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OPINION ARTICLE

The socioecological complexity of ecological restoration in Mexico

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Almost half of Mexican territory has been classified as environmentally degraded. The main response for the last 60 years has been reforestation to combat soil erosion and loss of forest cover, mostly carried out on private lands where negotiations with local stakeholders were critical. Despite four legal instruments referring to ecological restoration, no specific instrument that defines basic concepts, criteria and standards, required actions, or regulations to implement and evaluate ecological restoration exists. The Ministry of the Environment and Natural Resources is now solely in charge of restoration and only recently have external scientists been invited to be part of the process. Following important national and international events in Latin America and the Caribbean region, the First Mexican Symposium on Ecological Restoration was held in November, 2014. This historic event was the first action undertaken in Mexico to meet Objective 3 of the Global Strategy of Plant Conservation, coordinated in Mexico by the National Council for the Use and Knowledge of Biodiversity. Although mangrove ecosystems are the most endangered ecosystem type in Mexico, they were not well represented at the symposium. In contrast, several other ecosystem types, such as tropical dry forest and islands, have received increased attention. Overall, while the Symposium and above-cited policy initiatives are important steps, Mexico needs to increase its institutional capacities and social organization of the rural sector with regard to ecological restoration. Better integration of social and natural scientists and increased participation of Mexico internationally is also needed.

Key words: Global Strategy for Plant Conservation, networks, REPARA, SIACRE, social sciences

Implications for Practice

- More than half of the Mexican territory is in very critical condition in terms of loss of biodiversity and ecosystem health, and almost all protected natural areas are under potential threat of invasive species.
- In Mexico, most restoration projects need to take place on privately owned lands and in densely populated areas. This requires negotiations among many actors and indicates that more social science research is needed.
- A specific legal instrument to orient and implement ecological restoration actions in Mexico is needed.
- Restoration researchers should give more attention to the most endangered ecosystems, such as mangrove forests, as they are not sufficiently covered by current restoration actions.
- More attention to the science-policy interface and to international cooperation is also required.

Introduction

In Mexico, biodiversity is at risk because of complex socioeconomic factors and drivers and because historical restoration actions have been targeted to achieve rehabilitation-type minimal goals such as stopping erosion. Here, we analyze the socioecological complexity of ecological restoration in Mexico related to historical distribution of the land, chronic poverty, and lack of communication and participation of key actors. We also provide a report of the First Mexican Symposium on Ecological Restoration that took place in November, 2014, and gathered key actors to advance the study, best practice, and effectiveness and sustainability of ecological restoration in Mexico. Finally, we suggest possible steps to reach the ambitious goal of the Mexican effort for the Global Strategy of Plant Conservation that seeks the rehabilitation or restoration of at least 50% of degraded terrestrial and marine Mexican ecosystems by 2030.

Mexico is one of the 17 megadiverse countries recognized by Conservation International. However, in the last four decades, ecosystem degradation and deforestation have seriously affected rural areas. Evaluating the phenomenon of deforestation is complex because it has multiple origins and causes corresponding

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Table 1. Percentage of Mexican territory affected by four indicators of natural resource management problems. Each indicator was evaluated in 145 Biophysical Environmental Units (BEU) and assigned a qualitative category of degradation (very low, low, medium, high, and very high degree of deterioration); here we show percentage of territory included in the two highest degrees of degradation from Bollo-Manent et al. (2014) and references therein.

	Category of Degradation	
Indicators	*High (%)*	*Very High (%)*
Soil degradation	32	44
Deterioration of vegetation	14	22
Desertification	0.72	0.18
Deterioration of water bodies	0.89	2.92

to various biophysical and socioeconomic conditions. In the evaluation of the State of the Environment for Mexico in the year 2008, Bollo-Manent et al. (2014) identified 145 Biophysical Environmental Units (BEU). BEUs were assessed using 15 indicators for the management of natural resources, including those relevant to anthropic modification and socioeconomic status. Approximately 50% of the Mexican territory had some degree of degradation (Carabias et al. 2007; Anta-Fonseca et al. 2008; Bollo-Manent et al. 2014). Also, approximately 48% of the area covered by vegetation showed some level of degradation and desertification, and 6% of the BEUs analyzed were classified as having water bodies in critical states (Table 1). This level of degradation fosters other problems related to invasive species: 197 invasive plants were reported occurring in natural communities, and 39 invasive plants as having a high degree of invasion capacity (Domínguez et al. 2009). The most invasive plant species in terrestrial ecosystems were grasses (i.e. *Andropogon gayanus*, *Bromus tectorum*, and *B. rubens*), whereas aquatic ecosystems were registered as under threat from taxa of the Hydrocharitaceae, Potamogetonaceae, and Salviniaceae (Domínguez et al. 2009). In islands, invasion of exotic mammals such as feral cats and goats had caused or threatened the extinction of many endemic species of birds and rodents (Aguirre-Muñoz et al. 2008). These studies showed that almost half of the Mexican territory is environmentally unstable and that almost all natural areas under federal protection by the Mexican government (*Areas Naturales Protegidas*, CONANP 2014) are under potential threat of invasive plant or animal species.

