Vol. 10(1), pp. 1-11, January 2019
DOI: 10.5897/JSSEM2018.0714
Articles Number: 5C2428E59775
ISSN: 2141-2391

http://www.academicjournals.org/JSSEM

ACADEMIC JOURNALS
expand your knowledge

Journal of Soil Science and Environmental Management

Full Length Research Paper

Adoption of soil conservation practices through knowledge governance: the Mexican experience

Helena Cotler* and Maria Luisa Cuevas

Centro de Investigación en Ciencias de Información Geoespacial Mexico.

Received 28 September, 2018; Accepted 12 November, 2018

Top-down and centralized soil conservation programs have caused low adoption of sustainable practices. The adoption is a multistage and adaptive process that relies on the management of local knowledge. The results of 61 surveys were analyzed in order to systematize experiences of soil knowledge governance involving social organizations and farmers. Soil knowledge governance was done mainly through the sharing of experiences among farmers. This path resulted both in the strengthening of existing institutions and in the creation of new associative forms and rules. The incentives for farmers to maintain soil conservation practices went beyond the financial ones and reflected the diversity of their views and expectations: eating healthy food, diversifying agricultural production, and improving their social position in the community. The increased adoption of soil conservation practices that resulted from this approach led to the rethink the kind of public policies that would better help soil conservation in Mexico.

Key words: Public policy, soil conservation, soil knowledge governance, sustainable land management.

INTRODUCTION

Soils provide a wide range of ecosystem goods and services, particularly in terms of runoff control, water-holding capacity, ecosystem productivity, carbon sequestration (Amundson et al., 2015), food production (White et al., 2012) and biodiversity preservation (Ibañez et al., 2012); they also play a key role in at least seven of the proposed planetary boundaries (Bouma, 2014).

Soil erosion is a challenging issue not only because it causes yield loss (Montgomery, 2007) and has environmental impacts, but because it is also closely linked to rural poverty (Ruben and Pender, 2004). To address and mitigate this problem, programs have been developed with the help of governmental and non-governmental international funding. These efforts have been made under different premises and different names such as, soil conservation, conservation agriculture, climate-smart agriculture, and sustainable land management, which all express the same concern: implement low-impact agriculture that maintain soil quality.

At first, these programs were characterized by information transfer mechanisms limited to the unilateral transmission of specific technologies to farmers, without incorporating their demands, experiences and expectations (Manuel-Navarrete and Gallopin, 2012), and without considering site-specific biophysical conditions,

*Corresponding author. Email: Helena.cotler@gmail.com.

the type of agriculture (irrigated or rain-fed) or livestock production (intensive or extensive), or land extension (Damián and Toledo, 2016). These early programs, thus, tended to have a simplistic view of rural issues. Such top-down, unilateral mechanisms seem to explain why the conservation initiatives undertaken have faced low rates of adoption of practices by farmers (Helin and Haigh, 2002; Andersson and Ken, 2012; Arslan et al., 2014; Nkala et al., 2011; Ward et al., 2018).

Incorporating the knowledge built over decades to centuries into conservation initiatives requires knowledge governance, understood as “a fluid and historical processes of co-evolution between agents, organizations and institutional arrangements, and the knowledge they help to create and reproduce” (Manuel-Navarrete and Gallopin, 2012). The patterns of knowledge governance affect the mainstreaming of sustainability practices and integrate knowledge about their multiple dimensions (such as social, cultural, ecological; van Kerkhoff and Lebel, 2006). Due to the wide variety of ecosystem services performed by soils, no single level of governance can provide incentives for users to safeguard their long-term delivery (Orchard and Stringer, 2016). There is also growing acknowledgement that centralized, top-down mechanisms are inadequate for tackling land degradation as well as ensuring the sustainable use of natural resources more widely (Nagendra and Ostrom, 2012). Experience has shown that there is no “best practice” or innovative policy approach that can be applied to any type of region (Tödling and Tippl, 2005), and that no conservation practice is a panacea that can be adopted everywhere (Hudson, 1987).

General experience from the field and literature indicates that successful, scaled up and durable adoption of new technology requires consideration of both agro-ecological and socioeconomic factors affecting the incentives and constraints to adopt (de Graaff et al., 2008; Soule et al., 2000; Jara-Rojas et al., 2013; Arslan et al., 2014). It is however important to differentiate between the adoption of a new technology, generally done to increase economic profitability, and the adoption of a conservation strategy, which implies transforming the agroecosystem (de Graaff et al., 2008; Jara-Rojas et al., 2013).

In Mexico, soil erosion affects 60% of the land and 48.6% of the agricultural production units; while loss of soil fertility was mentioned as the main obstacle to the development of farming activities (INEGI, 2012). Soil erosion has costly consequences, with an estimated 38.3 to 54.5 dollars per hectare lost in yield and nutrients that have to be replaced by fertilizers (Cotler et al., 2011). The problem of soil erosion in Mexico has been addressed through the creation of public programs promoting technology packages that have not been discussed or agreed with farmers, nor adapted to the large social, environmental and cultural differences of a megadiverse country (Cotler et al., 2013; Turrent et al., 2014; Cotler et al., 2016; Damián and Toledo, 2016).

One of the main challenges to agriculture and livestock production is to create systems that are at the same time productive, resilient and adaptive to climate variability, and water and energy efficient, and this without damaging or polluting the environment (Arnés et al., 2013). In this respect, it is important to recognize that resilient soils are the foundation of resilient agroecosystems (Blanco-Canqui and Francis, 2016). Farmers working in different contexts have developed innovative strategies to improve soil quality and deal with climate variability (Altieri et al., 2015) to help develop adaptive climate-change response strategies (Astier et al., 2012). Such a “knowledge dialog” between generations and within communities has a long tradition throughout Mexico (Moreno-Calles et al., 2013; Toledo, 1990).

