Land Use Policy 29 (2012) 187–197

Contents lists available at ScienceDirect

Land Use Policy

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

Changes in land use, land tenure, and landscape fragmentation in the Tijuana River Watershed following reform of the ejido sector

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ARTICLE INFO

Article history:
Received 17 June 2010
Received in revised form 8 June 2011
Accepted 15 June 2011

Keywords:
Land use/cover change (LUCC)
Land use policy
Ejido
Ley Agraria
U.S.–Mexico border

ABSTRACT

Changes in land use and land tenure can influence both physical fragmentation and ownership fragmentation of landscapes, with implications for biodiversity. In this study, we evaluated changes in land use and land tenure in the Tijuana River Watershed, a region of high biodiversity and endemism, following the implementation of a new Agrarian Law which allowed for privatization and sales of communal land (ejidos) beginning in 1992. In order to understand changes in land use and cover, we constructed maps from aerial photographs and Aster images and measured changes between 1994 and 2005. In order to understand changes in land tenure, we collected data from Mexican government sources on ejido land size, ownership, and sales, and we conducted 55 structured interviews with ejidatarios in the watershed. Our results demonstrate that land-use/cover change between 1994 and 2005 was dominated by an increase in urban area and grasslands, and a decrease in coastal sage scrub, chaparral, and, to a lesser degree, agriculture. In particular, the conversion of coastal sage scrub has left a far more fragmented landscape than existed in 1994. In addition, most of the ejidos in the watershed, as well as individuals interviewed, had participated in some stage of the land certification and titling process allowed by the new Agrarian Law, resulting in substantial changes in land tenure. However, land tenure security appeared to play a larger role than a desire to sell land and, contrary to studies from other regions, full title to the land was obtained in a range of urban and rural settings, rather than primarily on land closest to urban zones. Our results suggest that past predictions regarding future urban growth and fragmentation of native vegetation in the region have proven accurate and highlights regions of change that merit further study.

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Introduction

Human activities such as forest clearing, agriculture, farmland intensification, and the expansion of urban centers, are examples of the many ways that human land uses have altered the world's landscapes. These land-use practices have provided societies with a variety of benefits, including increased food production, but often also come with trade-offs in terms of loss of biodiversity and alteration of hydrology and water quality, among others (Defries et al., 2006; Foley et al., 2005). In particular, shifts in land use such as land clearing for agriculture and urbanization have been associated with increased habitat fragmentation, which can lead to a loss of biodiversity (Defries et al., 2006). Fragmentation includes the decrease and isolation of natural ecosystems, which can impact biodiversity by causing population declines, reduction of resources, and negative effects on the movements of species, dispersal, and metapopulations (Soulé et al., 2004; Luck and Daily, 2003; Cooper and Walters, 2002; Zanette et al., 2000; Bender et al., 1998; Hanski and Gilpin, 1991).

Many of these types of changes in land use can be linked with the physical fragmentation of the landscape, which increases the number of land patches and decreases their mean size (Fahrig, 2003; Swenson and Franklin, 2000). At the same time, changes in land ownership can create ownership fragmentation, in which parcelization of a landscape presents the potential for future physical fragmentation (Gosnell et al., 2006; Ko et al., 2006). It is generally believed that an increase in the number of land owners and land parcels leads to greater fragmentation, and consequent loss of biodiversity; however, in some cases, large parcels may stay intact even as land is sold or transferred (Kjelland et al., 2007; Gosnell et al., 2006). Ortega-Huerta and Kral (2007) have noted that changes in land tenure can also play an important role in how land is managed, as each tenure system may be associated with particular social, economic, and cultural conditions, all

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0264-8377/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.landusepol.2011.06.006

of which influence management and can have implications for biodiversity.

Researchers who have examined the causes of land-use change have focused on a variety of factors, ranging from population pressures, changes in markets and technology, and government policies, among others, in an effort to understand changing land-use patterns (Mena et al., 2006; Campbell et al., 2005; Liu et al., 2005; Lambin et al., 2003; Homewood et al., 2001). In particular, state policies that are either directly or indirectly aimed at restructuring production systems have strong potential to drive land-use change (Thiha et al., 2007; Luers et al., 2006). In Mexico, reforms to Article 27 of the constitution and enactment of a new Agrarian Law (*Ley Agraria*) constituted a national-level policy reform that took place in 1992, allowing for the privatization of communal land known as *ejidos* (Perramond, 2008). This system of communal land ownership was originally established following the Mexican Revolution of 1910 in order to address unequal land ownership in the country; half of the land in Mexico was eventually transferred to ejidos, converting them into an important part of the agricultural sector in Mexico (Perramond, 2008; Assies, 2008; Lewis, 2002; Cornelius and Myhre, 1998). The reform of the ejido system legalized the sale and rental of ejido lands, making them available for parcelization and privatization and creating a legal market for ejido land that replaced the illegal market that was known to have existed prior to reform (Naylor et al., 2001). These changes also set up the potential for changes in land use, which is thought to be the product of the land market and the regulatory environment (Riebsame et al., 1996); the new Agrarian Law changed both simultaneously, with the policy change making it possible for ejido lands to legally enter the market.

