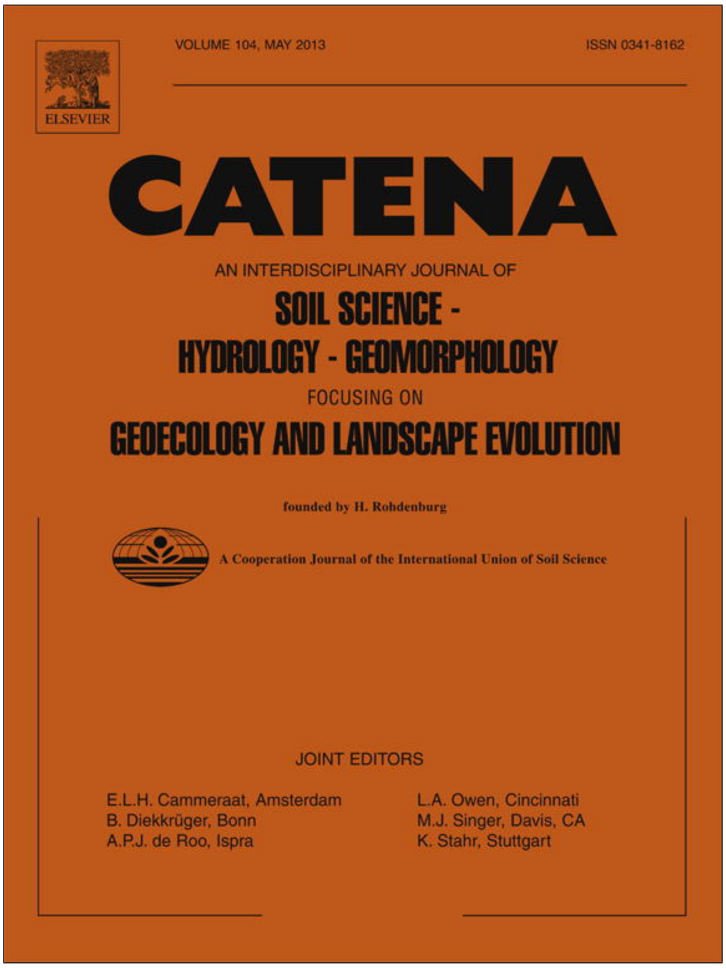
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Forest soil conservation in central Mexico: An interdisciplinary assessment☆,☆☆,★

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A B S T R A C T

An inter-disciplinary assessment of the conservation practices on forest soils in Mexico was conducted (i) to evaluate their effectiveness in terms of soil quality indicators and (ii) to use social indicators of their acceptance and execution; such information would be a means of improving the design and implementation of public policy. After four years of soil conservation measures in areas under common ownership, involving ditches, individual terraces or arrangement of plant material, soil indicators such as bulk density, total carbon, total nitrogen and pH in nine sites and 54 plots showed deficiencies in soil properties involved in productivity and hydrological regulation, in comparison with the control groups. The results suggest that the conservation practices are not improving any of these functions. Social indicators revealed that the soil conservation program only encourages participation through economic stimulus without considering that non-financial interest can play an important role, then the rate of adoption and replication of these measures is low. These results led us to make some suggestion with policy implications such as taking into account landscape heterogeneity and social complexity to define conservation actions; considering strengthening conservation attitudes among *ejidatarios* and also to assess the conservation program through results that have measured the impact of the practices on the recovery of soil quality. Interdisciplinary approaches to understand attitudes for soil conservation are a prerequisite in future research.

1. Introduction

Soil conservation policy in Mexico started in the 1940s, influenced by the decisions taken in the United States after the Dust Bowl in the 1930s. Between 1946 and 1986, soil conservation techniques were conducted in less than 2% of the country, giving assistance, technical training and subsidies (Simonian, 1999), without showing successful results (Vásquez, 1986).

Nowadays, land degradation affects 45% of Mexico (SEMARNAT-COLPOS, 2002). The government responds to this situation by legislating and establishing public policy programs. The perception of this resource within Mexico is reflected in eleven laws concerning the soil: six regard the soil as a substratum, and three as a source of productivity, while in only two are environmental concepts introduced (Cotler et al., 2007). These laws support public policy programs, among which the most important is the Forest Soil Restoration and Conservation Program implemented by the National Forestry Commission, in which conservation practices on forest soil are requested by the owners and carried out by them in return for a subsidy. This economic incentive is paid to producers "to do something he or she would not otherwise have done" (Pearce, 2002).

