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Rural-Urban Cactus Production - A Biosemiotic Study

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Abstract: *In this article, we use the perspective of the semiotics of culture and biology to analyze the rural-urban spaces of Mexico City in nopal production. This vegetable provides a stable food crop for the urban population, and an income for the local-rural community, while magueys are used as ornamental plants for city medians. The semiotics of culture is considered a complex, trans disciplinary theory in that it has the capacity to incorporate categories from other disciplines, while examining phenomena in an integral, non-binary way. It allows the study of space as a semiosphere combining cactus production for food and ornamental plants. Nopales constitute a green or plant barrier to human growth. They also help maintain the rural landscape, providing environmental services, such as aquifer recharge, atmospheric oxygenation, and carbon sequestration. Like other crops, cacti, such as nopal and maguey, are involved with the society that produces and consumes them. Given the economic importance of the towns in Mexico City, for example, we consider Milpa Alta a semiosphere on which the biological, the socio-cultural, the economic, and the ecological converge. In this article, we observe the capacity of the rural-urban that is a firm contender for economic, socio-cultural growth in all its complexity.*

Keywords: *rural-urban, cactus, nopal-vegetable, complexity, transdisciplinarity*

1. Introduction

The aim of this article is to use in situ research to create a complex-transdisciplinary model incorporating three types of knowledge: the empirical knowledge of farm workers and families who work the lands of Milpa Alta, the technical knowledge of those with basic academic knowledge, and that of scientists and technologists. The aim isto adopt a comprehensive view of the work and products undertaken together and contribute to post-hoc research on the work undertaken jointly in nopal production. To design the model, we worked with the Castro Gutiérrez family, who, throughout their lives, have been engaged in the production and sale of nopales, and other artisanal products such as jam, pickled nopales, and personal hygiene products. We also interviewed the authorities at the borough of Milpa Alta and the scientist and technologist, Dr.Octavio Eliceo Rivera Vergara, Director General of the Center for Innovation in Appropriate Agricultural Technology.

This research is justified by the importance of nopal production. This polysemic plant has a broad range of uses. In addition to its basic, artisanal function of contributing to human and animal nutrition, industrial, scientific, and technological uses have also been found through scientific and technological research.

2. Milpa Alta:Location and Agroecological Features

According to Altieri and Koohafkan (2014), indigenous knowledge systems that have given rise to resilient ecosystems provide multiple goods and services guaranteeing the food security and livelihood of millions of people in rural areas. The borough of Milpa Alta is one of the original towns in the Basin of Mexico, located in the south of Mexico City. Agriculture, albeit limited, remains one of its main socio-cultural, economic and political activities. The hypothesis explaining this phenomenon is the close link between its historical development and agricultural activity, which has enabled it to continue with its traditional agricultural practices linked to the land and nature (Toledo, 2015).

Milpa Alta, located in the southeast of the city, occupies 19% of the total area with 228 square kilometers (making it the second largest borough in size after Tlalpan).Of the 140 indigenous towns recognized by the Mexico City government, twelve are located in Milpa Alta:San Antonio Tecómitl, San Juan Tepenahuac, San Francisco Tecoxpa, San Jerónimo Miacatlán, San Agustín Ohtenco, Santa Ana Tlacotenco, San Lorenzo Tlacoyucan, San Pedro Atocpan, San Bartolomé Xicomulco, San Pablo Oztotepec, San Salvador Cuauhtenco, with Villa Milpa Alta being the borough capital (see table 1). The altitude of the mountain range in this borough ranges from 2,300 to 3,500 meters above sea level. The highest peaks are Teutli (2,700), Ocusacayo (3,220), Acopiaxo (3,320), Cuautzib volcano (3,510) and San Bartolo (3,220) (DDF, 1986).

3. Soil Climate and Vegetation

The climate has been classified as temperate sub-humid with summer rains, accompanied by high relative humidity C (WO) (W) (García, 1976). The average temperature is 13ºC from December-January and 28ºC from March-May with 746 mm/year rainfall. Soils are mostly of volcanic origin consisting of rhyolites, andesites, basalt, lava, pumice, as well as volcanic ash classified as androsols.(INEGI, 1994).