Theoretical approach

Concerns about soil dates back several centuries (Rasmussen, 1982) and grew with declining yields, erosion and most of all, drought and deforestation (Showers, 2006). Since the middle of the 20th century, soil conservation programs have followed the guidelines of international organizations, which, under certain ideological assumptions, have understood the soil erosion problem and outlined the steps required to address it (FAO, 1977; Biot et al., 1995; Simonian, 1999; World Bank, 2006; Showers, 2006).

Current governmental approaches promoted and implemented in different countries were classified by Biot et al. (1995) into three major categories based on the paradigms they pose about the causes of land degradation, the role of institutions, the market, the role of science and the peasant behavior, among others characteristics. These three-contested views about degradation are neither strictly sequential in their historical development, nor mutually exclusive (Table 1). However, since the globalization and industrialization of agriculture, pauperization of small farmers, and the loss of agrobiodiversity, several researchers and social movements have proposed new paradigms that take up the knowledge of peasants from many latitudes. These are based on the principles of food sovereignty, agrodiversity, resilience and defense of the territory (Altieri and Nicholls, 2008, Altieri and Toledo, 2011; Gliesmman, 2013; Holt-Gimenez, 2001; Via Campesina, 2013; Turrent et al., 2017; Astier et al., 2012; Astier et al., 2015). These proposals that collect local knowledge are opposed to the classic and neoliberal visions, adopted by the government agencies, in terms of values, where the concepts of efficiency, performance and homogeneity are not shared and in terms of participation, knowledge and the responsibility of small farmers.

In this context, this study sought to systematize

Table 1. Some characteristics of different peasant behavior paradigms.

	Institutional prescription	Peasant behavior	Immediate cause of erosion problems
Classic	Top-down centralized decision making.	Ignorant, irrational, traditional. Lack of participation by land-users in designing and implementing conservation technologies	Mis-management by users. Inadequacies of state bureaucracies charged with soil conservation strategies.
Populist	Bottom-up participation	Virtuous, rational, community-minded. It is required site-specific participatory study.	Mis-management by state, capitalists, big business
Neoliberal	"Market" policies, property rights, resource pricing	Rational egocentric	Poor government policies and bureaucratic rules & regulations. Direct relationships between poverty and land degradation.
Agroecology	Bottom-up recognizing local traditions, rights and knowledge	Peasants as central social actors in the processes of resistance to the neoliberal trade agenda and in the construction of alternatives based on their knowledge	Alliances between transnational industries, food corporations and governments that cause the dispossession of territories to peasants and indigenous peoples

Modified from: Biot et al. (1995).

experiences of soil knowledge governance involving social organizations and farmers or ranchers, with the aim of incorporating soil conservation practices and promoting sustainable land management. Emphasis was placed on: (i) mechanisms for building knowledge governance; (ii) the implementation of sustainable land management according to local socio-environmental conditions; (iii) institutions promoting and adopting soil conservation practices; and (iv) mechanisms for learning and monitoring soil conservation practices. The results of this study should lead us to rethink the kind of public policies that would better help soil conservation in Mexico.

MATERIALS AND METHODS

The study was conducted in two phases. The first one consisted in a compilation of case studies from social organizations working on farming issues at the national level, which were analyzed in light of the following criteria:
++
(i) A working method based on both ongoing dialog between NGOs and farmers and knowledge governance over 3 to 5 years;
(ii) The incorporation of soil conservation practices and implementation of sustainable land management.

In the second phase, for the case studies that met these criteria, a survey was conducted, which included both open- and closed-ended questions. The survey was conducted by various means: (i) through a website; (ii) by email; and (iii) on site, for farmers without internet access. The elaboration of the questionnaire followed several steps. First, the questions were elaborated according to the objectives of the research. As the questionnaire was directed towards two different groups: agricultural systems and silvopastoral systems, the specific questions on the systems were differentiated, for which a bibliographic review was made on these systems in diverse socio-environmental conditions of the country. Once the questionnaire was prepared, a group of experts on the subject reviewed it. They improved and validated the questions in terms of clarity and relevance.

Subsequently, the questionnaire was applied to a small but diverse group of 10 farmers, located in different ecological regions. The results obtained from these samples allowed refining of the questions. The questionnaire was accompanied by a text explaining the purpose of the study. Once we have all the questionnaires, they were classified according to the different type of systems, and the answers in each group were compared and analyzed.

The following four main topics were addressed:

(i) Selection of soil conservation practices as the result of a knowledge governance process involving social organizations and farmers;
(ii) The local context (social, institutional and ecological) surrounding the implementation of soil conservation practices;
(iii) New institutions promoting and adopting soil conservation practices; and
(iv) Mechanisms for learning and monitoring soil conservation practices.
The survey allowed information to be collected from both landowners and NGO technicians.

RESULTS

Sixty-one survey responses were obtained from farmers (32), ranchers (12) and technicians (17) working for social organizations. The completed surveys covered 20 out of the 32 Mexican states. Of the 61 case studies, 36 related to agriculture and 25, to livestock production. Slightly more than 30% of the survey responses were from regions with a temperate climate; 27%, from regions with a humid tropical climate; 23%, from regions with a semi-arid climate; 16%, from regions with a dry tropical climate; and 3%, from regions with an arid climate (Figure 1). The agricultural systems were mostly based on maize, which forms the basis of the Mexican diet and has deep cultural roots.

The average age of the farmers and ranchers who implemented soil conservation practices and transformed their systems was 48 years, which is below the Mexican countryside's average (55 years; INEGI, 2007).