This program has been running since 2002 and applies rules that seek to make the allocation of financial resources at national level transparent (CONAFOR, 2012). To access this annual subsidy, the owner of the land must submit an application. Once this application has been approved, payments are made (70% at the beginning and 30% at the end). But it is important to consider that about 55% of Mexican forest land is social property (called *ejido*) and that the *ejido* assembly is the highest authority. In this sense, to apply for the subsidy the *ejido* hire a technician or adviser, certified by CONAFOR, who assist in planning, siting, design and implementation of conservation works and also write the reports. The technical personnel selects a conservation practice from a manual (CONAFOR, 2006), in which 70% of the described conservation practices are mechanical, and the implementation should not exceed a predetermined cost. It is important to note that the program only finances one type of conservation practice for the entire plot. The final choice of the applied practice is approved in *ejido* assembly, which also defines the persons from the *ejido* who will be carrying out the conservation work and receiving a payment, but the assembly is under no liability to monitor and maintain the conservation works through time. Areas supported may be 10 to 150 ha

☆ Soil conservation practices assessment through soil and social indicators in Mexico.
☆☆ Soil conservation practices do not improve soil quality.
★ Conservation practices are implemented without considering biophysical setting and social environment.

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in regions with high levels of poverty and soil degradation. The amounts range from 204 USD/ha/year to 227 USD/ha/year. The maximum amount is granted when the properties are affected by gully erosion. This money covers what is paid to laborers who perform the selected conservation practice, and technician fees. The *ejidos* provide the materials they need to implement the practice, use their own tools, and if it is necessary pay for tractor hire. After 2 to 5 years, it is possible to request a one-off extra payment of 102 USD/ha/year for the maintenance of these works. Once the work is completed, CONAFOR checks a random sample (at least 10%) at national level. The execution of the works is supervised by a certified technician who assists (in technical aspects and training) with up to 1000 ha/year.

The program runs through financial incentives, with the conviction that it is the main driver to carry out soil conservation practices. This idea, much less explored in Mexico, has been widely discussed in other countries, where the empirical evidence shows that while is undeniable that profits do play a role, the assumption that it is the only role is highly contentious (Bishop et al., 2010; Chouinard et al., 2008; Nowak and Cabot, 2004; Sautter et al., 2011; Sheeder and Lynne, 2011). Soil conservation behavior involves many factors that come into play in a complex sequence (Lockeretz, 1990).

The performance of the program is subject to external evaluation of its operation, efficient use of the subsidies and the performance of environmental indicators derived from models (Magaña, 2007; Vargas, 2010). However, the effect of these practices on the recovery of soil quality has never been evaluated, and the acceptance and replication of these activities among the users have not been assessed.

Soil loss is a major international environmental problem, and we are still far from a solution (Lockeretz, 1990). The failure is not primarily technical (Feder et al, 1985; Lockeretz, 1990). The long and complex history of soil conservation (Showers, 2006) shows that interdisciplinary studies should integrate environmental, social, cultural and political issues in order to understand the process of acceptance, adoption and evaluation of soil conservation programs (De Graaff et al., 2008, 2010; Hudson, 1991; Mbaga-Semgolawe and Folmer, 2000; Sattler and Nagel, 2010; WOCAT, 2007).

In all cases, replication is seen as the main indicator of success, because a soil conservation program will endure if the actions are adopted by the resource owners (De Graaff et al., 2008; Green and Heffernan, 1987; Helin and Haigh, 2002). A lack of improvement, or even further degradation, is seen as an indicator that the program is ineffective (Nowak and Cabot, 2004).

Soils are not only producers of crops, they are also a habitat for a myriad of organisms, a biological and germplasm reserve, a regulator of water retention and filtration, a buffer environment, a maintaining component of nutrient, hydrologic, and energy cycles (Doran and Parkin, 1996; Lal, 2007; Larson and Pierce, 1991), and a contributor to the economic and cultural structure (Bone et al., 2010). The measurement of certain characteristics and indicators permits the evaluation of a soil in terms of a specific function, its degradation processes or the effectiveness of conservation practices.

A widely accepted method for assessing soil quality includes a description of a specific function of the soil based on the properties that provide this function (Carter et al., 1997; Ditzler and Tugel, 2002; Seybold et al., 1998). Changes in these soil physical, chemical and biological properties are used as indicators to assess recovery of these properties after special management practices (Bone et al., 2010; Campos et al., 2007). The positive effects of conservation practices or recovery on soil quality can be recognized in the short and medium term, assessing soil variables that have a differential response in time. For example, moisture content, bulk density and porosity have a short-term response ($<10^{-1}$ year), whereas the content of organic matter takes longer to reflect a change (10^{-1}–10 years) (Arnold et al., 1990; Seybold et al., 1998).

The only soil conservation practices that endure through time are those adopted by users and resource owners, as a result of their motivation, due to economic incentives and self-interest that are not directly related to profit or financial capacity (Sheeder and Lynne, 2011).