Plants thereare important because of the wide range of temperate climate species. The natural vegetation comprises the followingpine species:*P. teocote, P. leoiphylla, P. moctezumae*, *P. hartwegii* and *P.ayacahuite*; oak (*Quercus spp*.), juniper (*Juniperus spp*.) andMexican chokecherry (*Pronus serotina spp capulli*).It also includes other tree species such as*Eucalyptus spp., Erythrina coralloides, Schinus molle, mimoseafolia,* and *Eysenhardtia polystachya.*Shrubs comprise annual and perennial grasses (Gramineae) including the genera *Muhlenbergia, Festuca, Sporobolus, Heteropogon and Agrostis*.Xerophytic plants such as *Mimosabiuncifera, Opuntia spp.* and*Agave spp* have also been included as part of the vegetation.

4. The Milpa Alta population

Milpa Alta is distributed among twelve towns (see Table 1, although only ten productive towns are listed).It has a population of 137,927, of which 67,151 (48.7%) are men and 70,776 (51.3%) women, accounting for 1.5% of the total Mexico City population, INEGI, 2015. These indigenous towns in Milpa Alta are historical communities with a territorial base and their own cultural identities, distinct from the rest of Mexico City. Their forms of government and community relations, uses and customs increasingly clash with the urban modalities resulting from the unbridled growth characterizing the big city, putting pressure on traditional rural land use. According to the Mexico City Government Subdirectorate to Assist the Indigenous Population, they are called original peoples because they are the descendants of populations that lived in these areas before the existence of the Mexican State (Ortega, 2010).

Table1. *Total cultivated area and estimated nopal vegetable production in towns in the borough of Milpa Alta*

Town	Cultivated area (ha)	Estimated annual production (ton)	% of production
Villa Milpa Alta	2, 681	132, 000	65.07
San Lorenzo Tlacoyucan	712	36, 000	17.75
Santa Ana Tlacotenco	274	10, 800	5.32
San Juan Tepenahuac	95	6, 000	2.95
San Jerónimo Miacatlan	129	6, 000	2.95
San Agustin Otenco	110	5, 400	2.66
SanPedro Atocpan	30	3, 000	1.48
San FranciscoTecoxpa	94	2, 880	1.42
San Antonio Tecomiltl	34	720	0.35
San Pablo Oztotepec	28	30	0.15
Total	4,187	202, 830	100 planted

Source: *(Delegación SADER Mexico City, 2019)*

5. HOMEOSTASIS: SOCIETY-CULTURE-PRODUCTION BALANCE

As part of Mexico City, Milpa Alta has access to services in the metropolis such as water, electricity, drainage, and paving, which also lend it its particular urban nature. On the one hand, this is part of an effort to adopt a lifestyle similar to that of the city, theoretically integrated and standardized to match the realities of local perception. On the other hand, it is part of its struggle to maintain its identity, by distinguishing itself from the conventional rural sector existing throughout most of Mexico.(Losada, T. 2007). This type of urban agriculture has been recognized as a key activity of metropolisesto halt the development of urban sprawl by using open spaces to produce food and create jobs for disadvantaged groups as a strategy for making cities sustainable. (Losada et al., 2000)

Every culture has stabilization and destabilization mechanisms to ensure its self-eco-organization (Lotman, 1983 and Morin) in dynamic, homeostatic directions. Human beings have the capacity to organize their habits, customs, uses, and organization culturally in dynamic directions. This self-eco-organizing balance is what constitutes natural and cultural homeostasis.

6. MILPA ALTA, A HETEROGENEOUS/HOMOGENEOUS SPACE

From the perspective of the semiosphere of culture, Iuri Lotman (2000: 25-26) argues that the semiosphere is the symbolic space outside of which no meaning is produced. One of the characteristics of the semiosphere is its delimited nature linked to a certain homogeneity with a "closed nature."However, thanks to the translator filters cutting across symbolic borders, the semiotic space opens up to give way to new cultural elements, at which point it assumes a "heterogeneous nature."Milpa Alta preserves its uses and customs, yetit is open to the development of the city by incorporating urban elements as mentioned earlier, such as water, electricity, drainage and paving. It can therefore be deduced that it is a complex space linking the rural and the urban.

