DIFFERENTIATION AND COMPLEXITY IN AGROECOSYSTEMS OF THE MEXICAN SUB-HUMID TROPICS †

[DIFERENCIACIÓN Y COMPLEJIDAD EN LOS AGROECOSISTEMAS DEL TRÓPICO SUBHÚMEDO MEXICANO]

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SUMMARY

Background. In Mexico, the transition from a welfare state to a minimal state in the eighties generated a change in public policies that affected the poorest farmers in the country. **Objective.** This study analyzes the transformation of agroecosystem management practices in an area of the Mexican sub-humid tropics as a result of government abandonment of this productive sector. **Methodology.** This research is qualitative and requires techniques such as in-depth interviews and fieldwork. Thirty-seven (37) interviews were conducted with farmers over 60 years old. Participants were identified based on an intentional sample using the "snowball" technique. These findings are theoretically interpreted through Luhmann's complexity paradox. **Results.** The change in public policies, as well as the reduction in public spending assigned to the agricultural sector, led to changes in the management practices of agroecosystems, especially among producers with fewer resources that led to a process of differentiation between them and, at the same time, the existence of multiple interdependencies between them, as a way of dealing with the complexity derived from the conditions imposed by the predominance of a market economy, the abandonment of the government and, in recent years, the uncertainty in the behavior of the main agroclimatic variables. **Implications.** This work is qualitative and carried out in a local context but provides highlights on changes in areas relatively similar to the study area. **Conclusion.** The process of differentiation and interdependence among agroecosystems is based on the use of various technical-productive strategies, in addition to the use of collective work and social trust as social resources that help producers with fewer resources to deal with a complex problem.

Keywords: agriculture; adaptation; interdependencie; strategies; Luhmann.

RESUMEN

Antecedentes. En México, la transición de un estado de bienestar a un estado mínimo en los años ochenta generó un cambio en las políticas públicas que afectaron a los agricultores más pobres del país. **Objetivo.** El presente estudio analiza la transformación de las prácticas de gestión de agroecosistemas en un área de los trópicos subhúmedos mexicanos como resultado del abandono gubernamental de este sector productivo. Metodología. Esta investigación es cualitativa y requiere técnicas como entrevistas en profundidad y revistas de campo. Se realizaron 37 entrevistas con agricultores de más de 60 años. La identificación de los participantes se realizó en base a una muestra intencional a través de la técnica de "bola de nieve". Estos hallazgos se interpretan teóricamente a través de la paradoja de la complejidad de Luhmann. **Resultados.** El cambio en las políticas públicas, así como la reducción en el gasto público asignado al sector agrícola condujo a cambios en las prácticas

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de gestión de los agroecosistemas, especialmente entre los productores con menos recursos que condujeron a un proceso de diferenciación entre los mismos y, al mismo tiempo, la existencia de múltiples interdependencias entre ellos, como una forma de abordar la complejidad derivada de las condiciones impuestas por el predominio de una economía de mercado, el abandono del gobierno y, en los últimos años, la incertidumbre en el comportamiento de los principales variables agroclimáticas. **Implicaciones.** Este trabajo es de carácter cualitativo y realizado en un contexto local, cuyos resultados pueden evidenciar sobre los cambios que suceden en áreas relativamente similares al área de estudio. **Conclusión.** El proceso de diferenciación e interdependencia entre los agroecosistemas se basa en el uso de diversas estrategias técnico productivos, además del uso del trabajo colectivo y la confianza social como recursos sociales que ayudan a los productores con menos recursos a lidiar con una problemática compleja.
Palabras clave: agricultura; adaptación; interdependencia; estrategias; Luhmann.

INTRODUCTION

During the 1970s, Mexico was still managed politically through a welfare State, a form of the political system to which recurrent crises were attributed (Millán, 2002). This argument was used by the government in turn as a justification to carry out a number of deep changes that led to a series of normative and legal adaptations that modified the administration of public resources, as well as commercial exchange relationships, particularly the offer and demand of foods, raw materials and inputs (Rubio, 2004; 2006); all of this, under the signature of trade deals, with the aim of fostering competitiveness and making the most of comparative advantages in our country. This promoted for the economic system to be able to consolidate its supremacy in contemporary Mexican society (Millán, 2002).

In terms of agriculture, the reduction of public resources by the Mexican State allotted to the sector affected the poorest farmers in three fundamental aspects: 1) access to credits originated by the change in eligibility criteria of the agriculture and livestock promotion programs (Fox and Haight, 2010); 2) elimination of backing and subsidies of inputs provided by public agencies that ended up being completely dismantled; and 3) reduction of support for the commercialization of their harvests, technical assistance and training (Rubio 2004; 2006; Scott, 2008).

In this sense, this study explores from a qualitative approach this process of abandonment and exclusion of farmers by the Mexican State, especially those of low income, who in face of the official neglect attempt to continue reproducing their agroecosystems as their principal livelihood and identity. Therefore, it is a study that analyzes the information obtained through qualitative techniques with the purpose of exploring in a detailed manner the reconfiguration of management practices of agroecosystems and the interdependencies present among these that reflect a diversity of strategies of farmers to continue with their agricultural activity facing the negative effects derived from the abandonment of the promotion of agriculture from the Mexican State, as a response to the demands of a market economy and climate change.