After decades of implementation of soil conservation techniques, and in a situation of slow and erratic acceptance, alternative frameworks have been proposed for understanding the process of adoption of these practices (Bayard and Jolly, 2007; De Graaff et al., 2008; Helin and Haigh, 2002; Lynne et al., 1988; Sheeder and Lynne, 2011). The recognition by farmers that soil erosion is a problem is the necessary precursor to any intervention (De Graaff et al., 2008; Traoré et al., 1998). However, when projects have incentives, actions can be implemented without this recognition and farmers may lose interest and abandon the conservation practices when the incentives have ended (De Graaff, 1999).

Much of the literature on soil conservation is based on private land where each farmer makes a personal decision about its management. However, the situation is more complex when the lands are common good. Mexico has 30 305 *ejidos* and agrarian communities, of which more than 8000 have a common area covered by forests (Anta and Carabias, 2008). The collective management of forest resources presents other challenges related to social capital where bonds and norms lubricate cooperation and trust (Pretty, 2003). Accurate and reliable measures of users' perceived benefits are difficult and costly to obtain. However, some key variables that explain the collective land management have been identified (Ostrom, 2009). These relatively new concepts introduce significant challenges to government actions for soil conservation.

For a soil conservation program to be effective, it requires interdisciplinarity, because the practice applied must take into account site characteristics and the people who are involved (resource owners, technical personnel, funders). The meaning or interpretation placed on those behavioral patterns needs to be framed by the biophysical settings where they occur (Nowak and Cabot, 2004).

The objective of this study is to conduct an interdisciplinary assessment of forest soils under conservation works (i) to gauge through biophysical indicators their effectiveness in recovering soil quality, and (ii) to gauge through social indicators their acceptance and replicability by the resource owners. This knowledge should improve the design and implementation of the soil conservation public policy program in Mexico.

2. Materials and methods

In the absence of a baseline that allows comparisons of ex ante soil conservation works, control groups were used (Feinstein, 2007; Margoluis et al., 2009). These groups allowed comparisons between soils that were subject to soil conservation measures and those that were not. In the latter, inherent attributes of native soils were used as reference (Bezdicek et al., 1996). The two groups were on the same land under similar biophysical conditions, in order to assess the effect of conservation measures on soil quality.

The study area was in the temperate region of central Mexico where pine-oak forests dominate on mountain slopes in community-owned lands. The most common conservation practices performed in 2004 in forest ecosystems of the states of Querétaro, Hidalgo, Tlaxcala and Mexico were ditches, individual terraces and arrangement of plant material, performed as an accompaniment to reforestation (CONAFOR, 2006). All had been operating for 4 years.

The sampling strategy was based on the selection of sites with diverse social and biophysical characteristics in order to identify whether the practices chosen take into account the particular attributes of the site, or if as is common the farmers adopt a solution before the problem was clearly identified, achieving only a partial solution or unforeseen detrimental impacts (Loch, 2004).

Ditches are excavations (0.4 m wide × 0.4 m deep × 2 m long) along contour lines and perpendicular to the slope, separated from each other by 2 m, and alternating so that each ditch is opposite the space between ditches in the rows above and below. Individual terraces are circular or semi-circular embankments (mean diameter 1 m) along the contour lines, each with a forest tree planted at its center. The arrangement of plant material is a conservation practice in which plant debris derived from forestry operations such as pruning, thinning and burning is laid across the slope in strips. The purpose of these three practices is mainly to reduce runoff, prevent erosion and improve the soil conditions (CONAFOR, 2006).

For each of these practices, three sites were selected (Fig. 1) and within each site three plots with conservation works were compared with three control plots without conservation work, giving a total of 54 plots. In each plot, four samples of the surface horizon were taken, as well as undisturbed samples to measure bulk density.

The sampling design was different for each practice: for the ditches the samples were taken at the top of the excavation; on individual terraces the samples were taken in the middle of the embankment; and on plots with arrangement of plant material, the samples were taken above the strips.

Physical and chemical soil variables were used as indicators of the recovery of the ability of soils to maintain forest productivity and regulate the hydrological cycle, functions that this government program seeks to recover (Table 1).

These indicators were quantified as follows: bulk density (100 cm^3 cylinders); total porosity (ratio of bulk density to real density, pycnometer method) (ISRIC, 1992); total organic carbon (TOC) and total nitrogen (TN) (simultaneous determination in a total organic carbon analyzer TOC) (Bernard et al., 2004); pH (potentiometric determination over a soil:$CaCl_2$ ratio of 1:5); and moisture content (gravimetrically) (ISRIC, 1992). Texture was not considered as an indicator but rather as a contextual datum that allowed the interpretation of results (determination with hydrometer according to Bouyoucous, 1963). All measurements were in duplicate and a soil standard was used to control the reliability of results. The results were analyzed by joint or paired t-tests.