Every culture has a beginning and an end. This concept is linked to the principle of alternativity corresponding to alterations within the same level. For example, in the structural dyad: static-dynamic, open-closed, and homogeneous-heterogeneous, Milpa Alta society finds its functioning in this dialectic. It operates as a cultural sphere and general system of self-eco-organization in which a certain culture is constructed, provided it meets the necessary conditions—dialectical opposition—to enable the culture to function. In this respect, there is a need for unity (which Morin calls uniduality, single and collective at the same time), whose social function must intervene as a structure subject to unique constructive principles. The unit thereby creates its own model, such as the cultural model of Milpa Alta.

The peri-urban productive space contains two production models: the terrace of the southeast of the city and the agriculture of valleys on its periphery, including that of Teotihuacán. The production systems reported in these areas maintain a rigid spatial distribution determined by their dependence on man, as well as the intensity of work and environmental factors (low temperatures) that inhibit or promote productive expression. As mentioned earlier, the climate, topography and ecological diversity allowed the development of a wide range of productive activities in different spaces: town, peri-town, interface, and forest.

6.1. Village Space

The village space comprises birds, pigs, draft animals, dairy cattle, and a family orchard (see Table 2). Production is undertaken on the perimeter of the farmer's dwelling. Most (52%) of those surveyed reported that women and children are responsible for taking care of poultry, as well as playing a key role in feeding the pigs and tending the family orchard. Women are also in charge of housework. The production of poultry, pigs and family orchards is mainly for subsistence, with only 10% of households reporting selling them. The backyard is also where are draft animals sleep and are fed. The production of backyard animals and fruit trees is for subsistence, with small surpluses occasionally being sold the local market. Those in charge of these activities are mainly women and children. Draft animals are used to transport agricultural implements, as well as humans to the crops, while those in charge of handling and feeding them are adult men.

6.2. Peri-Village Space

The predominant agricultural activity in the peri-village space is the cultivation of the vegetable nopal (an extension or young cladode stem that acts as a leaf and is eaten as a fresh vegetable).The peri-urban space has steadily expanded, with the 2015 census reporting an increase from 2,300 to 4,028 ha for nopal cultivation during the period1984-1992.However, an approximate area of 4,187 ha has been estimated for the production of vegetable nopal since it can be harvested fifty-two times a year.

The towns with the largest area under cultivation are Villa Milpa Alta with 65.07% and San Lorenzo with 17.75% (see Table 1). This is possibly due to their proximity to the urban area (and therefore to the local market), which enables farmers to better attend to the cultivation of nopal and prevent theft. Other factors are determined by the improved care of the nopalplants, which require intensive labor, while other research has suggested the appropriation of the visual space. Most nopal vegetable cultivation area is located in the peri-village space (see Figure 2). A high percentage of the work is performed manually, with only a small number of farmers reporting using machinery. Women and children play a key role in selecting the nopales, removing the thorns and selling them at the local market. Seventy per cent of the men are responsible for the farm work, 16% use workers, 7% sell directly to the market and 7% sell the product to intermediaries. According to respondents, there is no specific season for establishing a nopal field.

Economic availability, and access to land and manure are among the factors that influence this decision. The main tasks involved in its production are weeding, pruning, fertilizing and pest and disease control. Although the life span of the nopal plant is one to fifteen years, some producers reported plants over twenty years old. Pests and diseases considerably affect production year round. During the productive life of the plant, it can be cut fifty-two times per year, with yields of fifty to sixty tons/year.

6.3. Interface Space

Producers in this area mainly grow maize as a monocrop and/or intercropped with beans, squash, and broad beans, under rainfed conditions. The surfaces destined for cultivation have an area of eighty to 100m² (94%), and 100 to 1000m² (6%).Research has shown that 41% of family income is obtained from the production of maize, beans and broad beans, 26% from wages, 20% from the sale of non-agricultural products and 13% from livestock. The land is plowed and maize planted shortly before the start of the rainy season, between March and April. Harvesting takes place between October and November. In each type of farmwork, the number of participants varies depending on the financial resources available and the family composition. Farmers use corn grain to feed their domestic poultry and occasionally cattle. Maize stubble is used exclusively to feed ruminants, with some farmers selling it to obtain an additional income.