Not only is biodiversity at risk at a national scale, but there is also cause for concern regarding impacts on the quality of life of people in rural areas who depend on the goods and services of local ecosystem (Adams et al. 2004; Liu et al. 2007). The socioecological complexity of restoration in Mexico is linked to private or collective land ownership—only 8% of the land belongs to the state (Lindig-Cisneros 2010). During the last decade, 80% of forests in Mexico were in the hands of local communities with collective concessions of land, known as "*ejidos*." *Ejidos* were created after the Mexican revolution by expropriating lands that exceeded the size limits of typical small landholdings and gifted to local groups, mostly comprised of indigenous people, for communal exploitation (Procuraduría Agraria 2000). This makes indigenous communities one of the most important decision-making groups in the country with regard to ecosystem management—though we caution they are not a monolithic group in terms of their composition, ideas, or positions and this label can be misleading. The collective term "indigenous communities" is used to refer to the communal practices and cultural identities that have allowed these peoples to develop institutional arrangements to obtain collective benefits and maintain sustainable production practices (Alcorn & Toledo 1998).

In 1991, an agrarian reform law made possible the division of *ejido* lands to promote private investment in the agricultural sector (Alcorn & Toledo 1998). However, nothing was done to alleviate poverty, vulnerability, and marginalization of the affected communities (Bray et al. 2007). At present, over 50% of the population on *ejidos* live in extreme poverty and lack educational access or abilities to complete even basic education (Bray et al. 2007). For example, the average school attendance per child on *ejidos* is 3.3 years, whereas the national average is 7 years (Merino & Segura 2003). In recent decades, small farmer markets in forest areas have also declined as a direct result of widespread loss of productive capacities caused by the ongoing deterioration of natural ecosystem resources and this deepens the poverty trap (Merino & Segura 2003). Farmers, pushed by population increase and poverty, extend crop cultivation to fragile marginal lands; these processes degraded lands further, reduced yields, and further impoverish farmers (Pearce & Warford 1993; Dasgupta & Mäler 1994; Reardon & Vosti 1995). To carry out restoration within this complex socioecological context, restoration ecology research and practice require a transdisciplinary approach.

Policy

As in most countries, Mexico does not yet have a clear federal policy regarding ecological restoration. The policies that do exist are focused on mitigation and compensation, albeit linked to programs for both prevention and recovery (Carabias et al. 2007). In the past 12 years, however, a broader view of restoration has emerged in public policies (Cervantes et al. 2008). Legally, Mexico has the federal power for actions for ecological restoration and has four legal instruments that refer to restoration: (1) the General Law of Ecological Equilibrium, (2) the Environmental Protection Act, (3) the Sustainable Forest Development, and (4) the General Wildlife Act. Being very broad in scope, such policies do not have specific goals related to restoration for the conservation of ecosystems; instead they are designed to maintain or increase productivity in agricultural lands already under exploitation (Carabias et al. 2007). There is the clear need for a specific legal instrument that defines the concepts linked to restoration, requires implementation of ecological restoration, provides levers to perform socioecological analyses, and specifies monitoring standards (Carabias et al. 2007).

Meanwhile, as mentioned, there have been some federal actions related to restoration, in the broad sense. For example,