Some have suggested that the reforms would not only end land redistribution by the government, but would reverse the direction of land transfers, moving land from the social sector to the private sector (Toledo, 1996). However, others have noted that having the ability to obtain individual parcels does not necessarily mean that land will be privatized or sold, and that the reforms can improve land tenure security (Perramond, 2008; Brown, 2004). Nonetheless, the reforms have generated concern about the possible impacts on rural and indigenous communities, the potential for increased deforestation and conversion of other types of non-forested land, the transfer of agricultural land to commercial farmers or other commercial interests, and the decline of ejido agriculture as land is rented out to private farmers (Smith et al., 2009; Vargas et al., 2008; Luers et al., 2006; Lewis, 2002; Naylor et al., 2001; Martínez Rodríguez, 2001). Ortega-Huerta and Kral (2007) also have noted that the changes initiated by the 1992 reforms of Article 27 increase the importance of understanding the link between land tenure systems and conservation outcomes. This link is particularly important in the case of the agrarian reform since 50% of the croplands and 80% of the forests in Mexico are associated with the ejido sector (Barton Bray, 1996). However, views on this relationship vary dramatically, with some seeing ecological degradation as the most likely outcome of a shift from smallholder, community-based land management to that of large landowners and firms, while others see the reforms themselves as part of a solution to already-existing land degradation within the ejido sector (Barton Bray, 1996; Toledo, 1996). Although little is known about the relationship between land tenure and the environment in Mexico (Barton Bray, 1996), past research there has found a relationship between the type of land ownership and biodiversity outcomes, with community-owned lands generally having higher measures of habitat conservation, such as the percent of land with natural vegetation cover and species richness of mammals and birds (Ortega-Huerta and Kral, 2007).

While the effects of the new Agrarian Law in any given region depend on a variety of factors, including the type of land ownership and management, the quality of the land, regional differences, and characteristics of individual ejido communities (Assies, 2008; Luers et al., 2006), its potential to drive changes in land tenure and use may be particularly relevant in areas known for high levels of biodiversity, where the potential ecological consequences of ownership fragmentation would be greater. One such area is the Tijuana River Watershed, which supports large numbers of endemic plant species and has already been subject to fragmentation of vegetation and wildlife habitat (Ojeda-Revah et al., 2008). In this study, we investigated trends in changing land ownership and land use/cover in the Mexican portion of the Tijuana River Watershed following the implementation of the new Agrarian Law. Specifically, we addressed the following questions: (1) What are the dominant changes in land use/cover that occurred in the Tijuana River Watershed between 1994 and 2005? (2) What effect has the reform of Article 27 and implementation of the new Agrarian Law had on land tenure across the watershed?

Background

Study area

The Tijuana River Watershed (TRW) is a 4532-km^2 basin that lies along the U.S.–Mexico border and is comprised of portions of northern Baja California and southern California (Ganster, 2005) (Fig. 1). Since the 1950s the watershed has been an important site for research on urban growth and changes in land use due to its unique characteristics (Wright, 2005a). It is a binational watershed that contains resources such as the Tijuana River, which are shared by the U.S. and Mexico, and it is home to one of the last coastal wetlands in Southern California, the Tijuana River Estuary (Ganster, 2005; Roullard, 2005). It also supports regionally significant native plant communities, including coastal sage scrub and chaparral (O'Leary, 2005).

Earlier research on changes in land use/cover in the Tijuana River Watershed found that native plant communities had been fragmented (Ojeda-Revah, 2000), while the Tijuana River Estuary began receiving increasing amounts of sediment from local urban development projects (Roullard, 2005). During the period 1970–1994, land use throughout the watershed changed substantially, most notably through expansion of urban areas which increased by more than 200 km^2 (Ojeda-Revah et al., 2008). During this period, 75% of all urban growth in the watershed occurred in the Mexican portion of the watershed, resulting in the conversion of coastal sage scrub, chaparral, and grasslands to urban areas (Ojeda-Revah et al., 2008). Some researchers have predicted that the urban fringe of the city of Tijuana will expand and reach smaller clustered communities to the east and south of Tijuana, eventually connecting and forming a continuous strip (Wright, 2005b). At the same time, studies from other regions have shown that, in many cases, these urban patches come at the expense of cultivated lands that once existed in areas surrounding the urban core (Seto and Fragkias, 2005). Whether these types of changes occur is particularly relevant in the context of the new Agrarian Law, which sought to increase productivity in the rural economy and "dynamize production" (Assies, 2008, p. 33; Cornelius and Myhre, 1998); however, no studies have been done in the Tijuana River Watershed, and the effects on agricultural lands in close proximity to urban areas are unknown.

Some of the factors that have been identified in promoting past urban growth in the Tijuana River Watershed include increases in migrant populations from Michoacán, Sonora, Nayarit, and Guanajuato in response to job creation from national border industrialization policies; poor infrastructure investment which pushed populations towards the outer edges of urban areas; and lack of law enforcement preventing illegal land-use change (Ojeda-Revah

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