6.4. Forest Space

The forest area comprises sheep, fodder, legume crops and meadows (both naturally occurring or artificially created).The use of forest resources is complex, due to its constant production throughout the year.

The forest provides building materials and energy for local people, in addition to supplying livestock and animals. Farmwork, as well as livestock and forestry activities, are synchronized and compatible with the economic and cultural life of the local population. The forest also provides trees, mushrooms, herbs, edible plants, and rituals. The felling of trees, hunting and soil extraction are forbidden. Local authorities attempt to prevent these practices and promote the rational use of resources. However, it is not easy to stop theft or illegal logging by outsiders.

Mushrooms, harvested during the rainy season, from June to September, are a resource with a high seasonal demand that satisfies family needs and occasionally, small surpluses are sold on the local market. Table 2 presents the agricultural and forestry activities of the four spaces.

Table2. *Different spaces and agricultural activities in the Milpa Alta borough*

Zone	msl*	Agricultural and forestry systems
Town	2300	Backyard (poultry and pigs), Dairy cattle, Draft animals (donkeys, mules, and horses), Family orchard (medicinal, ritual, ornamental plants and fruit trees)
Peri-village	2900	Prickly Pear Cactus *(Opuntia ficus-indica, L)* Prickly Pear Cactus *(Opuntia ficus-indica, L)* associated with flowers *(Geranium spp.)*, Vegetables: lettuce *(Lactucum spp.)*, Huazontle, *(Chenopodium nuttaliae)*, and spinach *(Spinaceaoleracea)*, Amaranth *(Amaranthus spp.)*,bees *(Apis mellifera)*
Interface	2900	Maize *(Zea mays)* Maize associated with squash *(Cucurbitas spp)*, beans *(Phaseolus spp)*, and chili *(Capsicum spp)*
Forest	3500	Production of sheep, maize, natural pastures, grasslands (naturally occurring and artificially created) Vetch *(Vicia sativa)*, forest collection activity: wood, charcoal, resins, plant soil, maguey *(Agave salmeana)* (pulque and maguey leaves) Wildlife *meters above sea level.

Source: *Rivera et al. 2003.*

7. MILPA ALTA: A CULTURAL STANDARDIZING DEVICE

According to Lotman, societies always have a "cultural standardizing device," whose function is performed by natural language. This denotes an intuitive sense of structurality and systematicity, transforming the "open" world into a "closed" one, in which borders are activated through filters and bilingual translators. In Milpa Alta, the most widely spoken indigenous language is Nahuatl, followed by Otomi and Mixtec. However, the majority of residents are mestizo and therefore speak Spanish. Nevertheless, their original thought is based on the dominant language of origin, and it is from this reality and language that they construct their thought. Based on this, they generate a culture as a text (fabric of codes), a complex generator of meaning that standardizes the Milpa Alta cultural model by reinforcing the identity of the reality experienced by Milpa Alta residents.

Major World Agricultural Heritage Systems are living, evolving systems of human communities closely linked to their territorial, cultural, or agricultural landscapes or their broader bio-physical-social environment. Human beings and their way of life have continuously adapted to the potentialities and limitations of their socioeconomic environments. By shaping landscapes, they have lent them extraordinary beauty, an accumulated wealth of traditional and cultural knowledge, and perpetuated significant biological diversity.

These Globally Important Agricultural Heritage Systems—GIAHS—have not only contributed to extraordinary, aesthetically beautiful landscapes but also to the maintenance of agricultural biodiversity, resilient ecosystems and a valuable cultural heritage of global importance. These ancestral agricultural systems, not always acknowledged by the scientific community, form the basis of contemporary and future agricultural innovations and technologies. Indeed, many scientists acknowledge that traditional agro-ecosystems have the potential to provide solutions to the unpredictable changes and transformations humanity is facing, in an era of climate change and energy and financial crises.(Koohafkan and Altieri 2011)

In regard to nopal products, its multifunctionality has meant that, in addition to being a nutrient-rich food, it has unique botanical and chemical characteristics. The integral use of this species is therefore extremely attractive for the agro-industrial sector. Various institutions, organizations and producers engaged in direct activities and/or the transformation of the nopal were contacted for this study.