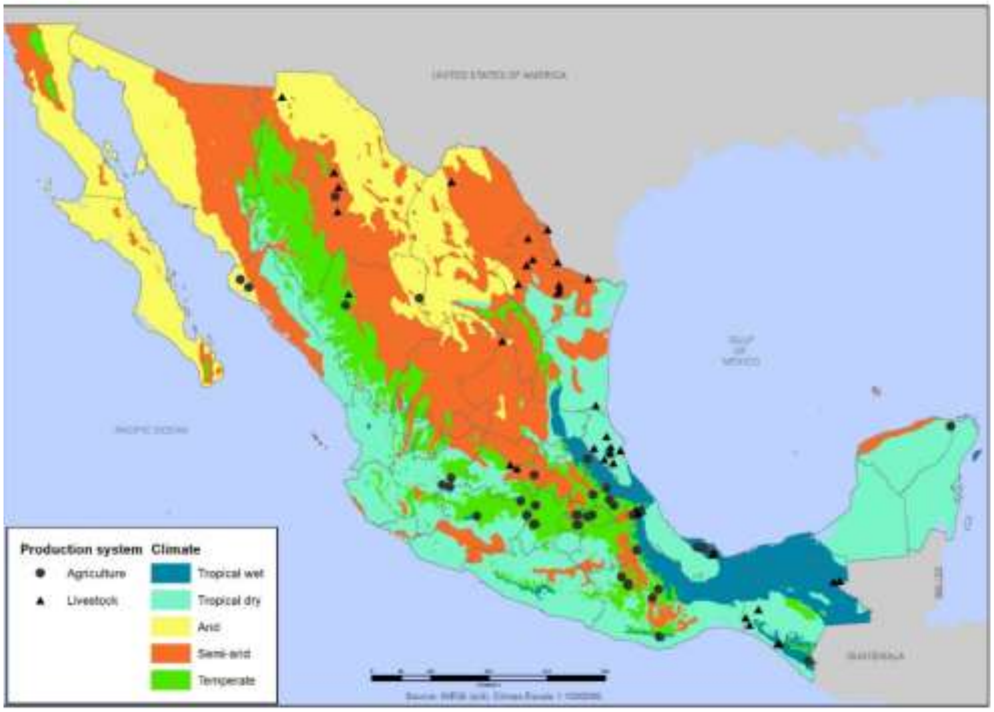

Figure 1. Sites covered by the survey of soil conservation practices and associated production systems and climates in Mexico.

Building of soil knowledge governance

The respondents to the survey reported the presence of 30 social organizations (NGOs), 12 community-led organizations: *ejido* (collective forms of ownership) committees, watershed committees, producer associations, 4 federal government organizations and 4 public academic institutions. These organizations had been working at the different sites for over 5 years, building relationships of trust, dialoguing with the farmers and encouraging them to think about their quality of life and expectations, thus triggering the building of new production systems. Different means were used to raise awareness of soil degradation problems by facilitating discussion and the sharing and appropriation of experiences. The main means used to build knowledge were those that allowed greater proximity between stakeholders (farmers, NGOs and researchers), such as workshops and the sharing of experiences among farmers or "knowledge dialog".

The main reasons why farmers decided to incorporate soil conservation practices and make substantial changes to how they manage their farm were (in decreasing order of importance): (i) preventing further soil erosion and increasing yield; (ii) increasing soil organic matter content, infiltration and plant diversity; and (iii) creating local jobs. Forty-five percent of the soil conservation practices were designed specifically for each site's environmental and social conditions by social organizations and farmers. The farmers already knew 24% of these practices; 17% were promoted through subsidies from a government program; and the remaining 14% unknown by the farmers at first, were introduced by the social organizations following a socialization and acceptance process.

The reported soil conservation practices were implemented on agricultural parcels or livestock parcels (Figure 2).

According to the survey responses, the practices most commonly used on the agricultural parcels were agronomic and vegetative practices, combined with mechanical ones. The agronomic practices most commonly used on these systems were crop rotation, the addition of organic matter to the soil, and intercropping (Figure 2). Of the mechanical practices, terracing was the most common. For 19% of the agricultural systems, a single agronomic practice was used; for 68% of them, two or more of these practices were used; and for the remaining 13%, no agronomic practice was used.

On the livestock parcels, the most commonly used practices were living fences, the reduction of animal load, pasture rotation and the planting of trees and shrubs. As with agricultural systems, most (over 75%) of the respondents implemented two or more vegetative practices. The mechanical practices were not implemented as often as the vegetative ones: 39% of the respondents reported that they did not use them. The new soil conservation practices were incorporated

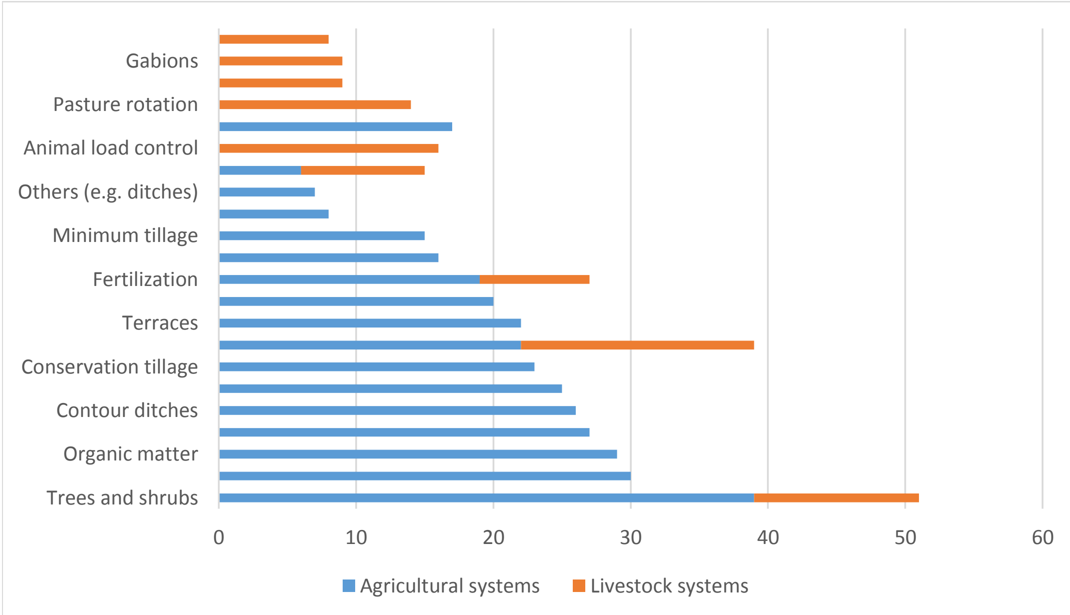

Figure 2. Results of soil conservation practices implemented on agricultural and livestock systems from survey.

gradually and led to radical changes in the whole production systems. Thus, the dialog and consensus built from knowledge governance allowed not only isolated practices to be incorporated, but also conventional systems to be converted into sustainably managed ones.