A complex predicament that Mexican agriculture suffers from today, and which may be explained through the Luhmann Paradox, which suggests that a system becomes more complex inwardly when attempting to deal with the complexity of its environment (Luhmann, 2006). who in face of the official neglect attempt to continue reproducing their agroecosystems, event that in the continuum of the reality of the Mexican sub-humid tropics is expressed in different agroecosystems due to the management practices that characterize them, but furthermore, because of the series of interdependencies that take place between them, and which allow them to continue with their individual and collective reproduction.

METHODS

Study area

The study was carried out in 2016, in El Limón, Angostillo, Xocotitla and Rancho Nuevo, four localities of the municipality of Paso de Ovejas, Veracruz, Mexico, which located in the central coastal plain of Veracruz in the Mexican sub-humid tropics between coordinates 19°17' - 19°22' latitude North and 96° 20'- 96°38' longitude West, with an altitude between 10 and 400 m above sea level (INEGI, 2010). It is a rainfed zone where the predominant types of soil are *barrial* or black soil (mollisol or vertisol), yellow soil (entisols), *cascajillo* (inceptisols) and sandy soil; these are shallow soils, stony and with low content of organic matter (López, 2008). The vegetation units that belong to the Veracruz sub-humid tropics and which are seen in the municipality of Paso de Ovejas are low deciduous forest, medium sub-perennial forest, riparian vegetation, and secondary communities (Medina and Castillo, 1993; Palacios-Wassenaar et al., 2014). The predominant climate is Aw° (w), warm sub-humid with annual precipitation between 1200 and 1000 mm (INEGI, 2009). In this region, the changes associated to climate change show a tendency to lower precipitation and higher temperature (Miranda-Alonso, 2012).

Methodology

This research is qualitative and required techniques such as in-depth interviews and field journal.

Thirty-seven (37) interviews were carried out with farmers, of whom: 5 cultivate only maize, 24 produce maize and raise livestock, and 4 of them breed livestock exclusively, as well as 4 people who only loan or rent their land to cultivate maize or obtain fodder for their livestock. The identification of the participants in the in-depth interviews was done based on an intentional sample through the "snowball" technique (Taylor and Bogdan, 1987). Farmers interviewed are over 60 years old. The number of interviews was determined heuristically since the moment in which the information obtained began to be redundant (Baker and Edwards, 2013). This information was transcribed and classified in a database according to a series of keywords: agreements, aid, pasture, water, trust, drought, conflicts, old age, and migration. (Mayring, 2002). This is how the statements were identified based on their content to finally be interpreted. This analysis was also used for the information generated with the field journal notes.

RESULTS AND DISCUSSION

Historical background of the agroecosystems in the study area within the context of a welfare State

The welfare State had an important role in the historical progression of agriculture in the municipality of Paso de Ovejas, Veracruz, Mexico, since the 1930s and until the 1980s. Starting in the 1930s, the large haciendas ceased to exist in the study area to make way to the conformation of *ejido* nuclei. This distribution allowed the former workers to have rights over land and, therefore, the possibility of a legal usufruct of parceled land. Thus, the new *ejidatarios*, although limited in resources to carry out their activity, could make decisions on their recently allotted lands.

In El Limón, Angostillo, Rancho Nuevo and Xocotitla, the *ejidatarios* were allotted with approximately 10 ha of rainfed land, in which they began to cultivate their own maize, in addition to sesame, tomato, chili and papaya for their own consumption and to breed some cattle. At the end of the 1960s, tomato and chili had their peak in the market, and both farmers who had up to 1 ha and those who cultivated some square meters were benefitted by this agricultural boom, the evidence of this prosperity of income is the construction of their houses in this period. As consequence, these conditions originated agroecosystems whose production had as objective the subsistence and the market, simultaneously.

Based on this, it is argued that the transformation of the agroecosystems that took place until the 1970s in agriculture of this region was part of the phenomenon called "Mexican Miracle", a process derived from the positive effect of a set of policies directed at agricultural development as a means to obtain inexpensive foods and raw materials, part of a National Development Plan that had as ultimate goal to stimulate national industry (Calva, 2004; Rubio, 2006). During this period that lasted approximately 24 years, these policies are expressed in favorable agricultural prices, flexible eligibility criteria for *ejidatarios* to be subject to capital loans with preferential rates, etc. This gave farmers relatively favorable conditions to develop their agricultural activity. All of this as a result of strategies to promote agricultural activity both in production and in commercialization through a government apparatus created expressly for this purpose (Soto, 2007).

This was possible because the State could still be considered as an agglutinative system (Millán, 2009) that directed agricultural policies and favored the relative inclusion of a sector of agricultural farmers of the county, among them, those from the Veracruz sub-humid tropics. A Mexican State characterized in this period by its centrality. However, the change toward an economic development model in the ending of 1980's, where the role of the State was substituted by the market, called by Millán (2002) a minimal State, led to the abandonment of the agricultural activity as consequence of the increase of the unfavorable agricultural prices, decrease of the offer, increase of the prices of agrichemicals, and lack of financing. This situation was expressed in the recomposition of the agroecosystems in the study area, when the cultivation of tomato, chili and papaya was abandoned gradually. These crops were finally excluded by the farmers in their agroecosystems to be devoted again to maize production and livestock whose production began to have as predominant objective the market.

