Journal of Environmental Management xxx (2013) 1–11

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Restoration of degraded agricultural terraces: Rebuilding landscape structure and process

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ARTICLE INFO

Article history:
Received 30 July 2013
Received in revised form
31 October 2013
Accepted 14 November 2013
Available online xxx

Keywords:
Agriculture
Restoration
Environment
Terrace
Mexico

ABSTRACT

The restoration of severely degraded cropland to productive agricultural capacity increases food supply, improves soil and water conservation, and enhances environmental and ecological services. This article examines the key roles that long-term maintenance plays in the processes of repairing degraded agricultural land. Field measurements from Tlaxcala, Mexico stress that restoring agricultural structures (the arrangements of landforms and vegetation) is alone insufficient. Instead, an effective monitoring and maintenance regime of agricultural structures is also crucial if the efforts are to be successful. Consequently, methods of wildland restoration and agricultural restoration may differ in the degree to which the latter must plan for and facilitate a sustained human involvement. An improved understanding of these distinctions is critical for environmental management as restoration programs that employ the technologies of intensive agriculture continue to grow in number and scope.

1. Introduction

Agricultural landscapes are the primary medium through which many societies receive critical environmental and ecosystem services (Swift et al., 2004; Swinton et al., 2007; Bohlen et al., 2009). Cultivation processes produce food and create agroecosystems that affect soil, water, climate, biodiversity, and a wide range of market and non-market driven services (Gliessman, 1998; Wood et al., 2000; Altieri, 2004). The degradation of agroecosystems represents both a decrease in the potential food supply and a degradation of the natural resources upon which society depends. The restoration of severely degraded agricultural lands to productive capacity, in the absence of a return to more 'natural' conditions, offers the potential for improved soil, water, and biodiversity conservation (Wade et al., 2008; Pywell et al., 2011). But as artificially structured, human-created environments, agrosystems require some degree of continued human involvement to develop (Doolittle, 2006). In prioritizing the short-term environmental remediation of degraded agricultural environments, restoration programs often neglect to plan for and facilitate processes of long-term maintenance. Maintenance is a critical, though often overlooked part of building and sustaining agroecological structures and processes.

Consequently, greater emphasis on the structures and processes of intensive agricultural environments, in many respects distinct from wildland or natural environments, is critical for environmental management. If the ultimate goal of restoration, broadly defined, is to build self-supporting ecosystems that are resilient to perturbation without further assistance (Ruiz-Jaen and Aide, 2005; SER, 2004), the restoration of agroecosystems indeed requires modified methods and criteria. Institutional efforts to restore severely degraded cropland may effectively apply the principles of restoration ecology, but they are likely to require a more sustained human involvement.

This study examines the role of maintenance in restoring the structures and processes of agricultural terraces along severely degraded hillslopes in the Mexican state of Tlaxcala (Fig. 1). Field measurements of surface erosion and sediment accumulation on newly restored terraces provide structural evidence of flawed restoration processes. Newly built, incipient terraces have been constructed upon degraded agricultural land. Erosion mitigation structures, retention ditches (*zanjas*) and vegetated berms (*bordos*), however, are degrading at unsustainable rates, with no plans for maintenance or upkeep. This study stresses that the processes of rebuilding agricultural landscapes, especially as a high-input form of environmental remediation, must also plan for and facilitate sustained site maintenance to be effective over the long term (10^{1-2} yrs). This fundamental characteristic of intensive agrosystems is often not considered in the search for quick and inexpensive approaches to repair environmental damage.

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http://dx.doi.org/10.1016/j.jenvman.2013.11.019

