Forest-Ha	Forest %	Sec. Forest-Ha	Sec. Forest %
Fortuna G. Giro	461.88	7.76	1.68	54.52	11.8
Jerusalem	1456.84	162.44	11.15	121.32	8.32
N. Poza Rica	858.12	181.96	21.2	115.24	13.42
Linda Vista	127.88	93	72.72	0.96	0.75
N. Huxitan	2372.72	1142.56	48.15	91.56	3.85
N.S.J Chamula	3559.8	1728.92	48.56	181.08	5.08
A.A. Tinta	1483.64	324.64	21.88	189.12	12.74
Candelaria	381.96	138.32	36.21	113.32	29.66
Rosario B.Vista	3752.32	1564.76	41.7	1274.92	33.97
S. Vicente	2073.44	293.84	14.17	1183.68	57.08
S.J.Bautista	1155.92	259.36	22.43	347.2	12.49
Vicente Guerrero	2778.68	875.16	31.49	1116.16	40.16
S. Ana Laguna	2119.68	469.4	22.141	1187.76	56.03
Espiritu Santo	3926.77	2549.95	64.93		
Fco I.Madero	2148.93	444.69	20.69		
Las Margaritas	3578.08	173.61	4.85		
Plan A.Prieta	912.7	410.76	45		
Yaxha	2676.53	1692.53	63.23		
S. Sebastian	482.54	79.04	16.38		

Table 3. Lands with forest and secondary forest cover in each community

3.4.2 Availability of land suitable for agriculture

The slope is a good indicator of land suitability for agricultural activities. Base on this criterion the lands were considered as suitable, if the slope is less than 8%, moderately suitable, with slopes between 8y 16%, low suitable with slopes between 16 and 45%, and land not suitable to agricultural activities, if the slope is larger than 45%. Figures 5, 6 and 7 show the distribution of land according to the slope classes for each community.

Based on the analysis of figures 5,6 and 7, the communities studied, were classified, based on their natural capital (estimated by the availability of land suitable for agriculture) into four groups: a) a first group in which more than 70% of the lands are suitable for agriculture, most of the soils (vertisols and luvisols) have from moderate to high fertility, include the follow communities: Las Margaritas, Plan Agua Prieta, Espiritu Santo, Francisco. I. Madero, San Sebastián and Amparo Agua Tinta (see figures 6); b) a second group of communities in which 50% or more of their lands have a moderate to high suitability, the soils predominantly Luvisols and cambisols, have moderate to high fertility,, include the communities of Nuevo San Juan Chamula, Jerusalem, Nueva Poza Rica and Fortuna Gallo Giro (c) a third group in which between 30 and 50% of their lands have moderate to high suitability , the soils predominantly luvisols and cambisols, have moderate to high fertility; includes the communities of Lindavista, Nuevo Huixtán, Candelaria, San Juan Bautista, San Vicente, Vicente Guerrero and Santa Ana La Laguna; and (d) a fourth group formed only by the community of Rosario Buena Vista where less than 10% of their lands are suitable for farming, the most of soils are leptosols, of low fertility.