Through the Ministry of Rural Development and Equity for Communities (SEDEREC, a Mexico City government agency), we found information indicating that although there is no formal register of farmers, it is estimated that the number of people engaged in this activity in Milpa Alta exceeds ten thousand, accounting for nearly 30% of the employed population. In regard to productive organization, in 2016, Cahue, Calderón and Ruiz (2006) identified the following local (cooperative) and business organizations linked to the production and transformation of nopal: a) Farmers' organizations: Union of Maguey and Nopal Farmers, Agricultural Union of Nopal Vegetable Farmers of Milpa Alta; b) Cooperatives: San Lorenzo Tlacoyucan, Teuhtli Organic Nopal Farmers, Teuhtli Lugar de Piedra, Gapodema, Tlacoyucan Nopal and Vegetable Farmers, Nopal Selecto. According to FAO, the following uses of nopal have been identified (see Table 3):

Table3. *Nopal and its multifunctional derivatives*

Functions	Production
Food and beverage agribusiness for human consumption	Production of various foods such as pickles, jams, juices, nectars, dehydrated products, concentrates, syrups, alcoholic and non-alcoholic prickly pear and nopal beverages
Animal feed agribusiness	Supplements and feed from leaves and waste from the prickly pear processing industry, such as shells and seeds
Pharmaceutical industry	Gastric protectors made from mucilage extracts; nopal powder capsules and tablets
CCosmetic industry	Creams, shampoos, lotions
Food supplement industry	Fiber and cladode flour for diabetes and obesity control
Natural additives Industry	Cladode gum; fruit coloring
Construction sector	Cladodic binding compounds
Energy sector	Biogas production from leaves
Agricultural input production sector	Nopal products as soil drainage improvers
Tourism industry	Crafts based on lignified cladodes
Textile industry	Indirect use of the plant as a host for cochineal to produce natural dyes

8. CONCLUSIONS

8.1. The Discursive Semiotic Complex Model of the Milpa Alta Area

In the case of nopal production studied, we have observed that participatory communication has been established between members of each of the nopal organizations and government and academic institutions. Technology is transferred from institutions to farmers through technicians, meaning that the prevailing discourse is the hegemonic one. The aim is therefore to use the semiotic-discursive model to promote alternative communication (Albán 2011) so that the transmission of knowledge and knowledge is not merely unilateral, but instead a dialogue of academic and institutional knowledge. This will guarantee that authentic participation occurs between subjects possessing empirical knowledge and subjects possessing academic and institutional knowledge, thereby creating a recursive loop.

The aim of dynamizing this type of technological innovation system is to examine several aspects within the same system. To this end, we propose a semiotic-discursive model that comprehensively considers several factors, aspects, and environments. The basis of this model is the theory proposed by Iuri Lotman.In this respect, the concept of semiosphere is crucial. For Lotman, culture forms a system of signs, whereas culture is “non-hereditary information that human societies collect, preserve and transmit” (Lotman 1978:21).In other words, it is non-hereditary because it is not transmitted through the genetic code. In this respect, Milpa Alta farmers comprise the semiosphere that is the “great system,” the semiotic universe whose existence makes “the particular sign act” come true. In other words, the entire discursive and semiotic production within the various nopal groups produces meaning for all their members. Since each of the languages and texts concerning Milpa Alta are particular sign acts, we are referring to particular semiotics, in other words, to subsystems of the “great system”. Milpa Alta therefore represents the “great semiotic system” in which three components coexist and co-participate: institutions, farmers, and technicians, who, in turn, comprise sign subsystems.