Extra agricultural work and extra-farm work as a form of financing for management practices of agroecosystems

Facing the lack of backing or credits for the farm holders by the State, a strategy of farmers to finance their subsequent agricultural cycle was performing works outside their plot/farm, the farmers with less resources and/or schooling began to be hired as workers by bricklayers, coal sellers, stevedores, etc. Those with more schooling and/or resources have done so as managers of sugarcane plantations and ranches, managing small businesses devoted to commerce, public transport and food sale. This evidences how workers with less resources and/or schooling carry out extra agricultural work in more dangerous conditions, of greater physical demand, and less autonomy in the administration of time, particularly that devoted to agricultural work. This situation regularly forces such farmers to a temporary and/or pendular migration, relatively distancing them from the spatial unit, on which their agroecosystems are superposed, affecting the

beginning and the development of different management practices performed during the agricultural cycle.

Vázquez-Palacios (2003) mentions that around 45 % of the *ejidatarios* in central Veracruz migrate toward nearby cities, north of the country, to the United States and Canada, performing tasks in the service sector and as agricultural day workers. Although the destination of migration is similar to the one found in the study area, the percentage of migration of the farmers interviewed is only 23 % migration. Meanwhile, the percentage of migration of their children was also similar to the piece of data mentioned by the author. Likewise, the empirical evidence agrees with Vázquez-Palacios insofar as in past decades most of the migrants returned to their locality and/or *ejido* nucleus in a pendular migration. This process served the farmers, in a specific moment, to have knowledge about cattle farming, vegetable crops, and fruit tree management, situation that has allowed them to introduce other components in their agroecosystems.

Currently, this type of migration is lower and those who carry it out perform predominantly activities related to the service sector. Now, most farmer´s son who migrate do it permanently, since, in addition to the lack of economic resources for the reproduction of the agricultural cycle and domestic life, there is a greater pressure for the productive space, with migration being an alternative to this problem (Vázquez-Palacios, 2003). Thus, in the first years of migration these people are a valuable source of financing, but their absence also means the loss of family workforce.

Revaluing the use of *vuelta de mano* and its transformation as a means of favors exchange and employment generation

The use of *vuelta de mano* ("payback") is a collective work form inherited from ancient Mesoamerican societies that is still current in the study area. Velázquez (2014) argues that *vuelta de mano* is a social interaction produced through an active exchange of help that is given and received in the form of work, and that its result in economic terms is fundamental for farmers and their families; likewise, it is a means that strengthens the community and intercommunity spheres, and generates a positive social valuation for those who practice it.

In the study area, temporal and permanent migration, particularly of the youngest people, changed the organization of agricultural work, since it reduced the availability of family workforce and its financing became critical. The farmers had to search for alternatives, in face of the impossibility of the use of *vuelta de mano*, which has been limited solely to the agricultural activities of sowing and harvesting. This fact expresses the crisis of a collective form of work based on reciprocity derived from sharing family and friendship ties, which allowed in the past the emergence and use of trust as a social resource (Luhmann, 2005). And, although it is less frequently used, it is still conceived as a non-monetary alternative when in need of workforce.

In localities like El Limón, the farmers gave new meaning to *vuelta de mano*, which evolved into a "monetarized payback"; that is, it was no longer collective work based on exchanging favors, but rather it also involves payment for the day work performed. Thus, work groups have been formed where each one of the members have available workforce, but without forgetting that their availability requires payment for it (the farmers mention that it is a means to give each other work). The possibility of continuing within each work group depends on their members fulfilling the expectations of their peers; this guarantees their permanence in the group and having workforce for their own activities as part of the management of their agroecosystems. Although there are no studies about this theme, it is inferred that this observed phenomenon can be associated to the fact that the locality where it was observed is the closest to urban centers. Meanwhile, in the farthest locality, which is Xocotitla, where farmers grow their maize in plots with complicated access, *vuelta de mano* during the harvest implies in addition to the workforce of their peers, the use of their beasts of burden to transport the harvest.

Land division by the Certification Program of *Ejido* Rights (Programa de Certificación de Derechos Ejidales y Titulación de Solares) and its effect on the administration of time in agroecosystem management

After 20 years, the opinions of farmers in the study area about the effects of land plot certification are varied. Some of the interview respondents mentioned that the land devoted to agricultural activity decreased, and this was because the farmers who worked more had more land, and they even used the land of farmers who were "lazy". In *ejido* nuclei like Angostillo and El Limón, there are those who mentioned that this process allowed the access of this means of production to those who had been partially excluded. "Before PROCEDE there were *ejidatarios* who did not have land, those who had more money had taken over the land, and even those who were free […] had more of their terrain, they had it all fenced in."

It is inferred that this differentiation is linked to the unequal access to financing of some *ejidatarios*. This process is connected to the government support provided by the State at that time and with the economic resources accumulated by the previous generations in their family nucleus, which

allowed some farmers to occupy larger agricultural spaces, nearby and perhaps with better characteristics in terms of soil quality.

With PROCEDE, a process of intensification in land use began, that is, some areas were devoted exclusively to maize cultivation and others to livestock production. This situation deepened with the operation of the Program for Direct Supports to The Farmland (*Programa de Apoyos Directos al Campo*, PROCAMPO) with a mistaken idea about farmers, in terms of the program prohibiting the change of crops and the support being linked to a plot located in a specific place (Leonard et al., 2004).