At the same time, the representatives of each agrarian core participated in a semi-structured interview to assess the perception, acceptance and execution of each work. The main issues addressed in these tripartite interviews (Fig. 2) were related to the adoption of soil conservation practices (De Graaff et al., 2008).

In total, 27 representatives were interviewed in the nine communities studied as a first approach to obtaining the community perception (Whyte, 1985), and their opinion about the program and the practices. The results were subjected to descriptive statistics but are also supported by particular views made during the interviews.

3. Results

The selected sites are representative of central Mexico, in which the soil conservation practices were explored to scan the impacts over sites with different biophysical and social environments.

Each group of nine sites where a soil conservation practice was carried out shared some common characteristics (Table 2). The sites chosen for the arrangement of plant material have a higher diversity and density of tree and shrub vegetation that keeps the ground covered, and therefore are less subject to erosion. The ditches were dug on clay-loam or clay soils, mostly uncovered and likely to erode as terraces and gullies. The individual terraces were built in very shallow, stony soils.

Within each practice, the indicators showed variability (Table 3) because the selected sites had different biophysical characteristics. But there is a clear trend for some indicators when comparing control soils, used as a reference, with those in soil conservation practices, and this allowed analysis of whether the practice is having the desired effect.

Contrary to what might be expected, soils with ditches had higher bulk densities than the control soil. None of the soils with ditches, individual terraces or arrangement of plant material showed a change in moisture content and porosity. Both carbon content and nitrogen content were lower in the soils where ditches and individual terraces had been established. The effects of the arrangement of plant material were positive, i.e. it favored a decrease in bulk density in the three sites analyzed.

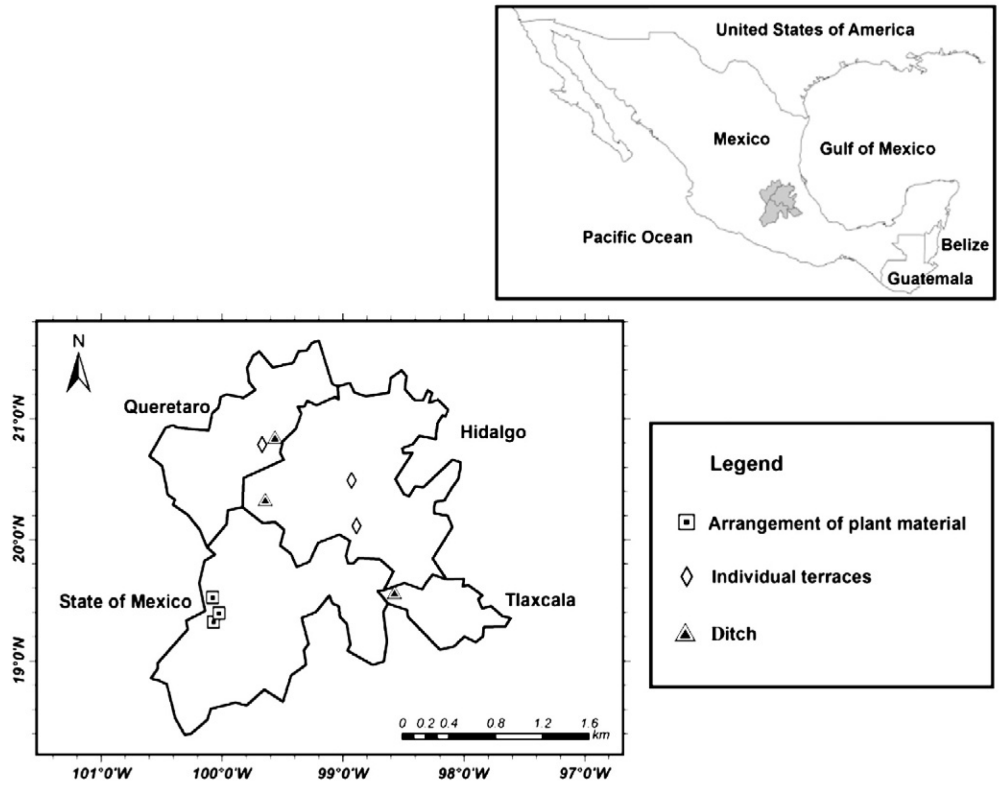

Fig. 1. Location of study sites.

Table 1
Physical and chemical indicators of soil function. The shading show the indicators used to depict each.
Function (modified from Burger and Kelting, 1999).

Main function	Soil function	Indicators							Texture
		Bulk density	Porosity	Total Carbon	Total Nitrogen	C/N	pH	Moisture content	
Maintaining productivity	Root growth promotion								
	Filtering and retaining water								
	Maintaining biogeochemical cycles								
	Promotion of biological activity								
	Carbon capture								
Water cycle regulation	Filtering and retaining water								

The cumulative effect of four years under a soil conservation practice was not positive. Indicators related to productivity and water cycle regulation were less favorable in plots with conservation practices than in control plots without (Table 4). Bulk density, TOC and TN differed significantly between ditches and control plots. TOC, TN and pH differed significantly between individual terraces and control plots. For both ditches and terraces, soil indicators on the control sites were superior. In soils where plant debris was strewn, the differences were not significant.

During the field work it was observed that the slope ($>10°$) of the land with ditches on clayey soils encourages regressive erosion, promoting the formation of gullies. Also, excavated soil material can be eroded and the organic carbon of the material is prone to accelerated mineralization (Geissen et al., 2013; Kimble and Lal, 2000).

The results suggest that the conservation practices are not improving maintenance of productivity or water regulation. Hence, the public policy program of soil conservation accompanying the reforestation may not be meeting its objectives.

3.1. Acceptance and replicability of soil conservation practices

All study sites were on communal lands, where the introduction of practices is a collective decision taken in *ejido* assembly. The representatives of the *ejidos* had an average age of 54 years, and 70% had completed primary education. All respondents performed agricultural and forestry activities, but their involvement varied; 32% defined themselves as farmers, 32% were engaged in masonry, and 36% in trade and services. In recent decades, soil conservation practices have been subsidized under various government programs (Cotler, 2010). Although 52% of respondents mentioned that they had been engaged in a soil conservation practice for >10 years, only 22% knew the practice recommended by government technicians.

Increased rural–urban migration has exacerbated the shortage of the rural labor force (Taylor and Stamoulis, 2001), but above all has led to a loss of accumulated knowledge of their own and site-specific cultural practices. In terms of soil conservation, 65% of the respondents mentioned "traditional" conservation practices previously performed, consisting of live barriers (or slow-building terraces) formed with maguey (*Agave salmiana*), which in addition to retaining soil were used to obtain products such as sisal (fiber) and "chinicuiles" (edible lepidopteran larvae).

The perception of the forest soil erosion problem was clear for 65% of respondents, who blamed mainly deforestation, and 64% recognized the importance of soil conservation practices to improve performance. Answers reflecting attitudes towards conservation included "*we want to preserve more*", "*we would like to have a showpiece forest*" or "*we need to show more concern about forest conservation*".

Although 36% of the respondents perform these practices as a means of conserving the productivity of their forest, 40% of respondents were not satisfied with these practices, owing to the little influence they have over the success of reforestation. For 68% of respondents the continuance of these works will depend on financial support and training, and for the remaining 32% continuance depends mainly on technical support. Respondents stressed the need for a different relationship between the farmers and the government. The repeated mention of "*more approach to communities*, *less office and more field*" suggests an interest in physical proximity and empathy between the governmental agency and the farmers. Proposals that reflect this concern include the establishment of demonstration plots to promote the interest of the people in conservation, and the exchange of experiences between *ejidos* to increase the dissemination of the work. All these observations highlight incentives, not necessarily financial, that are absent today from the soil conservation program. Even so, the greatest impediment to conservation measures, in a country where 60% of the rural communities have a high to very high level of poverty (Vélez et al., 2007), is economic (Fig. 3).

Responses such as "*if one is left alone nothing is accomplished*, *cooperation is necessary*" indicate the importance of social organization and the difficulty of reaching agreement. The lack of rules and standards for management of forests in communal areas is an important obstacle to the successful implementation of measures.

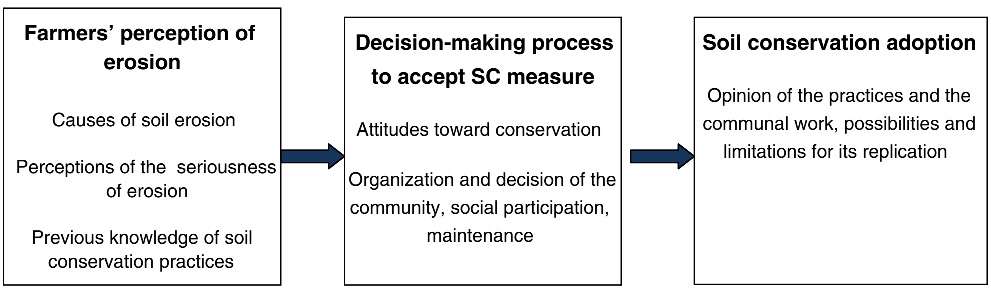

Fig. 2. Issues covered in the semi-structured interviews.

Table 2
Characteristics of sites where conservation practices were conducted.

Site	Slope	Vegetation	Erosion features	Texture
		Arrangement of plant material		
Santa María, Estado de México	18°	Pinus, *Cederla odorata*, *Jacaranda mimosifolia*, *Casuarina equisetifolia*, shrub	Soil covered by debris, without apparent erosion	Sandy loam
La Mesa, Estado de México	17°	*Abies religiosa*, *Quercus* sp., *Arbutus* sp., *Alnus* sp., *Salix bonplandiana*	Soil covered by debris, without apparent erosion	Sandy loam
San Pablo Malacatepec, Estado de México	13°	Abies *religiosa*, *Pinus* sp., herbs	Soil covered by debris, without apparent erosion	Loam
			Ditches	
Vithejé, Hidalgo	8°	Shrubs, herbs	Light, diffuse erosion in spots of bare soil	Sandy clay loam
Banthí, Querétaro	16°	*Quercus* sp., *Agave* spp., *Pinus* sp. *Cederla odorata*, *pteridophytes*	Light, diffuse erosion in spots of bare soils, diffuse erosion in little terraces (2 cm), sparse debris on surface. Gully formation	Clay
San Mateo Actipan, Tlaxcala	5°	*Pinus* sp., grasses	Soil completely covered by grasses	Clay loam
			Individual terraces	
Sombrerete, Querétaro	15°	*Pinus* sp.	Total soil loss	Silty clay loam
Lomas de Guillén, Hidalgo	8°	*Agave lechugill*, herbs	Bare soil with stoniness over 70%	Clay
San Agustín Tlaxiaca, Hidalgo	12°	*Pinus* sp., *Opuntia* sp., *Agave* spp., herbs	Covered soil with stoniness over 70%	Clay loam

Another hurdle in conservation is lack of knowledge about the proposed practices, which are selected from a manual without a clear identification of the problem and regardless of social and environmental heterogeneity and traditional practices (Fig. 3).

In general, perception, acceptance and replication by the inhabitants were consistently poor. Thus, four years after these practices were established, none of them had been replicated in other areas of their *ejido* without the support of government.

Even though there is an awareness of environmental deterioration, the soil conservation program only promotes participation by economic stimulus, without considering that "no financial interests can play a role" (Sheeder and Lynne, 2011).

Residents accept and carry out practices in exchange for economic stimulus, but the low adoption and replication of these practices may be mainly attributable to scant training, to the increase in migration that exacerbates the shortage in the labor force and weakens social organization, and to the absence of a wider range of stimuli.

4. Discussion and conclusions

Forest sustainability includes criteria such as the maintenance of soil productivity, defined as its ability to operate within a broader ecosystem, where its functions include the production of plant biomass, carbon capture and regulation of water quality and quantity (Burger and Kelting, 1999).

In our study area, the proxy indicators selected for soil productivity and water regulation (bulk density, total carbon, nitrogen, porosity and moisture content) did not improve after four years with ditches and terraces that are the conservation practices more widespread in Mexico; rather, they worsened in comparison with control sites.

Deterioration or lack of improvement, in soil properties suggests that after four years these techniques have not fulfilled the expectations, and this could be regarded as an indication of an ineffective program (Nowak and Cabot, 2004).

One step in monitoring soil function is the identification of properties and the selection of a minimum set of indicators to serve as a proxy in

Table 3
Physical and chemical indicators of soils with and without (control sites) conservation practices (mean and standard deviation, $n=3$).

Variable	Ditches		Individual terraces		Arrangement of plant material	
	with	without	with	without	with	without
Moisture content (%)	21.05 ± 2.77	20.48 ± 3.18	21.06 ± 1.42	19.5 ± 1.31	107.52 ± 17.92	82.34 ± 5.95
	41.74 ± 2.03	52.74 ± 1.84	10.93 ± 1.12	9.76 ± 1.17	37.49 ± 5.08	54.55 ± 7.42
	22.96 ± 6.29	24.17 ± 4.75	26.65 ± 2.33	22.68 ± 1.18	45.54 ± 8.25	40.09 ± 7.14
Bulk density (g/cm^3)	1.32 ± 0.004	1.18 ± 0.05	1.01 ± 0.08	1.16 ± 0.04	0.49 ± 0.12	0.55 ± 0.03
	0.95 ± 0.02	0.74 ± 0.1	0.92 ± 0.02	0.92 ± 0.02	0.77 ± 0.02	0.61 ± 0.03
	0.99 ± 0.14	0.96 ± 0.17	0.85 ± 0.02	0.88 ± 0.02	0.77 ± 0.13	0.88 ± 0.07
Total carbon (%)	1.87 ± 0.05	2.31 ± 0.08	6.47 ± .0.63	7.2 ± 0.24	11.14 ± 3.99	10.01 ± 0.95
	5.92 ± 2.04	7.96 ± 1.34	6.70 ± 0.25	6.77 ± 0.65	8.87 ± 0.99	9.15 ± 0.42
	1.95 ± 0.5	2.73 ± 1.28	2.69 ± 0.13	3.8 ± 0.18	17.49 ± 1.10	13.925 ± 1.17
Total nitrogen (%)	0.17 ± 0.01	0.21 ± 0.01	0.21 ± 0.04	0.23 ± 0.01	0.97 ± 0.24	0.73 ± 0.06
	0.39 ± 0.12	0.48 ± 0.1	0.37 ± 0.00	0.41 ± 0.04	0.55 ± 0.03	0.55 ± 0.05
	0.18 ± 0.05	0.25 ± 0.1	0.24 ± 0.01	0.33 ± 0.01	1.42 ± 0.08	1.08 ± 0.14
Carbon/nitrogen (C/N)	10.95 ± 0.64	11.17 ± 0.46	30.38 ± 2.61	31.33 ± 2.27	12.43 ± 2.66	13.74 ± 0.98
	15.07 ± 0.72	16.67 ± 1.16	18.35 ± 1.15	17.39 ± 1.41	16.21 ± 0.84	16.79 ± 2.29
	10.88 ± 0.75	10.50 ± 0.88	11.19 ± 0.21	11.54 ± 0.32	12.29 ± 0.18	12.94 ± 0.64
pH	6.55 ± 0.14	6.91 ± 0.45	6.53 ± 0.14	6.38 ± 0.06	6.39 ± 0.22	6.42 ± 0.06
	7.18 ± 0.15	7.47 ± 0.18	8.01 ± 0.2	7.97 ± 0.1	6.82 ± 0.17	6.46 ± 0.02
	6.52 ± 0.23	6.32 ± 0.23	6.52 ± 0.23	6.39 ± 0.15	5.7 ± 0.06	5.87 ± 0.11
Total porosity (%)	40.01 ± 1.99	43.7 ± 2.16	51.69 ± 4.04	47.23 ± 1.62	72.53 ± 6.43	60.64 ± 1.92
	50.22 ± 0.91	67.51 ± 12.02	53.76 ± 1.22	51.45 ± 1.20	61.46 ± 1.04	69.49 ± 1.7
	52.76 ± 6.59	54.47 ± 8.17	57.53 ± 1.04	56.22 ± 1.03	54.48 ± 7.55	51.15 ± 3.68

Table 4
Significant differences in edaphic indicators between soils under conservation practices (cp) and soils without conservation practices (wcp) (Level of significance: *α = 0.10, **α = 0.05, ***α = 0.01). Fields with (–) show no significant differences.

	Moisture	Bulk density	Total carbon (%)	Total nitrogen (%)	pH	Porosity
Ditches	–	cp > wcp**	wcp > cp**	wcp > cp**	–	–
Individual terraces	–	–	wcp > cp***	wcp > cp***	cp > wcp**	–
Plant material arrangement	–	–	–	–	–	–

monitoring changes caused by management practices (Burger and Kelting, 1999; Powers et al., 1998; Schoenholtz et al., 2000).

The indicators used here were sufficiently sensitive to identify changes caused by conservation practices, and this is a first step in assessing the impact of public policy on the conservation of soil quality in Mexico.

Soil quality and sensitivity to change are highly variable, therefore soil management should be site-specific. This is not achieved by a public policy program at the national level, where actions are established a priori and are not always chosen for their appropriateness to the site. This is especially true when 70–80% of the soil conservation practices are mechanical (Magaña, 2007; Vargas, 2010). The selection of these techniques in the context of a public policy program is mainly due to the focus on these structural measures which are "attention grabbers because they are spectacular and conspicuous … however, they are hardly ever adequate on their own" (WOCAT, 2007).

Assessment of the impact of these techniques on soil quality allows us to register the benefits to the farmers themselves, as a means of accountability (Feinstein, 2007). 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. Experience shows that monitoring and evaluation leads to important changes and modifications in the approaches and technologies (WOCAT, 2007).

In the context of the adaptive management that is needed in view of the complexity of socio-environmental conditions, the absence of positive results might be attributable to erroneous assumptions, poorly executed actions, or changing conditions of the sites, or a combination of these factors. The inherent uncertainty in this complexity can be faced by treating soil conservation actions as experiments that can be upgraded in response to evaluation (Salafsky et al., 2001). Therefore, current soil conservation practices should be monitored and evaluated with regard to their adoption by the local owners and to their effects on soil properties.

The decision to adopt soil conservation techniques should be supported by attitudinal behavior, and by social and economic site-specific aspects (De Graaff et al., 2008; Ervin and Ervin, 1982; Green and Heffernan, 1987; Lapar and Pandey, 1999; Sheeder and Lynne, 2011). However, in Mexico they are shaped by three fundamental institutional

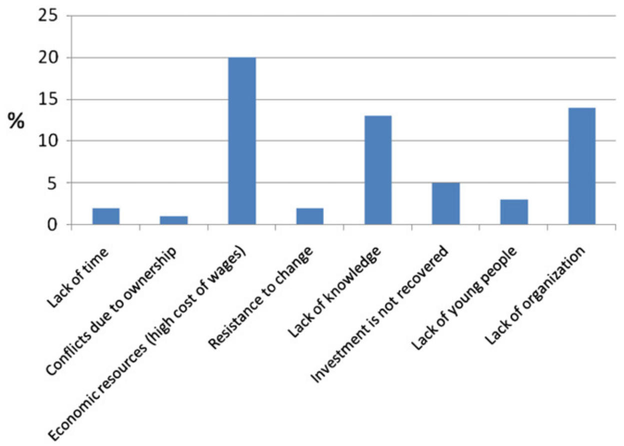

Fig. 3. Perception of respondents about the main obstacles for successful implementation of soil conservation measures.

and social situations: (i) the long tradition of subsidies has forged the dependence of farmers on the government (Merino, 2009), (ii) 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), and (iii) the construction of top-down programs has emphasized financial stimulus and does not recognize and strengthen empathy towards conservation behavior. In this regard, Sheeder and Lynne (2011) conclude that "policy instruments that facilitate expression of (the) shared ethic may be more likely to

Table 5
Current and proposed assumptions of the Forest Soil Restoration and Conservation Program in Mexico.

Current assumptions	Proposed assumptions
Forest soil conservation can only be promoted through economic stimulus	Soil conservation programs should also consider non-economic incentives and recognize attitudes and concern toward conservation, such as self interest.
The soil conservation practices can be performed under any socio-environmental condition	The selection of a practice needs to consider the local socio-environmental situation including ecological conditions and organizational capacity of communities.
	The soil conservation program should strengthen local institutions (*ejidos*) and thereby also agreements and communal work.
	The program needs to recognize the diversity and complexity of views of farmers (*ejidatarios*) and their idiosyncratic choices, in order to define an appropriate management case by case.
	The traditional practices can be an option for soil conservation.
	Landscape heterogeneity should be acknowledged through the combination of various practices, adapted to the socio-environmental conditions.
It is more important to retain sediments, through mechanical practices, than to preserve soil quality.	Soil conservation should emphasize maintenance of soil functions, mainly soil productivity and water regulation. Indicators associated with these functions are organic matter, bulk density, porosity, and soil structure, which can be enhanced by vegetative practices. Mechanical actions require inputs whose lack hinders replicability (specific knowledge, labor and machinery)
Conservation works are carried out regardless of the severity of soil erosion	Soil erosion is a multifactorial problem. Its control requires identification of the social and biophysical reasons that led to the degradation.
	Practices applied should consider the severity of the erosion.
Technicians are evaluated by the number of works they have carried out and the total area covered, regardless of the outcome.	The assessment should consider strengthening conservation attitudes among *ejidatarios* and the drive to farmer-to-farmer technology diffusion, in order to transform soil conservation into a learning process.
The program is evaluated in terms of its operation, efficient use of the subsidies and environmental indicators derived from models	Evaluation should include the impact of the practice on the recovery of soil quality and the adoption of the activities among the users.

increase conservation technology adoption rates than policies that stress only financial incentives". Other experiences of conservation behavior (Chouinard et al., 2008; De Graaff et al., 2010; Lockeretz, 1990; Nowak and Cabot, 2004; Sattler and Nagel, 2010; Sheeder and Lynne, 2011) take into account multiple motivations for adoption choices of soil conservation.

There is extensive literature concerning what motivates producers to adopt conservation practices and what determines the level of adoption in the USA (Chouinard et al., 2008) and in other countries (De Graaff et al., 2008; Maybery et al., 2005; Neill and Lee, 2001; Ryan et al., 2003), yet most of the findings are absent from the design and implementation of soil conservation policy in Mexico.

The Forest Soil Restoration and Conservation Program has progressively evolved, mainly in relation to the certification and performance of the technicians, but has remained constant in terms of program assumptions and conservation measures.

The experience gained in the present work leads to the proposal of some adjustments to the assumptions in order to have a program that achieves soil conservation (Table 5).

Soil conservation is not only a technical matter. Recognition is required that there is as much diversity in the human dimension of resource management as there is in the biophysical resources managed. Moreover, the meaning or interpretation placed on those behavioral patterns needs to be framed by the biophysical settings in which they occur (Nowak and Cabot, 2004). This diversity leads to the need for policy to move away from the historical "one size fits all" (Sheeder and Lynne, 2011). The basic reason for simplifying assumptions is to avoid the risk of a nuanced and time-consuming policy, but oversimplification may, in striving for efficiency, sacrifice the capability of producing the desired result (Nowak and Cabot, 2004).

This finding shows the value of understanding soil conservation attitudes and behavior and of recognizing cultural and biophysical variability. Since effective soil conservation is determined by the interrelationship of social environments and biophysical setting, an interdisciplinary approach to assess soil conservation will be a pre-requisite in future research.

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