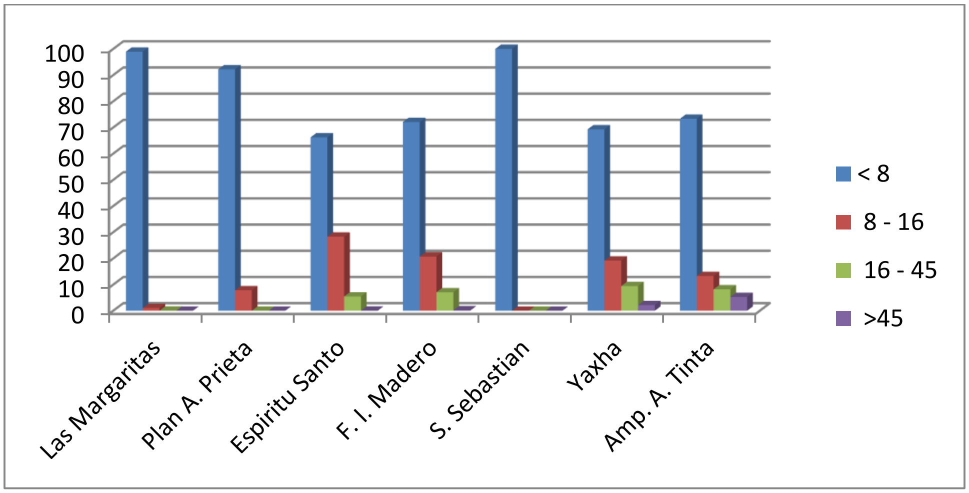

Figure 5. Percentages of land based on slope classes for each community

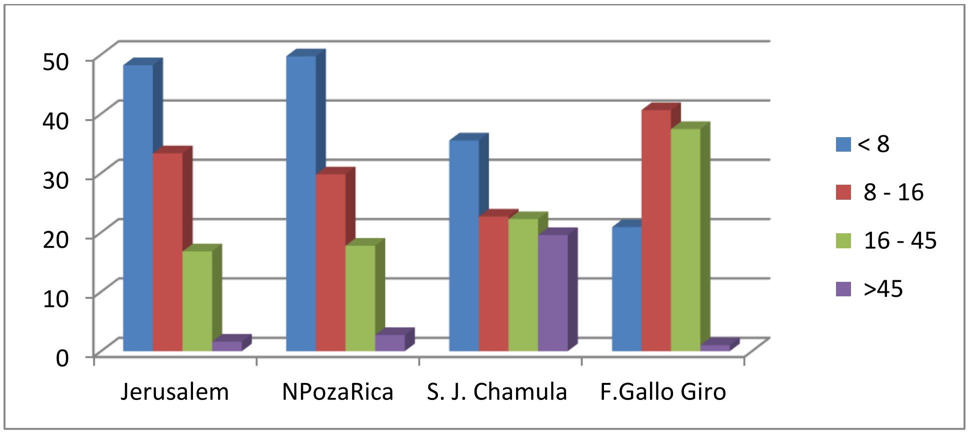

Figure 6. Percentages of land based on slope classes for each community

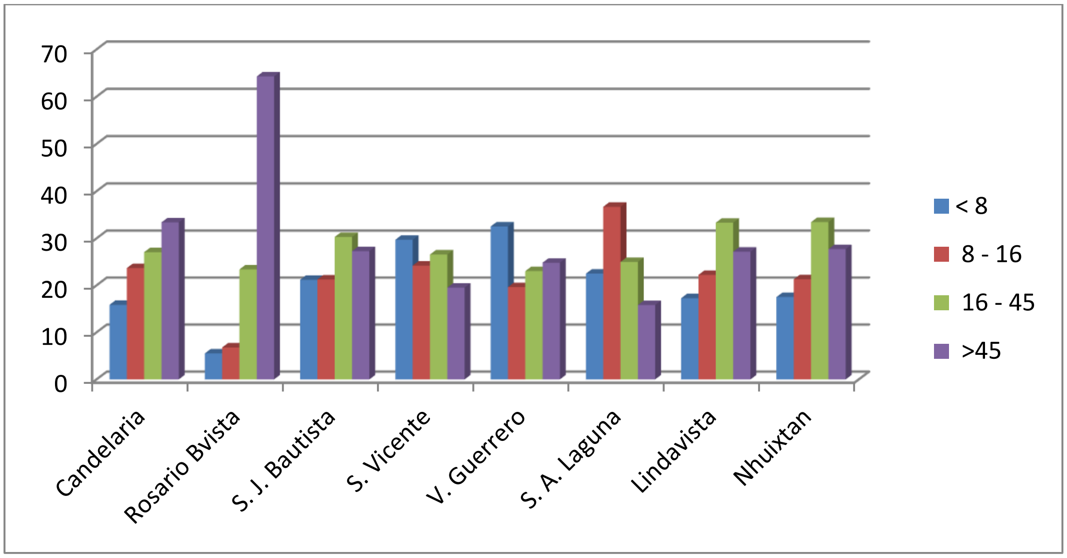

Figure 7. Percentages of land based on slope classes for each community

4. Conclusions

Cuando se analizan las características ambientales y sociales de un territorio, así como sus interacciones, los resultados descritos en párrafos anteriores muestran la gran heterogeneidad que existe dentro de los municipios, la cual en el caso de México puede ser analizado tomando el ejido como unidad espacial de análisis.

Otra conclusión importante que se puede extraer del analsis de los resultados es que la localización espacial y el grado de conectividad que presenta una entidad espacial, en este caso una comunidad son factores determinantes del funcionamiento espacial de dichas entidades. Asi por ejemplo, propiedades espaciales del ambiente tales como el capital natural y diferencias en el acceso a servicios, pueden influenciar la trayectoria de cambio de un sistema (una comunidad) dentro del paisaje, la clase y magnitud de transformación social, asi como la habilidad del sistema para responder y adaptarse a diferentes tipos de perturbaciones.

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