to recover productivity in agricultural lands, the most common practice in Mexico between 1930 and 1960 was reforestation actions, that is establishment of tree plantations (Cervantes et al. 2008). Later, between 1999 and 2005, reforestation activities were carried out in 193,000 ha per year and soil improvement (with green manures, fertilizers, and plant cover for soil retention) in 59,000 ha per year (Cervantes et al. 2008). In 2005, the Mexican government invested 35.5 million U.S. dollars through the *Consejo Nacional Forestal* (CONAFOR; National Forest Commission) for soil protection through reforestation (Carabias et al. 2007). The General Law of Ecological Equilibrium in its section 87-BIS-1 established that those revenues from permits, authorizations, and licenses related to wild fauna and flora will be used for restoration activities (Ley General del Equilibrio Ecológico 2015). There is also a Mexican Forest Fund that receives money from a program called *Compensación Ambiental por Cambio de Uso de Suelo de Terrenos Forestales* (environmental compensation for change in forest land use, CONAFOR 2015). The law related to this program establishes that those public or private companies interested in doing some change in forest land use should compensate for the damage. Therefore, this Fund constitutes an unpredictable and insufficient source of funds for ecological restoration (Carabias et al. 2007) unlike the comparable 2012 compensation law enacted in Colombia (Aguilar et al. 2015). For example, to reforest 16 million hectares and recover the 43.5 million hectares of soil registered as degraded in 2007 (Cervantes et al. 2008), it would be necessary to reforest 400,000 ha per year, and to augment the soil biota in 1 million hectares of soil per year until 2050, and for this, more than 68 million U.S. dollars of investment *per year* will be required (Cervantes et al. 2008). However, the Mexican Forest Fund is allocating only 2 million U.S. dollars per year to restoration actions (CONAFOR 2015). The scope of the tasks facing ecological restoration practice is thus quite daunting, even without considering socioecological complexity, and that is why specific legislation is needed.

As mentioned, though, ecological restoration is multidisciplinary and in countries like Mexico it must be multisectorial. In Mexico, this activity is virtually dependent on the *Secretaría del Medio Ambiente y Recursos Naturales* (SEMARNAT; Ministry of the Environment and Natural Resources) and, to a lesser extent, on the *Secretaría de Agricultura*, *Ganadería*, *Desarrollo Rural*, *Pesca y Alimentación* (SAGARPA; Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food). Some incentives to restore degraded land are available from a program that translates to a "Payment for Environmental Services" launched by CONAFOR—which has focused mainly on reforestation. The effectiveness of these programs is not clear because there has been no systematic and reported monitoring (see Murcia & Guariguata 2014, for an example of an initial evaluation at a national scale that could serve as a model for Mexico).

New Initiatives: The First Mexican Symposium on Ecological Restoration at Cuernavaca

To advance the study, practice, and effectiveness of ecological restoration in Mexico, we sought to bring together all groups currently involved in the ecological restoration of Mexican ecosystems. Following important meetings held recently in Latin America and the Caribbean (Aguilar et al. 2015; Echeverria et al. 2015), the Cuernavaca meeting was held on 19–20 November, 2014, at the University of the State of Morelos. This national symposium was held on an emblematic date: 20 November was the anniversary of the Mexican Revolution of 1910, the first revolution of the twentieth century (Meléndez 1987). The idea for this symposium was conceived at a Workshop held in September 2013 in Mexico City organized by the National Council for the Use and Knowledge of the Biodiversity (CONABIO). This workshop with the participation of academics, government agency workers, and restoration practitioners aimed to select the participants for the committees to coordinate each of the six objectives of the Mexican Strategy of Plant Conservation (CONABIO 2012*a*). This Strategy is part of the Mexican effort for the Global Strategy for Plant Conservation (Aronson et al. 2014); in particular, Objective 3 calls for the rehabilitation or restoration of at least 50% of degraded terrestrial and marine Mexican ecosystems by 2030 (CONABIO 2012*a*). After a search in various academic publications databases, 25 participants from 17 academic, government, and civil institutions encompassing social, experimental, and practical aspects of restoration ecology were invited to the symposium. Most invited oral presentations discussed experimental biological studies (52%), while only a fifth related to social components (including the participation of landowners; 21%) and even fewer had a clear practical focus (17%). This symposium was conceived within important actions to restore ecosystems launched by CONABIO and several Mexican Universities (CONABIO 2015) and international schemes (such as the above-mentioned Global Strategy for Plant Conservation).

Some disconnection was seen between the ecosystems with the highest percentages of loss in Mexico and those best represented in the poster contributions of the Symposium. For example, mangrove ecosystems in Mexico have the highest percentage of area lost (47%), with lowland humid forests and cloud forests having 41% of area lost (CONABIO 2012*b*). No studies concerning mangroves, besides the one invited, were presented at the symposium. The ecosystem type best represented at the symposium was seasonal tropical dry forest, even though it is only in third place, nationally, in percentage of area lost (36%; CONABIO 2012*b*). A previous review (Meli 2003) showed that for tropical America, seasonally dry forest was the second least represented terrestrial forest ecosystem in the restoration literature, whereas humid forest was the most studied. Also, important positive efforts related to the removal of invasive species for restoration of biodiversity on islands were shown (Ceccon & Martínez-Garza 2014). Happily, previously neglected but important ecosystems are now gaining recognition and attracting research studies.