The reduction of the surface of those who got to have more land led to the decrease in the grazing area and, therefore, of the herds. In fact, those who had scarce livestock had more limitations to gain access to grazing, because the practice where livestock wandered around the *ejido* nucleus ended. Most of the farmers began to close off their plots with fencing. Before land division, the livestock moved from the grazing areas to the zones of watering holes, and this was no longer possible after PROCEDE. This implied that farmers made changes in their time management, since with the livestock being confined to a certain area they had to supply them with water. This situation is critical during the dry season. The older women and men who did not have family workforce, or whose grazing areas were far from the sources of water supply for the livestock to drink at, abandoned this activity. Instead, the enclosing of plots devoted to maize cultivation allowed it to be harvested in a delayed way, because there was no longer the possibility that someone else's cattle would enter the cultivation areas. Leaving the folded maize in the plot became a way of storing to wait for better prices for the grain, particularly for farmers who do not have a space or adequate containers for its storage.

With land division, an incipient land market emerged, through which the farmers by having legal certainty of their land have the possibility of offering all or part of their land in a moment of economic crisis or of decrease in their physical capacities. Until now, those who have purchased plots in the rainfed zone are characterized for having some connection to the *ejido*: they are children of *ejidatarios* who have migrated and accumulated some economic resources, the most competitive *ejidatarios* who hoarded a good part of the old *ejido* property (Mestries, 2006), as well as some smallholding owners with whom they even share the area of the *ejido* settlement. Some of these lands acquired have had the main objective of obtaining fodder for livestock (Quesnel and del Rey, 2005). This agrees with what Camou (1998) suggested, when he argues that the process of converting to livestock has been more dynamic in the smallholder sector and is characterized by its greater dependence on agricultural lands than on pasture lands.

With the existence of an incipient land market, the inter-generational and intra-family solidarity began to break down, which allowed members of the family who did not own land to have access to cultivation lands. And although there is still land loaning among family members, sometimes when the son/daughter who has been designated as successor of the land rights decides to sell, he/she leaves his/her siblings without the possibility of usufruct from the land, which is why they have to look for alternatives such as the loan or rental of land with other family members or peers.

Access to cultivation land water for the functioning of agroecosystems: loaning, rent and resource exchange

Since more than a decade ago, children and grandchildren of some *ejido* founders had to make use of loaned lands because they did not have a productive property of their own derived from an endowment or inheritance of *ejido* or smallholding rights. Land loans favored by the links of blood relation and friendship, as happens in other parts of the country after the changes in the legal framework of the land (DOF-LA 1992; Orozco-Hernández et al. 2017). In the study area, this loan implies that the farmer fulfills with the condition of providing some service to its owner, in exchange for being able to use it one to three years. Some of these services are: taking care of the property, repairing fences, and surveilling the plot. These types of services are not necessarily carried out when the land loan is offered by a family member, generally a brother or a father. The time of the loan in this modality is regularly longer, however, it can end abruptly when the successor of the rights dies and the succession rights go to a single child, this as part of the provisions of the Agrarian Law where it is specified that only one person can inherit the rights which usually go to the first-born or last-born (DOF-LA 1992; Almeida 2012). Next, some of these variants of loan and exchange are listed:

a) Those who cultivate maize and loan the area for livestock that belongs to others to consume the residues after the harvest.
b) Those who ask to borrow a surface from another farmer to sow maize with the promise of letting them use the residues after the harvest.
c) Those who cultivate maize in a plot halfway, for example: father-in-law and son-in-law.
d) Those who cultivate maize in their plots and make bundles with the residues to sell to those who do have livestock in the dry season.
e) Those who do not sow maize and also do not have livestock, but do own a plot,

which they loan to others to graze their livestock in exchange for some favors.

f) Those who do not sow maize and also do not have livestock, but do own a plot, which they rent out to others to graze their livestock.

g) A person without land can ask for a plot in loan, committing to clearing the ground and converting to pasture the surface occupied at the end of the maize harvest.

In the last decade, farmers began to rent land to graze cattle; they are those who have achieved to increase their herds, and who in many cases have become specialized solely in breeding some animals. Other farmers with financial resources have managed to expand their livestock surface, since the changes in the Agrarian Law of 1992, expanding their livestock surface by acquiring cultivation land whose aim is to obtain fodder for the livestock. In this sense, the agrarian structure ceased to be a limitation for the expansion of the livestock surface; this expansion of the livestock frontier can be cataloged as a late conversion to livestock production. This agrees with what Camou (1998) suggested, when he argues that the livestock conversion process has been more dynamic in the smallholder sector and is characterized by its higher dependence on agricultural lands than on pasture lands. This late livestock conversion could not succeed without the existing differentiation among agroecosystems and the inter-dependencies between them, as is shown by Figure 1.

Although access to land is important, having water for the livestock to drink is vital, particularly now when the dry period has become prolonged (Magaña et al., 2009). These loans have made functional again the livestock activity for some farmers, while for others they have meant the end, since after land division, the animals could no longer move to the areas with drinking holes, and when hot having available workforce or time, some farmers decided to abandon livestock breeding. That is, access to water could not be explained without the interdependencies established between farmers and medium and large scale owners whose productive areas are adjacent to the localities in the study area and have access to areas with drinking holes. Camou (1998) mentions that there is a structural relationship between the medium and large livestock farmers and the small-scale breeders through links of dependency and subordination, of competition but also of collaboration, as shown in Figures 1 and 2.