Sustainable land management in a local context

Most agricultural systems were located on *ejido* land (50%) or in communities (28%), and 48% were small-scale, consisting of 1 to 3 ha. They used mainly family labor (52%) or a combination of family and hired labor (33%). In most cases (57%), the production was for self-consumption with the sale of surplus; 19% of the production was only for self-consumption; and 24% was to be sold in local markets. Some of the reported agricultural systems covered more than 20 ha, used exclusively hired labor and had their production sold in both regional and international markets.

The livestock systems were located on *ejido* land (77%) or private land (23%) and varied widely in size, from less than 5 ha to over 100 ha. The smallest parcels used mainly family labor, and their production was for self-consumption only (48%) or self-consumption with the sale of surplus. The parcels over 50 ha large, however, tended to use a combination of family and hired labor, with the products destined for both regional (48%) and international markets (52%). In most cases (70%), the soil conservation practices were applied on degraded soils to restore soil properties and functions; they were thus used as a corrective measure rather than to prevent soil erosion.

Initially, the agricultural systems consisted of rain-fed monocultures (of maize or another cereal) that used agrochemicals and produced low yields, while the livestock systems consisted of extensive productions on moderate to steep slopes, with grazing lands obtained by slash-and-burn. The incorporated soil conservation practices mainly sought to transform the agricultural systems into sustainable managed lands by diversifying crops and adding organic matter to the soil. In many sites, these practices led to the recovery of *milpa*, the traditional polyculture of maize, squash, beans, chili peppers and other edible species.

The original production systems were thus transformed into sustainably managed lands, as shown in Table 1. The agricultural systems were diversified into *milpa* interspersed with fruit trees, maize interspersed with fruit trees, maize grown on terraces with fruit trees, avocado agroforestry systems and conservation tillage systems (maize and soy). As for the livestock systems, they were modified into silvopastoral systems (with species compatible with the climate, humid tropical or dry tropical) or holistic livestock systems.Although the proposed production systems are, in principle, sustainable, the environmental and social conditions of the sites where they were implemented were not always appropriate. A clear example of this is conservation tillage. In the case of small *ejido* lands, it was promoted by government organizations; while in that of large private lands, it was initiated by the owners themselves with the help of producer associations. In the first case, the system was not fully adopted because when it was implemented, the

Table 2. Environmental, social and institutional characteristics of the agricultural and livestock systems converted into sustainable managed lands through soil conservation practices from surveys.

Type of sustainable managed land	Climate	Size of property	Type of labor	Support needs	Destination of production	Land Tenure
Milpa interspersed with fruit trees	Temperate and humid tropical	Small	Family	High demand for training (to design furrows and manage fruit trees)	Self-consumption and sale of surplus	*Ejido*
Maize interspersed with fruit trees	Temperate	Small	Family	Demand for training (to manage fruit trees)	Self-consumption and sale of surplus	*Ejido* and community
Maize grown on terraces with fruit trees	Temperate and semi-arid	Small	Family	Demand for training (to manage fruit trees)	Self-consumption and sale of surplus	*Ejido*
Avocado agroforestry system	Temperate	Small	Family and hired	Producers learned by themselves through observation	Self-consumption and sale of surplus	Private
Conservation tillage system (maize and soy) with irrigation	Temperate	Large	Hired	Long learning process through courses, workshops and the support of other producers	Sale in international markets	Private
Conservation tillage system (maize) without irrigation	Temperate to semi-arid	Small	Family	Support needed to improve the agricultural system (leaving the stubble on the ground) and modify the livestock system accordingly	Self-consumption and sale of surplus	*Ejido*
Silvopastoral system	Humid tropical	Medium	Family and hired	Demand for support to design the new system and manage livestock	Self-consumption and sale of surplus in regional markets	*Ejido* and private
Silvopastoral system	Dry tropical	Medium	Family and hired	Demand for support to design the new system and manage livestock	Self-consumption and sale of surplus in regional markets	*Ejido* and private
Holistic livestock system	Semi-arid to arid	Large	Hired	High demand for support: radical change in the paradigm of livestock production	Sale in regional and international markets	Private

*Small: less than 5 ha; medium: 5-20 ha; large: over 20 ha.

government organizations did not consider the fact that local production systems integrated both agricultural and livestock activities. Stubble being an essential input for feeding the animals, it could not be left on the ground. In the second case, the farmers had no livestock and simply stopped selling the stubble to livestock producers to incorporate it into the soil (Table 2).