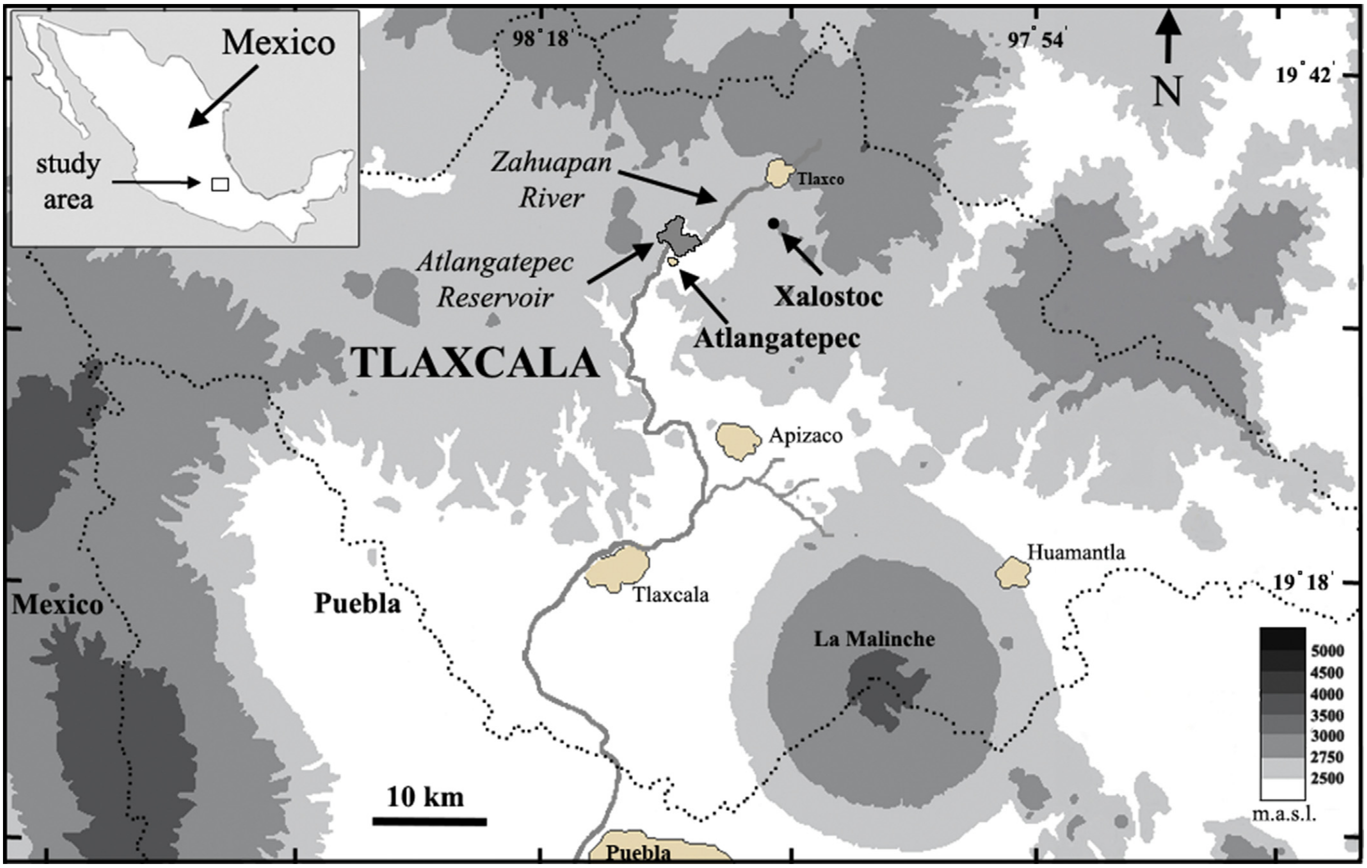

Fig. 1. Map of the study area.

1.1. Agroecological restoration with traditional technologies

The repair of ecosystem processes is a critical component of successful environmental restoration (Bradshaw, 1997; Whisenant, 1999; Herrick et al., 2006). But with about 33% of Earth's surface under some form of agricultural production (FAO, 2013), an improved understanding of agroecological processes has become increasingly relevant in environmental management. Restoration ecologists have incorporated many of the land-shaping technologies of intensive agriculture into wildland repair efforts (Jordan et al., 1987; Harper, 1982), although with mixed results (Whisenant, 1999 p. 16). Far from a panacea for environmental problems (Altieri, 1995), some traditional or indigenously developed technologies nonetheless offer advantages over conventional approaches in that many represent cost-effective, low external input (LEI), and ecologically sustainable forms of environmental management (Gliessman, 1998; Reijntjes et al., 1992). But transferring traditional strategies into modern restoration contexts can be problematic (Wilken, 1989; Kaimowitz, 1990), as distinctions between agroecological structures and processes, especially those involving incremental changes (Doolittle, 1984), are often overlooked or inadequately understood. Top–down efforts that attempt to mimic traditional structures can prove ineffective or counterproductive over the long term (Chapin, 1988; Doolittle, 1989).

Traditional farming approaches represent useful baseline analogs for contemporary development, restoration, or adaptive management efforts (Altieri et al., 2012; Berkes et al., 2000; Reij et al., 1996; Erickson, 1988). But comparative studies of their effectiveness are key, as accepting and implementing them on purely emotional or ideological grounds is irresponsible (Butzer, 1996). Moreover, once a strategy is chosen, planning for, funding, and evaluating a program can be problematic due to insufficient technological understanding or lack of an adequate system of program evaluation (Wilken, 1989). Ultimately, agricultural composition, structures, and other forms of landesque capital may require time to develop (Blaike and Brookfield, 1987 p. 9), as centuries of incremental modifications and fine-tuning of agrosystems are difficult, if not impossible to replicate with a few hours of bulldozer or backhoe work. Where the basic technologies are appropriate, successful implementation or modification requires collaborative, adaptive, long-term thinking, especially at the institutional level (Critchley, 1999).

Agricultural terracing is an ancient and widespread approach to intensive cultivation. Terrace forms range from step-like horizontal planting surfaces (treds) with supporting vertical walls (risers), to parallel rows of plants that only slightly modify the degree of hillslope (Treacy and Denevan, 1994). By leveling hillslopes, all terraces seek to create better planting surfaces that mitigating surface erosion and deepen soils (Spencer and Hale, 1961), in effect, conserving soil and water. But as carefully built environments, terraced landscapes are also prone to degradation. The artificial leveling of hillslopes creates greater potential for erosion as the terraced surface competes with geomorphic processes that seek to return the hillslope to its natural gradient (Borejsza, 2006). Terraced landscapes can be among the most fragile of built environments (Treacy, 1989), although their vulnerability to degradation depends on a wide range of factors often stemming from mismanagement (Barbier, 1990) or abandonment (Inbar and Llerena, 2000; Hunter, 2013). Restoring terrace agriculture requires a fine-grained understanding of the human agency,

Please cite this article in press as: LaFevor, M.C., Restoration of degraded agricultural terraces: Rebuilding landscape structure and process, Journal of Environmental Management (2013), http://dx.doi.org/10.1016/j.jenvman.2013.11.019