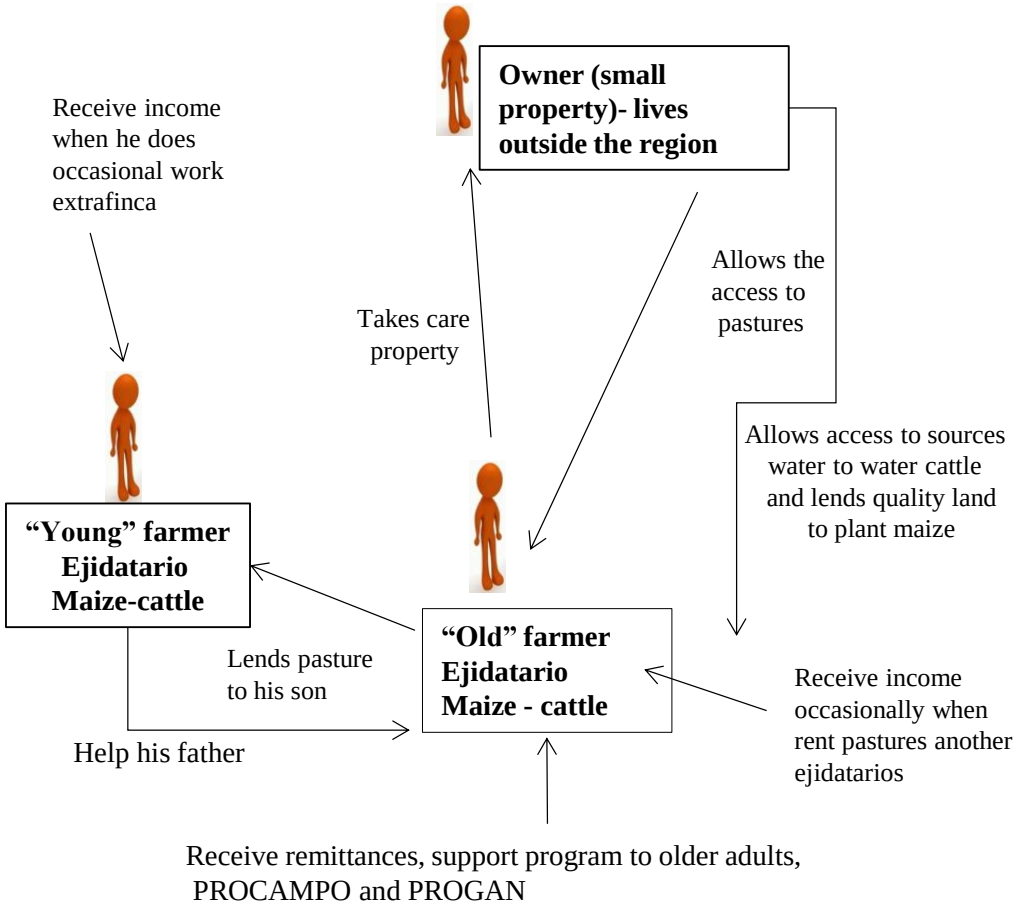

Figure 1. Relationships based on solidarity and reciprocity between members of an extended family and a smallholder in Xocotitla, Paso de Ovejas, Veracruz, Mexico. Source: Prepared by authors with information generated through an interview with the participant.