New (and old) institutions to promote and implement soil conservation practices

In over 90% of the cases, social organization played an important role in reducing costs, sharing knowledge, expanding networks and contacts, and communicating risks. In the case of *ejido* lands, where many decisions—regarding government programs, the maintenance of water infrastructure and roads, common areas—are made by the *ejido* assembly, joint reflection by

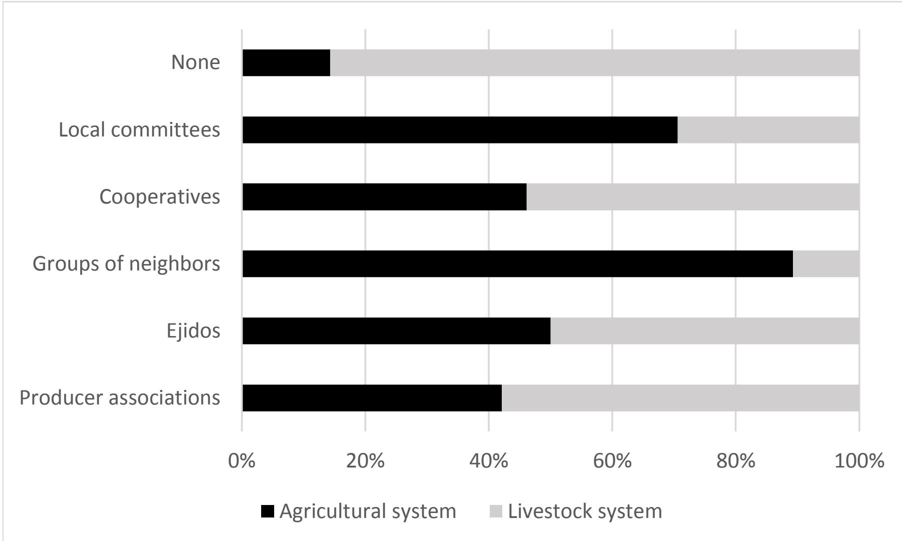

Figure 3. Best social organizations to successfully implement soil conservation practices in agricultural and livestock systems according to the survey.

farmers and NGOs allowed to make commitments to strengthen the *tequio* (community tasks), improve accountability for the resources obtained, and control the animal load in common areas, among other achievements. Thus, the dialog about soil conservation practices resulted in the strengthening of local institutions.

Regarding the agricultural systems, respondents mentioned that the creation of groups of neighbors, producer associations and local committees proved to be useful, as they allowed inputs like compost, *bocashi* (compost activator) and organic pesticides (*bioles, caldos*) to be produced jointly. For the livestock systems, cooperatives helped reduce both the costs of buying livestock inputs and selling prices, thanks to their many members (Figure 3). A small percentage of respondents mentioned that they did not need any social organization. In all these cases, the lands were for private use, with all management decisions made by the owners themselves.

In most cases, a single organization was considered insufficient to accompany the process, as it rarely had all the knowledge required to both design and assess soil conservation practices, or lacked the financial and technological resources to do so. The results show that the presence of different organizations (such as, local, academic, governmental, social, etc) working in conjunction led to a polycentric governance that strengthened the process of adopting these practices.

Mechanisms for learning and monitoring soil conservation practices

Soil conservation practices require extra work. For landowners to take ownership of them, it is thus important that they see tangible results of their implementation. According to the survey, the results of these practices were evaluated by: (i) measuring yield for livestock systems and carrying capacity (evaluating product quality was also mentioned); (ii) participatory monitoring based on local knowledge, to identify sedimentary changes in water bodies; and (iii) technical monitoring (such as, monitoring of the survival of fruit trees, maintenance of mechanical works, monitoring of the proper functioning of furrows).

Three to five years after the implementation of soil conservation practices, more than half of the respondents identified positive changes in their parcels, the main ones being, in decreasing order of importance: (i) reduced soil erosion; (ii) increased yield; (iii) increased soil organic matter, and thus increased infiltration and soil moisture retention; (iv) increased plant diversity; and (v) the creation of local jobs.

The incentives for farmers to maintain soil conservation practices were very diverse. Among the main ones, the following were mentioned: (i) eating healthy food (grown without agrochemicals), particularly in the case of agriculture for self-consumption; (ii) diversifying crops, in order to have products to sell all year round; (iii) reducing soil erosion, which threatened the integrity of their property; and (iv) improving their social position in the community by being seen as innovative people, with the possibility of teaching and seeing their family united around a new project (thus reducing the migration of young people).

Most of the time, soil conservation activities are not incorporated into traditional production systems and, as such, may represent extra work. The respondents to the survey identified different barriers to carrying them out. Among the main ones, they mentioned the lack of money, the lack of acceptance by the other community members, the lack of technical support, and the lack of social organization. These barriers were overcame mainly by organizing themselves with residents of the same community and its surroundings, looking for training opportunities and, in many cases (51%), requesting financial support from the government. The respondents however mentioned that without this funding, they could continue to carry out soil conservation practices, if the landowner actively participates in them and they receive support from civil society organizations.

The lack of acceptance of better practices by other members of the community was reported to be one of the main barriers to propose and implement them. However, 55% of the respondents mentioned that they have replicated the practices on other parcels, resulting in higher yields and noticeable improvements in soil condition and agricultural biodiversity.

DISCUSSION

Historically, Mexico's soil conservation programs have followed the guidelines of international organizations, which, under certain ideological assumptions, have understood the soil erosion problem and outlined the steps required to address it (FAO, 1977; Biot et al., 1995; Simonian, 1999; World Bank, 2006; Showers, 2006). The main weakness of these programs has lied in not considering knowledge governance involving different stakeholders as a critical success factor (Simonian, 1999; World Bank, 2006).

Policy and attitudes regarding soil conservation practices have changed markedly over the course of the past half century (Carlisle, 2016). During this time, various studies have shown that the success of a soil conservation program depends on the adoption of practices, and that this process relies on the management of local knowledge, which better represents the local conditions (Angeon et al., 2014).

The adoption of soil conservation practices is a complex process (de Graaf et al., 2008; Eakin and Wehber, 2009; Manuel-Navarrete and Gallopin, 2012; Angeon et al., 2014). Here, various factors come into play: personal and family factors (such as, attitudes, knowledge, family situation, migration), social factors (such as, technical support, land tenure, migration), physical factors (such as, slope, erosivity and climate variability, soil erodibility), institutional factors and collective action (such as, rules, standards, community work), as well as economic factors (such as, income, debt, outside job).