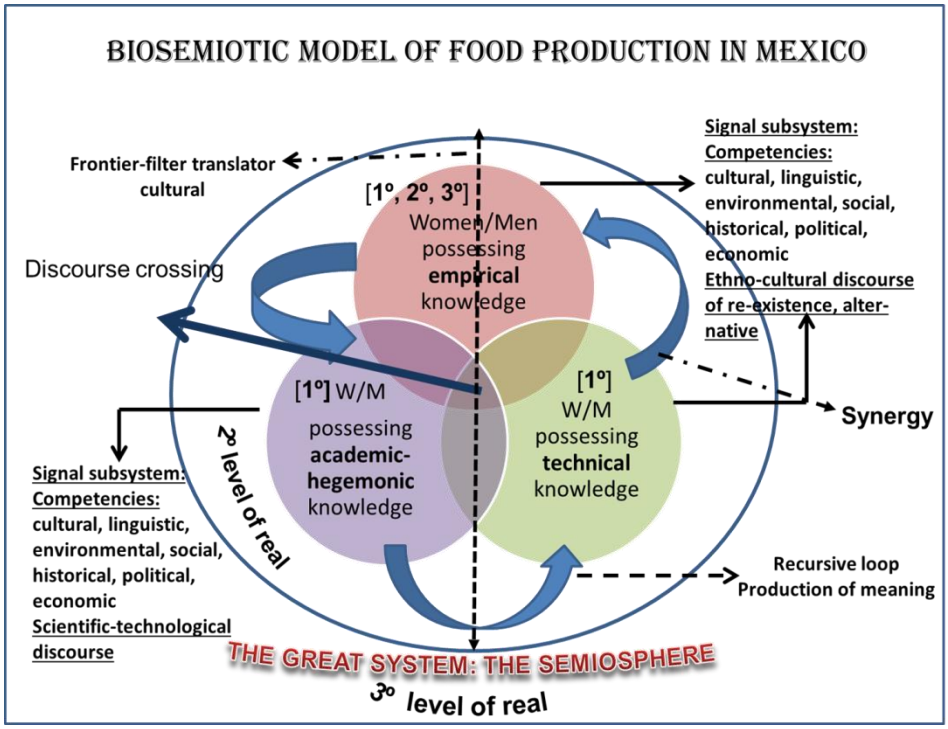
Each component is characterized and energized by its inter subjective relationships and socio-cultural practices. Thus, subjects possessing hegemonic academic-technological knowledge produce technical-scientific discourses and cultural products and transmit them to the group of farmers, which also constitutes the sign subsystem. This group not only includes farmers but also their families and laborers, whose inter subjective relationships give rise to their rituals, food, music and all aesthetic, social, economic and cultural productions. Despite having distinct languages and codes, they all belong to the same subsystem and semiosphere. This happens as a result of “the coexistence of discrete verbal languages and iconic languages, in whose system the different signs do not form chains, and instead are found in a homeomorphic relationship, acting as mutually similar symbols [...]”(Lotman, 1978:28).

In this order of ideas, Mexican farmers and farm workers have defined their own semiotic universe as a space for agroecological and livestock culture, which holds a common memory. This consists of a set of constant texts, or the unity of codes, or their invariance, or the uninterrupted, regular nature of their cultural transformation, which, in turn, shapes the memory of the culture (Cfr.Lotman, 1985) of activities involved in tending to animals, the land, water, agriculture and their environment.

The discursive semiotic model regards Milpa Alta as the great system in which various subjectivities and socio-cultural practices are incorporated and interrelated. This is an extremely dynamic system in which heterogeneities and homogeneities converge. Convergence is achieved through the translating filters of the border that allow the entry of cultural elements so that they are resemanticized. If this interrelation is achieved recursively, then it involves the production of meaning that exists within each of the components and its interrelationship with the other two.

The semiotic-discursive proposal is that subjects possessing empirical knowledge: farmers, farm workers, wives, sons and daughters who participate in the work of nopal agroecological production, transmit their knowledge to subjects possessing scientific and technological academic knowledge. The latter, in turn, process this knowledge and transmit it to subjects possessing technical knowledge, who, in turn, return it to the first subjects, so that all knowledge is incorporated, without any of it being excluded. In this exchange of knowledge, semiotic-discursive formations operate and are dynamized. In the production of information and knowledge, one should not overlook the environmental, cultural, historical environment of the countryside and the city. The discursive production of farmers will therefore be different from that of academics. It is essential to note these discursive distinctions, as well as the semiotic production that operates primarily in cultural productions, such as objects: work tools for farmers and academics which they use to create agricultural knowledge.

Finally, the proposed dialogue between the knowledge of the three components, in addition to being in a recursive loop, contemplates the entire complex of activities, whatever their nature, so that in its triadic relationship, the semiotic-discursive model performs the function of technology transfer and innovation viewed from the standpoint of complexity. See Diagram 1.



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