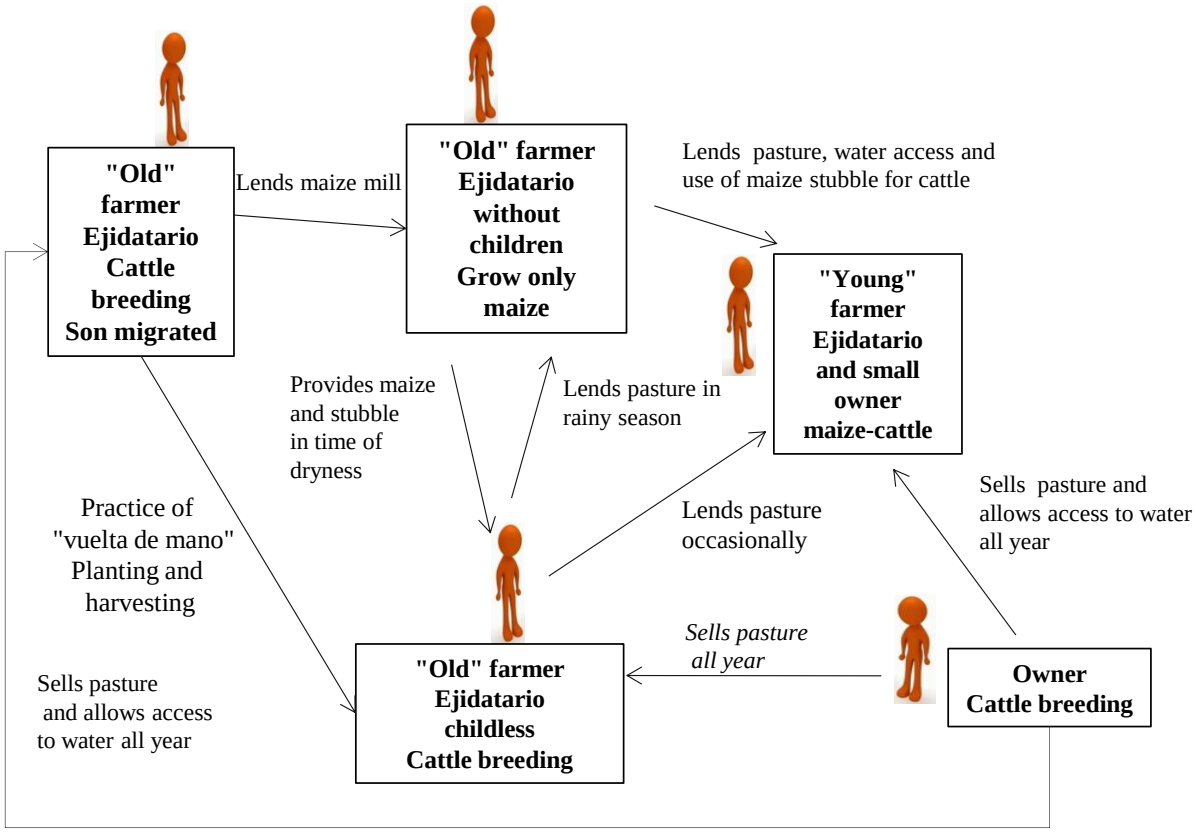

Figure 2. Interdependencies between agroecosystems that express how access to grass and water takes place between farmers members of an extended family and an owner in Angostillo, Paso de Ovejas, Veracruz, Mexico. Source: Source: Prepared by authors with information generated through an interview with the participant.

Use of the *acriollado* H-507 maize

The introduction into the study area of the improved maize H-507 in 1975 was successful, and since that time it coexisted to different degrees with native maize. It should be pointed out that H-507 was generated by the National Institute of Forest, Agriculture and Livestock Research, and distributed to farmers in the social sector by the National Seed Producer (Gómez-Montiel et al., 2013). The supply of this type of seeds was suspended gradually when the National Seed Producer began to be restructured in the 1980s and finally disappeared in 2000. This gave place to private companies in the 1990s that offered improved maize races to occupy 96 % of the seed market in Mexico (Espinoza, 2003; Espinosa et al., 2014). Consequently, since the 1990s, improved maize races were adopted massively. With this, the cultivation of maize races *cuarenteño*, *negro*, *delgado*, *crema* and *tuxpeño* was abandoned, and even the use of national hybrids like H-507, to finally focus on the production of the maize races cultivated at present: *Pionner* supplied by the multinational of the same name, and *Dekalb* by Monsanto. That is, the role of the State was substituted by the market interests.

In reality, this implies that currently the sole purpose of hybrids generated by multinational companies is to satisfy the demand from agro-industries, some of them transnational (Rubio, 2006; Castañeda et al., 2014). Something that makes this situation worse for farmers is that these multinationals are controlling both the generation of the seed, their supply, and agrichemicals associated to their management, the commercialization of the harvest, thus closing a perverse cycle (Quist and Chapela, 2001). That is, the influence of global economic interests on a local reality.

The introduction of improved maize races led to other changes, among them sowing at higher density, such as has happened in other zones of the state of Veracruz (Zurita et al., 2012). This is how there was a change from a density of approximately 15 thousand plants of native maize races to a density of 40 or 50 thousand plants of improved maize races. In addition to the seeds, the farmers with higher financial capacity could gain access to the whole technological package associated to them, while those of lower capacity adopted the practices selectively. Even so, the changes carried out are expressed in an increase of the production that is part of the main arguments that still now justify their use. However, their use has always been limited by the farmers of low income due to their financial capacity since it represents a greater investment.

The increase in production volumes, which went from two tons in native maize races to more than four in improved maize races under favorable soil humidity conditions, favored the need of more efficient de-kernelling particularly in terms of time, condition that favored the commercialization of the grain to intermediaries. Thus, mechanical de-kernelling was introduced, which is carried out most of the times in the farmers' plots where currently the trucks arrive to transport the grain to the market. This reconfigured the agricultural landscape of the rainfed zone, since the areas of higher fertility and accessibility were used for the cultivation of improved maize races, leaving to the native maize races the more secluded areas and of difficult access.

However, after almost three decades of use of improved maize races, and particularly the use of maize races that are supplied by multinationals, the farmers recognize the loss of their native seeds which implies the dependency of the purchase of improved seeds, and the package of inputs associated to them, as well as their negative effects on their health, the soil and other species, situation that originated the simplification of the *milpa*. However, the higher production obtained with the improved maize races gave them more money, and now they have to buy foods. In face of this situation, some of the farmers have started using *acriolladas* H-507 seeds, which have been saved and selected in the family nucleus (Espinosa-Calderón et al., 2012).

Use of agrichemicals, impacts on soil and on the health of farmers

In addition to the fertilizer, other agrichemicals like pesticides and herbicides began to be used for maize cultivation. This meant an increase in the productivity of work, the substitution of the workforce, and the reduction of time devoted to this activity making it possible for farmers, in some cases, to finance a larger cultivated surface or to have time for day work and/or to perform activities other than agricultural ones. However, after nearly three decades the environmental effects of these agrichemicals in the study area are perceived by the farmers.

Likewise, before the massive use of agrichemicals, the cultivation of maize was part of a larger spatial and temporal arrangement (*milpa*). That is, the farmers in the study area cultivated or managed different species of plants that had the main purpose of providing foods for their diet, which included the consumption of leaves, grains, fruits and even fungi. Presently, the diet has been simplified and the exploitation of byproducts in their cultivation areas is limited primarily to obtaining residues that may be used as food for livestock in the dry season. A study by Casanova-Pérez et al. (2019) found that 72% of the interviewed farmers perceive that the use of agrochemicals has resulted in low soil fertility.

In terms of the farmer, the use of agrichemicals is already a theme of social communication within the localities for several causes. The first, because since having used them for many years, and increasing the doses according to criteria of empirical nature, farmers have started to suffer intoxications. In this sense, García-Gutiérrez and Rodríguez-Meza (2012) mention that Veracruz, together with Sinaloa, Chiapas and Jalisco are the states where pesticides are used most in the country. In this regard, farmers indicate that intoxications have become recurring so that now their application is made by the children and/or dayworkers(relatively young and healthy in relation to the physical conditions of the old farmer), hired for this activity in particular and whose average age is 58 years.

The second reason why farmers are worried is the purchasing cost of herbicides and pesticides, its use for long time has increase of resistance by parasites, which is why they have limited their use when applying them in a very specific way, in certain areas of the plot or in specific parts of the plant or set of plants infested. According to their opinion, this reduces costs, reduces soil contamination, and a greater impact in their health. The same happens in the case of fertilizers, since because they cannot cover the costs of fertilizers they carry out fertilization once, knowing full well that the yield of the maize harvest would be lower (Larque-Saavedra et al. 2019).

Selling native maize races in vicinity markets

In the study area, only 5 farmers interviewed sow native maize, called by farmers, Creole maize (Márquez-Sánchez, 2008). This is maize for specific culinary use: corncob consumption, preparation of *atoles* and *tamales*. Although these are a minority (3 % of the farmers surveyed), their strategy is innovative, which has implied that these farmers have become active entities in search for alternative and/or private markets. The search for similar experiences documented in the rest of the country are minimal in this sense, with studies carried out in some communities of Puebla, Tlaxcala, Guerrero and Oaxaca standing out (López-Torres et al., 2016; Mora Van Cauwelaert, 2017), whose findings point out that the native maize races are of high demand in certain segments of local and regional markets, where final consumers use them to elaborate tortillas, dishes and beverages associated to a specific culture, used in the domestic level or in gourmet restaurants or of high culinary specialty (SAGARPA, 2014; López-Torres, 2016; Mora Van Cauwelaert 2017).

The most frequently commercialized native maize during the phase of field research was *negro* maize, its price per kilogram is 200 % higher than the

improved maize. Based on the in-depth interviews it was found that those who cultivate this native maize, do it in relatively remote areas where both Pionner or Decalb maize races are sown, because the phenological stages of both maize races should not coincide since they could cross genetically causing for grains of unwanted characteristics to appear during the harvest of improved maize, and these not fulfilling the expectations of market agents (SAGARPA-ASERCA-CIMA, 2016). This would bring as consequences the emergence of conflicts between *ejidatarios*. Therefore, the farmer who wants to sow native maize needs to consider a spatial temporal arrangement in their agroecosystem to keep from affecting their peers' harvest.

Furthermore, a previous study indicates that 16% of farmers have opted to plant H-507 *acriollado* corn (a seed corn released by INIFAP in 1961) or CP-569 (seed generated and marketed by the College of Postgraduates to farmers in its Priority Attention Area). From the farmers' perspective, both seeds in conjunction with native maize are an alternative to the conditions of lower humidity and higher temperatures that affect the cultivation of corn (Casanova-Pérez *et al.*, 2019).

Use of maize residues as a source of fodder for bovine livestock during the dry season

The interest of farmers for raising bovine livestock has the aim of obtaining or complementing income, particularly in critical times, since its commercial value facilitates obtaining money relatively fast in face of any conceivable situation. This is the reason for the search for grazing areas, sources of water for this purpose, and maize as a source of residues for the livestock. Morales-Carrillo (2008) mentions that there has been a reconversion of the surface to crops that leave more plant cover after the harvest for its use as fodder, which agrees with what happens in the study area, where sesame seed and beans are considered crops that do not produce pasture for the livestock. Thus, the exploitation of livestock cannot be explained without the relation it has with maize production both by those who own and those who do not own livestock.

Therefore, maize residues have become an important source of food for livestock, since the grain harvest is carried out in the dry season. If the farmer doesn't own livestock, the residue is donated or sold to those who do. Those who do not sow can purchase it, as part of the existing flows between agroecosystems. In addition, maize leaves are now kept or used to make bundles. De-kernelling in the plot allows for the leaves to be easily transported to the place where the livestock is located or vice versa.