The diversity of these factors makes it clear that the adoption of such practices is not a linear process. Several studies have also highlighted the importance of understanding the adoption of soil conservation practices as a multistage, adaptive process rather than instantaneous, single-step decision-making (Coughenour, 2003; Carlisle, 2015). Any change in the farmer's situation (like the need to migrate in order to supplement income, or a debt incurred due to health care costs) can set back the implementation of these practices, even if the farmer is convinced of their value. Another factor that can undermine the adoption of soil conservation practices is the inconstancy of regional and national policies regarding priority issues-which tend to change with every change of government—, or a change in NGO priorities and funding. This instability can affect the payment of recurring costs for the purchase of machinery, fixing water infrastructure or training, among others. This illustrates both the strength and the weakness of polycentric governance systems (Orchard and Stringer, 2016) where, on the one hand, the responsibilities and capabilities are distributed among several stakeholders, but on the other, vulnerabilities increase accordingly.

This study shows that an important step towards adopting soil conservation practices was having them designed by several social organizations and farmers through soil knowledge governance, considering the environmental, social, institutional and economic conditions specific to each site. As a result, most of the chosen practices were agronomic and vegetative measures that promote ecological diversity, reduce soil erosion, and add organic matter to the soil, hence improving soil quality (Lal, 2014). Such a preference for this type of practice has been reported for other areas with different environmental and social conditions (Carlisle, 2016). Thus, there seems to be a departure from the current paradigm of government programs for soil conservation, which are often managed by a centralized administration in a top-down manner, without considering environmental and social differences. This may be why mechanical practices like check dams, ditches and stonewalls have dominated so far (Biot et al., 1995; Lapar and Pandey, 1999; Cotler et al., 2013, 2016).

In a context of public policy program, these mechanical, structural measures may have been preferred as "attention grabbers because they are spectacular and conspicuous… however, they are hardly ever adequate on their own" (Liniger and Critchley, 2007). The literature on soil conservation has tended to emphasize the importance of financial incentives in adopting practices (Lapar and Pandey, 1999; De Graaff et al. 2008). Although such incentives are, indeed, important in a poor rural context, they do not meet the diversity of views, concerns and values of this population. This study shows that in the case of agriculture for self-consumption, important incentives also include improving the environment, ecological diversification, playing a leading role in the community, and improving the quality of their food. This contrasts with large regional and international producers, for which “money is the best incentive”. This agrees with various studies that found that “immediate financial benefits were less important to farmers than long-term soil health” and food security (Carlisle, 2016, Damián and Toledo, 2016). Sheeder and Lynne (2011) also concluded, “policy instruments that facilitate expression of (the) shared ethic may be more likely to increase conservation technology adoption rates than policies that stress only financial incentives”. Other experiences on soil conservation behavior (Lockeretz, 1990; Sheeder and Lynne, 2011) have emphasized the multiple motivations that are at play at the time of adopting soil conservation practices.

In Mexico, as in other Latin American countries, decades of intense rural–urban migration have caused the abandonment of agricultural activities, the breakdown of local knowledge, and a weakening of social organization (Anta and Carabias, 2008). Incorporating young people into a process of soil knowledge governance may thus provide them with a means of valorizing their biological and cultural heritage (Maffi, 2001).

In the production systems analyzed, soil knowledge governance focused mainly on the joint implementation of practices and alternative land management, based on the farmers’ knowledge and expectations. The methods for assessing the practices and the system as a whole, however, are to be strengthened. The monitoring of works and evaluation of acceptability would transform soil conservation into a learning process that would gradually increase the confidence of the farmers in its efficiency. Indeed, experience has shown that monitoring and evaluation lead to important changes and modifications in the approaches and technologies used (Liniger and Critchley, 2007). Participatory research could open new channels of communication to develop methods for the participatory monitoring of soils using local indicators and tools. Soil conservation should no longer be seen as an isolated problem, separate from the other environmental issues faced by rural areas. Since rural areas are characterized by different biophysical and social conditions, the goal should not be to build soil conservation programs of a top-down nature, but programs that are flexible, adaptable to local conditions, and built jointly with the farmers through knowledge governance.

Conclusions

Up to now, Mexican government programs for soil conservation have been based on international guidelines and implemented in a top-down manner. Specific technologies have been unilaterally transferred to farmers without incorporating their demands, experiences and expectations, and without adapting the practices to the different environmental, social and institutional conditions (Manuel-Navarrete and Gallopin, 2012). This has led to a very low adoption rate of soil conservation practices.

In recent years, a consensus has emerged that the identification and implementation of soil conservation practices jointly with farmers is key to redesigning new agroecosystems that are both resilient and sustainable (Astier et al., 2012; Stringer et al., 2014; Altieri et al., 2015). In the cases analyzed here, the polycentric governance of soil knowledge allowed agroecological alternatives to be developed jointly with NGOs, academic and government organizations, and farmers. The incentives for farmers to continue to invest time, resources and effort in these agroecosystems reflected the communities’ diversity of views, concerns and values. Small farmers were sensitive to incentives such as eating healthy food (grown without agrochemicals), diversifying their income, reducing soil erosion and improving their social position in the community by being seen as innovative people, with the possibility of teaching and seeing their family united around a new project. Thus, unlike the approach set forth in government policies for soil conservation, the incentives were not limited to financial ones.