Against the backdrop of armed conflict, violence, and social crisis in Mexico, a strong message coming out of the symposium was that ecological restoration activities can and should be socially embedded so as to make their implementation more relevant and robust. Halting or reversing environmental degradation through effective and relatively large-scale ecological restoration could help to reduce poverty and social conflict if those actions also help to increase land productivity, reduce risks related to environmental degradation, and provide income, job and livelihood opportunities for local rural communities (DellaSala et al. 2003) and, in turn, for the nation as a whole. For example, the research group of the Regional Multidisciplinary Research Center (CRIM; crim.unam.mx) represented by Eliane Ceccon made a presentation at the symposium, suggesting developing research strategies to generate ecosystem services, thereby increasing agricultural productivity and human well-being. The best strategy suggested in this case was to augment natural capital (*sensu* Aronson et al. 2007) at the landscape scale, combining ecological restoration of natural ecosystems with "productive restoration" techniques (Ceccon 2013), e.g. agroforestry and environmentally friendly agroecological systems such as the introduction of legumes and trees with fleshy fruits into agricultural systems, that could increase the organic matter and nitrogen content of soil (Ceccon et al. 2015; Hernández-Muciño et al. 2015) and to function as stepping points among fragments in degraded landscapes (Uezu et al. 2008). The methodology used was "action-research," wherein local farmers participate as co-researchers (McNiff 2013). Restoration approaches such as this one will favor stronger ties among scientists, government, and civil society, thereby—hopefully—reducing social and political tensions and fostering national reconciliation in Mexico. However, experiences in other countries have shown that ecological restoration must be totally integrated into socioeconomic and political planning at regional or national scales in order to succeed (see also Aguilar et al. 2015).

Where to Go From Here?

Our mission, namely to assist and connect efforts aimed at the "restoration of natural capital" to promote revitalization of rural communities, cannot advance if we ignore the current conditions of social injustice in Mexico. To reach this goal, it is necessary to know each other a bit better, and to join forces among researchers, civil society, businesses, and practitioners in order to work together for a social reconstruction in alignment with ecosystem restoration in Mexico. The re-launching of the Mexican Network for Ecological Restoration (REPARA—*Red de Restauración Ambiental* in Spanish) to strengthen ties among the organizations and institutions working on restoration in Mexico today and to strengthen ties with the recently created Ibero-American and Caribbean Society of Ecological Restoration (SIACRE) (Echeverria et al. 2015; Zuleta et al. 2015) is a big achievement.

An explicit policy is also now necessary to consolidate an institutional government reform to harmonize public policies including restoration and rural production (land sharing, *sensu* Phalan et al. 2011) that incorporate ecological restoration of degraded ecosystems, and more broadly, the restoration of both natural and social capital. Both types of restoration must be suited to the specific socio-politico-cultural context at project sites, such as the indigenous communal properties found in much of rural Mexico, and balancing both types to favor ecological and economic sustainability, rigorously monitored with environmental, social, and economic parameters, and supported by relevant public legislation (see Aronson et al. 2011).

Necessary actions include the following: (1) to design effective and accessible economic instruments (e.g. carbon bond market) to accelerate the restoration activities, (2) to develop capacity building, (3) to strengthen science and technology in restoration establishing land degradation as a national problem to get funding for basic and applied research to solve it, (4) to foster a social construction of the restoration concept associated with the welfare of people through campaigns on radio, television and electronic media, and (5) to strengthen networks among all involved social actors.

There are some potential actions that we can suggest. For economic instruments, it is necessary to look at the global benefits of carbon mitigation associated with community forest management (see below) that could help leverage needed investments in local forest restoration capacity: In Mexico, there are circa 500 communities with community forest management businesses that maintain forest cover, restore density and commercial productivity in previously mismanaged forests, and abandoned agricultural areas (community-based forest management; Bray et al. 2003). This important social capital, which is part of rural Mexican tradition, should be included and favored in ecological restoration instruments. To do so, social investments is needed, supported by government promotion and financial support of farmers' cooperatives, technical assistance, and training in business administration and ecological restoration. For capacity building, multidisciplinary curricula in graduate programs including links with different actors of society related to restoration are needed (see Ceccon & Cetto 2003); for example, a graduate program in sustainability, which includes ecological restoration in its curriculum is about to start in the National University of Mexico. First steps toward reaching these goals have been taken with the Mexican symposium and the re-launching of the REPARA and the strengthening of ties with SIACRE. However, continuous forums with the REPARA community and all the social actors are necessary to keep this in motion. The other three needs we suggest await discussion at events like the SIACRE international congresses—it is important that these venues now exist and thrive in the emerging nodes of restoration ecology like Mexico, and Central and South America.

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