The use of residues from the maize harvest is an example of the interdependencies that farmers foster between their agroecosystems, and they imply: loaning and/or renting pastures, residues, even access to watering holes, between those who produce maize, maize-livestock, livestock-maize, or only raise livestock. Thus, livestock and maize have become the fundamental components of agroecosystems for being components that "understand quite well" and which are the basis of a necessary relation between farmers who own livestock or not, with those who sow maize or not. Among those who abandoned maize and converted their whole surface to pasture area, this late process of conversion to livestock production has contributed to the development of a land market that makes possible for some farmers to expand their livestock producing area.

In the case of some old farmers, they are leaving aside maize production to devote themselves exclusively to livestock breeding; this is possible through alliances within their extended family network to obtain grains in times of crisis of the pasture land, and to provide their loaners with a grazing area when they are cultivating their maize. The sales income from their livestock is added to that obtained periodically through welfare programs of support to the elderly and agricultural and livestock promotion such as PROCAMPO and the Livestock Promotion Program (*Programa de Producción Pecuaria Sustentable y Ordenamiento Ganadero y Apícola,* PROGAN).

Thus, livestock production is no longer part of the modernization of the Mexican tropics as it happened in the 1970s, but rather as a late conversion to livestock production, which functions as an emergent strategy to obtain periodical and relatively more stable income for older farmers who own land, have access to water for the livestock to drink, and can establish helping connections with their family members.

Theoretical-conceptual and methodological aspects that must be discussed

From the Luhmann perspective, the way of farming in the study area became more complex with the objective of dealing with the complexity of the environment (Luhmann, 2006), from the economic (high costs of inputs, low agricultural prices, lack of financing, training and technical assistance), social (individualization of production, erosion of solidarity and social trust), and environmental (degradation of the soil, changes in the main agroclimatic variables) dimensions. To deal with this complexity, farmers were forced to establish and to innovate with a series of strategies that allow them to continue with their agricultural work. The result of this has been the establishment of interdependencies between the agroecosystems without which these could not continue reproducing.

This brings with it several theoretical-conceptual implications that should be reviewed. In the first place, it is imperative to go beyond the conception of the agroecosystem as a production site equivalent to a ranch, farm, plot, *milpa*, garden, etc. Based on a theoretical approximation that allows conceptualizing it as a logical construction, an abstraction that eases the interpretation of agricultural reality, where the limits are not physical (García, 2009; Casanova-Pérez et al., 2015). In the study area, this means that the study of the functioning of maize, maize-livestock and livestock agroecosystems should not be solely based on the analysis of the physical components located in a specific production space (plot/farm), since in reality the functioning of maize and livestock agroecosystems could not be explained without the interdependencies established by the farmers through a series of agreements of solidarity, reciprocity or based on monetary terms (land rental, pasture purchase).

Secondly, it is important to suggest again the significance of the subsistence farmer, term related to obtaining their food and their family's (SAGARPA-FAO, 2012; Farré, 2015), since now the maize produced is sold to intermediaries to solve different needs in the short term and with the money obtained, purchasing maize grains or tortilla for their food during the rest of the year. The aim is the same; however, to reach it, other economic actors intervene that place them at risk. Thus, subsistence should no longer be associated with maize production as its foundation, but rather as one of the means through which farmers obtain incomes, directly or indirectly, that are used to supply themselves and their family with foods or other essential necessities. In the study area, the subsistence of the farmers and their families also involves the income generated by extra-farm work, day work and resources given by social assistance programs by the Mexican State.

In third place, what should a farmer be called, who is sowing native maize again against the tide? A farmer who has found a market niche that allows him to obtain a higher price per kilo than the one obtained for a kilo of improved maize. This strategy was observed in four farmers from two localities that are part of the study area. Although they could be thought of as isolated cases, this does not decrease the value of this behavior where the farmer takes advantage of a product in a vicinity market that responds to a particular culinary use within nearby communities and cities, religious festivities, etc.

These strategies have been developed by farmers to continue with the reproduction of their agroecosystems. Strategies that respond to precarious, restrictive and conflictive situations, and which allow the poorest farmers to continue with their agricultural activity. This requires information divided into themes at the social level regarding alternative markets, understanding the requirements, the needs or the desires of those who have the possibility of loaning land to those who do not have land or have very little. In addition, there are older farmers and without family who when recognizing the livestock market prices as more stable, have decided to abandon maize cultivation and reconvert their activity solely to livestock breeding, but with relatively nearby lands and water sources for drinking, generating a process of late conversion to livestock production.

This new reality undoubtedly requires theoretical approximations that allow the study of agroecosystems as complex systems (Casanova-Pérez et al., 2015), in order to then highlight the importance of understanding how these interdependencies function, which evidence that the limits of the agroecosystems definitely exceed the physical limits of the production units (Herrscher, 2008).

CONCLUSION

In Mexico, the transition from a welfare State to a minimal State in the 1980s produced changes in the structure and functioning of agroecosystems in the study area, and therefore, in their management practices. Consequently, a process of differentiation was generated between the agroecosystems, as a response of the individual strategies of the farmer, at the same time that a series of interdependencies were established among them as part of the strategies of collective nature, which nowadays allow farmers to continue reproducing. These interdependencies reflect the complexity of agricultural work within a local context that results from the effects of an imbricated relationship between the economic and environmental crises. This puts to the test the theoretical approaches used in the study and analysis of agroecosystems, particularly those of their delimitation, and refer to the search for theoretical-conceptual architectures based on complex systems, such as happens with the Luhmann paradox.

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