Despite several years of working together in a framework of soil knowledge governance, the agroecosystems analyzed remain fragile and vulnerable, notably to changes in the political and economic priorities of the government and NGOs. For this reason, polycentric governance systems should be based on public policies that are flexible, bottom-up and adaptable to different environmental, social and institutional conditions and that incorporate local knowledge. What is required for the upcoming soil conservation programs is both vertical scale-up (institutionalization) and horizontal scale-up (expansion of the practices), with multi-level decision-making and a long-term, flexible funding that will allow a learning process to take place.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors appreciates the Fundación Gonzalo Río Arronte I.A.P. for funding the research through Espacios Naturales y Desarrollo Sustentable A.C. (ENDESU). The authors are grateful to Edge Software Services S.A. de C.V., in particular Daniel Romero for his support in the design, programming and follow-up of the online survey. They also acknowledge Isabelle Gamache, Ph.D. for her recommendations to improve the English translation.

This project received funding from the Fundación Gonzalo Río Arronte I.A.P. through Espacios Naturales y Desarrollo Sustentable A.C. (ENDESU). The authors thank Edge Software Services S.A. de C.V., in particular Daniel Romero for his support in the design, programming and follow-up of the online survey. They also thank Isabelle Gamache, Ph.D. for her recommendations to improve the english translation.

REFERENCES

Altieri M, Nicholls C (2008). Scaling up agroecological approaches for food sovereignty in Latin America Development 51:472-80.

Altieri M, Toledo MV (2011). The agroecological revolution in Latin America: Rescuing nature, ensuring food sovereignty, and empowering peasants" Journal of Peasant Studies 38(3):567-612.

Altieri M, Nicholls C, Henao A, Lana A (2015). Agroecology and the design of climate change-resilient farming systems. Agronomy for sustainable development 35:869-890.

Amundson R, Asefaw A, Hopmans WJ, Olson C, Sztein AE, Sparks LD. (2015) Soil and human security in the 21st century. Science 348(6235):647-653.

Andersson J, Ken G (2012). On heretics and God's blanket salesmen. In: Sumberg, J., Thompson, J. (Eds.), Contested Agronomy: Agricultural Research in a Changing World. New York, Routledge pp. 22-46.

Angeon V, Ozier-Lafontaine H, Lesueur-Jannoyer M, Larade A (2014) Agroecology Theory, Controversy and Governance. In: H. Ozier-Lafontaine and M. Lesueur-Jannoyer (eds.), Sustainable Agriculture Reviews 14: Agroecology and Global Change, Sustainable Agriculture Reviews 14, DOI 10.1007/978-3-319-06016-3_1

Anta S, Carabias J (2008). "Consecuencias de las políticas en el uso de los ecosistemas y la biodiversidad. Capital Natural de México". Políticas Públicas y Perspectivas de sustentabilidad, CONABIO, México 3:99.

Arnés E, Antonio J, del Val E, Astier M (2013). Sustainability and climate variability in low-input peasant maize systems in the central Mexican highlands. Agriculture, ecosystems and environment 181:195-2015.

Arslan A, McCarthy N, Lipper L, Asfaw S, Cattaneo A (2014). Adoption and intensity of adoption of conservation farming practices in Zambia. Agriculture, Ecosystems and Environment 187:72-86.

Astier M, García-Barrios L, Galván-Miyoshi J, González-Esquivel CE, Masera O (2012). Assessing the sustainability of small farmer natural resource management systems. A critical analysis of the MESMIS program (1995-2001). Ecology and Society 17(3):25.

Astier M, Argueta A, Orozco-Ramírez Q, Virginia González M, Morales J, Gerritsen P, Escalona M, Rosado-May F, Sánchez-Escudero J, Martínez TS, Sánchez-Sánchez C, Arzuffi R, Castrejón F, Morales H, Soto L, Mariaca R, Ferguson B, Rosset P, Ramirez THM, Jarquin R, Moya F, Gonzalez-Esquivel C, Ambrosio M (2015). Historia de la agroecologia en México. Agroecologia 10:9-17.

Blanco-Canqui H, Francis CA (2016). Building resilient soils through agroecosystem redesign under fluctuating climatic regimes. Journal of soil and water conservation 71(6):127-133.

Biot Y, Blaikie MP, Jackson C, Palmer-Jones R (1995). Rethinking land degradation in developing countries. World Bank Discussion Paper 289. Washington D.C. 94 p.

Bouma J (2014). Soil science contributions towards Sustainable Development Goals and their implementation: linking soil functions with ecosystem services. Journal of plant nutrition and soil science 177(2):111-120.

Carlisle L (2016). Factors influencing farmer adoption of soil health practices in the United States: a narrative review. Agroecology and Sustainable Food Systems 40(6):583-613, DOI: 10.1080/21683565.2016.1156596

Cotler H, López AC, Martinez-Trinidad S (2011). How much cost soil erosion? Approximation to an economic valuation of the loss of agricultural soils in Mexico. Investigaciones Ambientales 3(2):31-43.

Cotler H, Cram S, Martinez-Trinidad S, Quintanar E (2013). Forest soil conservation in central Mexico: an interdisciplinary assessment. Catena 104:280-287.

Cotler H, Martinez M, Etchevers DJ (2016). The conservation of organic carbon in agricultural soils of Mexico. Contributions of the research and its relation with public policies. Terra Internacional 43(1):125-138 http://132.248.10.25/terra/index.php/terra/article/view/81

Coughenour CM (2003). Innovating conservation agriculture: The case of no-till cropping. Rural Sociology 68(2):278-304.

Damián TV (2016). Agroecological Utopistics, peasant innovations and food security in corn Benemérita Universidad Autónoma de Puebla. México, 76 p. https://www.uccs.mx/downloads/index.php?id=file_577b485e87d89

De Graaff Graaff J, Amsalu A, Bodnar J, Kessler A, Posthumus H, Tenge A (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. Applied Geography 28:271-280.

Food and Agriculture Organization (FAO) (1977). Soil conservation and management in developing countries. FAO Soils Bulletin 33, Rome. http://www.fao.org/docrep/018/ar113e/ar113e.pdf

Helin J, Haigh MH (2002). Better land husbandry in Honduras: towards the new paradigm in conserving soil, water and productivity. Land Degradation and Development 13:233-250.

Hudson WN (1987). Soil and water conservation in semi-arid areas. FAO Land and water Development Division. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/docrep/t0321e/t0321e00.htm#TopOfPage

Holt-Giménez E (2001). Scaling-up sustainable agriculture. Lessons from the Campesino a Campesino movement. Low External Input Sustainable Agriculture 17(3):27-29.

Gliessman SR (2013). Agroecology: Growing the roots of resistance. Agroecology and Sustainable Food Systems 37:19-31.

Ibañez JJ, Krasilnikov P, Saldaña A (2012). Archive and refugia of soil organisms: applying a pedodiversity framework for the conservation of biological and non-biological heritages. Journal of Applied Ecology 49:1267-1277.

Instituto Nacional de Estadística y Geografía (INEGI) (2007). VII Agricultural Census of livestock Mexico. http://www.inegi.org.mx

Instituto Nacional de Estadística y Geografía (INEGI) (2012). Encuesta Nacional Agropecuaria Mexico. http://www.inegi.org.mx/est/contenidos/proyectos/encuestas/agropecuarias/ena/ena2012/

Jara-Rojas R, Bravo-Ureta EB, Engler A, Diaz J (2013). An analysis of the joint adoption of water conservation and soil conservation in Central Chile. Land Use Policy 32:292-301.

La Vía Campesina (LVC) (2013). "Llamamiento de la VI Conferencia de la via campesina <https://viacampesina.org/es/llamamiento-de-yakarta/ Accessed 3 July 2018.

Lal R (2014). Soil conservation and ecosystem services. International Soil and Water Conservation Research 2(3):36-47.

Lapar ML, Sushil P (1999). Adoption of soil conservation: the case of the Philippine uplands. Agricultural Economics 21:241-256.

Liniger H, Critchley W (2007). Where the land is greener. Case studies and analysis of soil and water conservation initiatives world-wide. WOCAT, CTA-FAO-UNEP-CDE, 364 p.

Lockeretz W (1990). What have we learned about who conserves soil? Journal of Soil and Water Conservation 45(5):517-523.

Maffi L (2001). On biocultural diversity: linking language, knowledge and the environment. Smithsonian Institution Press, Washington.

Manuel-Navarrete D, Gallopın G (2012). Feeding the world sustainably: knowledge governance and sustainable agriculture in the Argentine Pampas. Environment, Development and Sustainability 14:321-333. DOI 10.1007/s10668-011-9326-4.

Montgomery DR (2007). Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences 104:13268-13272.

Moreno-Calles AI, Toledo MV, Casas A (2013). The traditional agroforestry systems of Mexico: A biocultural approach [in Spanish]. Botanical Science 91(4):375-398.

Nagendra H, Ostrom E (2012). Polycentric governance of multifunctional forested landscapes. International Journal of the Commons 6:104-133.

Nkala P, Mango N, Corbeels M, Veldwisch GJ, Huising J (2011). The conundrum of conservation agriculture and livelihoods in Southern Africa. African Journal of Agricultural Research 6(24):5520-5528.

Orchard S, Stringer L (2016). Challenges to polycentric governance of an international development project tackling land degradation in Swaziland. *Ambio* 45:796-807. DOI 10.1007/s13280-016-0791-8.

Ruben R, Pender J (2004). Rural diversity and heterogeneity in less-favoured areas: the quest for policy targeting. Food Policy 29:303-320.

Simonian L (1999). The defense of the land of the jaguar. A history of conservation in Mexico. Secretaria de medio Ambiente y recursos naturales y pesca. Comisión Nacional para el conocimiento y uso de la biodiversidad, Instituto mexicano de Recursos naturales Renovables, México.

Sheeder JR, Lynne DG (2011). Empathy-conditioned conservation: "walking in the shoes of others" as a conservation farmer. Land Economics 87(3):433-452.

Showers BK (2006). Soil erosion and conservation: an international history and a cautionary tale, pp. 369-406. In: Warketin PB (Ed) Footprints in the soil. People and ideas in soil history. Elsevier, 548 p.

Soule MJ, Tegene A, Wiebe DK (2000). Land tenure and the adoption of conservation practices. American journal of Agricultural Economics 4:993-1005.

Stringer CL, Fleskens L, Reed M, de Vente J, Zengin M (2014). Participatory Evaluation of Monitoring and Modeling of Sustainable Land Management Technologies in Areas Prone to Land Degradation. Environmental Management 54:1022-1042.

Tödling F, Tippl M (2005). One size fits all? Towards a differentiated regional innovation policy approach. Research Policy 34:1203-1219.

Toledo V (1990). The ethnobiological perspective: five reflections about peasant sciences, with special reference to Mexico. Ciencia especial 4:22-29.

Turrent A, Espinosa A, Cortes IJ, Mejia H (2014). Strategy analysis MasAgro-maiz. Revista Mexicana de Ciencias Agrícolas 5(8):1531-1547.

Turrent A, Cortés J, Espinosa A, Hernández E, Camas R, Torres JP, Zambada A (2017). MasAgro o MIAF ¿Cuál es la opción para modernizar sustentablemente la agricultura tradicional de México? Revista Mexicana de Ciencias Agrícolas 8(5):1169-1185.

Van Kerkhoff L, Lebel L (2006). Linking knowledge and action for sustainable development. Annual Review of Environment and Resources 31:1-33.

Ward SP, Bell A, Droppelmann K, Benton G (2018). Early adoption of conservation agriculture practices: understanding partial compliance in programs with multiple adoption decisions. Land Use Policy 70:27-37.

White JP, Crawford J, Cruz DM, García MR (2012) Soil Management for Sustainable Agriculture. Applied and Environmental Soil Science 202:1-3.

World Bank (2006). Enhancing agricultural innovation: how to go beyond the strengthening of research systems. Economic Sector Work report, Washington, DC. Available on: http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf