LINKING LAND USE AND POLICY IN THE TIJUANA RIVER WATERSHED

PROJECT NUMBER: NR-08-02

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NARRATIVE SUMMARY

The study of land-use change and practices is particularly important for watershed and land management, as land use and cover have a strong influence on water resources and ecosystem health. These changing land uses have a range of outcomes for the natural environment, especially for ecologically sensitive ones like the Tijuana River Watershed (TRW). The single greatest threat to native plant communities in this region has been habitat loss and fragmentation. Due to the impacts that different land uses can have on habitat it is crucial to understand the nature of changes in land use in order to develop appropriate conservation strategies.

The social and economic processes that drive land-use change vary dramatically in border regions such as the TRW. Therefore, while mapping land uses is an essential step, it is likely that the differences in the way in which those uses are carried out on the U.S. and the Mexican sides of the border are large. Ultimately, policy directed at managing land use in ways that will positively affect watershed health within the region must account for these trans-border differences. From 1994 to 2005, a period of rapid change, a conservation policy titled the Multiple Species Conservation Program (MSCP) was implemented in the U.S. portion of the watershed and a new Agrarian Law (Nueva Ley Agraria) was implemented in the Mexican portion. Both policies had the potential to influence land use in several different ways. This study sought to examine land-use change in three ways: by characterizing current land cover and land use and evaluating changes since 1994, by characterizing land ownership within the watershed, and by evaluating the role of land-use policy changes.

This study found a continuing trend of fragmentation in the watershed. In the Mexican portion of the watershed, mapping also indicates that grasslands can be a precursor to urbanization, with urban land having expanded in areas that were grasslands in 1994 and grasslands expanding into areas that had been mostly coastal sage scrub in 1994. This suggests that much of the area surrounding Tijuana that was converted to grasslands between 1994 and 2005 will likely convert to urban areas in the future. This study also illustrates that policies can have effects that are counter to their original goals. Although the primary purpose of the new Agrarian Law was to revitalize the agricultural sector, in the case of the TRW more land has moved out of the agricultural sector than has moved into it. Instead, the new Agrarian Law appears to be facilitating urbanization. While it is too early to tell if MSCP is accomplishing its intended goals,

given that a large portion of it has still not been implemented fully in the TRW, results from this study suggest that MSCP immediate impacts are often misunderstood. The misconception that large amounts of private land are being purchased is common, although attitudes towards conservation in the county are generally positive.

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INTRODUCTION

The study of land-use change and practices is particularly important for watershed and land management, as land use and cover have a strong influence on water resources and ecosystem health (Ojeda, et al. 2008; Schilling and Spooner 2006; Twarakavi and Kaluarachchi 2006; Li, et al. 2006; Farley, et al. 2005; Jackson, et al. 2005). Changes in land use, such as urbanization and agriculture, can provide society with a variety of benefits, but also have been associated with habitat fragmentation and loss of biodiversity (Defries, et al. 2006). The decrease, isolation, and separation of natural ecosystems through fragmentation can result in population declines, a reduction of resources, and negative effects on the movements and dispersal of certain species (Soulé, et al. 2004; Luck and Daily 2003; Cooper & Walters 2002; Zanette, et al. 2000; Bender, et al. 1998; Hanski & Gilpin, 1991). Land-use and land-cover changes also have broader effects on stream and estuarine ecosystems, particularly as they affect erosion and the deposition of sediments (Nilsson, et al. 2003; Howarth, et al. 1991).

Project Area

The California Floristic Province, stretching from southwest Oregon to northern Baja California, is internationally recognized as one of the world's 25 biodiversity hotspots (Myers, Mittermeier, and Mittermeier 2000; Conservation International 2008). It encompasses the South Coast Floristic Region, an area along the U.S.-Mexican border known for supporting the highest number of endemic plant species in the California Floristic Province. In the center of this floristic region lies the Tijuana River Watershed (TRW), a 4,532 km^2 basin comprised of portions of northern Baja California and southern San Diego County (Ganster 2005) (Figure 1).

The TRW has several key physical characteristics that make it unique. First, it is a binational watershed with one-third of its area in the United States and two-thirds in Mexico (Wright 2005a). It is one of the many examples of shared resources in the region, including water and ecological resources, which are bisected by an international border. The headwaters of the river begin in eastern San Diego County and travel south across the border into the city of Tijuana, eventually returning to San Diego where the river drains into the Pacific Ocean. Second, the watershed contains one of the last coastal wetlands in Southern California, the Tijuana River Estuary (Ganster 2005; Roullard 2005). The 2,500-acre publicly owned reserve is located north of the city of

Tijuana in San Diego County and is the endpoint for rivers and streams in the watershed as they travel through the estuary into the Pacific Ocean. The estuary also serves as an important rest stop for migratory birds traveling south along the Pacific Flyway (Roullard 2005). Finally, the TRW supports a significant number of native plant communities, including a variety of species of coastal sage scrub and chaparral (O'Leary 2005). These globally rare plant communities provide habitat to a number of threatened and endangered wildlife species (O'Leary 2005).

Rapid change has occurred in the past several decades, including population growth and accompanying changes in land cover and use, which ultimately affect the quantity and quality of the water reaching the Tijuana estuary (Wright 2005a). Erosion and sedimentation, which are strongly linked to land cover and land use, are of particular concern, as sediment deposition is considered a major problem due to its impact on the wetland habitat of the Tijuana estuary (Roullard 2005). Resources in the watershed have become severely impacted by humans, with the distribution of the watershed's 1.4 million inhabitants being the primary factor affecting the natural environment of the basin (Wright 2005b; Liverman, et al. 1999). The intensity and location of inhabitants corresponds with the type of land use for residential, economic, recreational, transportation, and commercial purposes, and in recent years land-use planning on both sides of the border has allowed for increased urban development (Vela 2005; Wright 2005b).

These changing land uses have a range of outcomes for the natural environment (Liverman, et al. 1999). The single greatest threat to native plant communities in this region has been habitat loss and fragmentation (Conservation Biology Institute 2004). The two dominant vegetation communities, coastal sage scrub and chaparral, along with communities of juniper scrub and riparian woodland have been fragmented over time (Ojeda-Revah 2000). The native vegetation is important because it provides habitat to species such as the California gnatcatcher (Polioptila californica californica), southwestern arroyo toad (Bufo californicus), light-footed clapper rail (Rallus longirostris levipes), and the quino checkerspot butterfly (Euphydryas editha quino). Each of these species has been listed as federally threatened or endangered (U.S. Fish and Wildlife Service 2002, 2001, 1993). Due to the impacts that changing land use can have on habitat, it is crucial to understand the nature of these changes in order to develop appropriate conservation strategies.

Previous Research

Past work in the watershed included a study of land-use changes from 1970-1994 during a period of industrialization (Ojeda-Revah, et al. 2008). During this time urban expansion was the dominant change in land use, with urban areas expanding over 200km² throughout the watershed. Specifically, areas of chaparral, agriculture, and grasslands were converted to urban areas (Ojeda-Revah, et al. 2008). The expansion of urban uses in the U.S. portion of the watershed was caused by population growth, suburban growth due to the combination of two policies that lowered taxes in rural areas, and road construction, while in Mexico population growth, job creation policies,

and poor infrastructure investment were considered the dominant factors (Ojeda-Revah, et al. 2008). Past work on the characterization of land use in the TRW provides valuable information for understanding how patterns have changed over time (SDSU/COLEF 2005). However, the most recent map of the TRW was based on 1994 data, leaving a gap of 16 years during which land cover and land-use change in the watershed have not been characterized. During this time, some areas of the watershed have been converted to urban uses, while agriculture has expanded in others. Extreme urban development has occurred in parts of the watershed, with projections for large increases in residential development on both sides of the border during coming decades (Vela 2005). This urban growth can have substantial effects on the quality and quantity of surface water and groundwater, while agricultural activities on both the U.S. and Mexican sides of the border are considered contributing factors in the deterioration of habitats and water supplies in the region (Wright 2005a; CBI 2004). The watershed has one of the largest numbers of threatened and endangered species in North America, a trend that has been linked to changes in land use associated with the growing population in the watershed (Ganster 2005).

While it is understood that land-use change in the TRW has continued over the time period since the last mapping, the specifics of the types, locations, and rates of change had not been evaluated. The Las Californias Binational Conservation Initiative (CBI 2004), which relied on pre-1995 data, noted the need for further research to better document and understand processes in the binational region. In particular, it emphasized the need for field-based studies that help to elucidate the conservation values of land in the border region. A current understanding of land-use dynamics in the watershed is necessary to establish a base for understanding how these land uses affect ecosystem and watershed processes within the TRW and estuarine health downstream.

Policies in Effect

The social and economic processes that drive land-use change vary dramatically in border regions such as the TRW (Ojeda, et al. 2008). Therefore, while mapping land uses is an essential step, it is likely that the differences in the way in which those uses are carried out on the U.S. and the Mexican sides of the border are large. Ultimately, policy directed at managing land use in ways that will positively affect watershed health within the region must account for these transborder differences. There has been a call for a shared conservation vision for the border region (CBI 2004). However, part of such a vision must include a shared understanding of land-use patterns and problems and how policy mechanisms might influence those trends. During this period of rapid change, a conservation policy entitled the Multiple Species Conservation Program (MSCP) was implemented in the U.S. portion of the watershed and a new Agrarian Law (Nueva Ley Agraria) was implemented in the Mexican portion. Both policies had the potential to influence land use in several different ways.

New Agrarian Law (Nueva Ley Agraria)

In 1992, the Mexican government amended the constitution, establishing a new agrarian policy that reformed the land ownership system that was established following the Mexican Revolution of 1910 as a response to unequal land ownership in the country. Beginning in 1917, Article 27 of the Mexican Constitution allowed communities or groups of peasants to petition for land that would be granted to the group as an ejido; 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). Ejido land could not be sold or transferred and ejidatarios could not work their land with hired labor nor could they leave their ejido land for a period longer than two years without risking the loss of ejido rights (Johnson 2001). However, with economic decline in Mexico in the 1980s, federal support for the ejido system also declined (Perramond 2008). At the same time, Mexico's agricultural sector had stagnated and, globally, there was an emphasis on market reform and international competitiveness. In 1992, in an effort to modernize the agricultural sector in Mexico and increase agricultural productivity, the government undertook reform of the ejido system by reforming Article 27 of the constitution and introducing the new Agrarian Law (Naylor, et al. 2001; Cornelius and Myhre 1998). The key changes included the end to the government's obligation to continue redistributing land; the ability of ejidatarios to obtain individual certificates to their land by participating in the Programa de Certificación de Derechos Ejidales y Titulación de Solares (PROCEDE); the right of ejidatarios who have their land parcels certified to legally sell, rent, sharecrop, or mortgage individual parceled land, and the right of the ejido to decide by vote to sell common lands; an end to the stipulation that ejidatarios must work their land personally or risk losing it; and the ability of ejidatarios to enter into partnerships with outside investors, including receiving foreign direct investment (Assies 2008; Luers, et al. 2006; Cornelius and Myhre 1998). 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.

Under the reform, obtaining a land certificate and a land title are two separate components of the process. The first step involves having the land parceled by the Instituto Nacional de Estadística y Geografía (INEGI), which sets the legal boundaries for the different parcels of land within the ejido. In the second step, the owners of individual parcels may obtain full title, known as *dominio pleno*, by which the land is converted from ejido to private property (Lewis 2002). According to the Registro Agrario Nacional (RAN), which issues titles for ejido land, 95% of all ejidos in Mexico are currently involved in some phase of the process, although a much smaller percentage have obtained full title (RAN 2009; Pedrin 2009; Assies 2008). Because parcelization and certification are sufficient to provide more secure land tenure and to use the land for collateral, obtaining full title through *dominio pleno* has been seen as a response to opportunities to sell land, particularly in urban areas where land prices are high and *dominio pleno* would allow ejidatarios to sell to urban developers (Assies 2008; Galeana 2004).

There has been a great deal of speculation about how the new Agrarian Law would affect land use and land tenure. Some have suggested that ejido lands would primarily move from the social sector to the private sector (Toledo 1996). Others have suggested that participation in PROCEDE may not necessarily lead to the sale of ejido land, but rather simply result in more secure land tenure (Perramond 2008; Brown 2004). Other concerns over the reshaping of Article 27 include negative impacts on rural and indigenous communities, potential increase in deforestation and conversion of other types of non-forested land, the commercialization of agriculture, and the decline of ejido agriculture and a shift to private farms (Smith, et al. 2009; Vargas, et al. 2008; Luers, et al. 2006; Lewis 2002; Naylor, et al. 2001; Martínez Rodríguez 2001).

Given the potential effects of the new Agrarian Law on land use and land tenure and the fact that 50% of the croplands and 80% of the forests in Mexico fall within the ejido sector (Barton Bray 1996), understanding the relationship between these effects and conservation outcomes becomes increasingly important (Ortega-Huerta and Kral 2007). While some see the reforms as leading to ecological degradation, others see the changes as addressing an existing problem of degradation on ejido lands (Barton Bray 1996; Toledo 1996). While the effects of the new Agrarian Law differ based on regional and individual ejido characteristics (Assies 2008; Luers, et al. 2006), it is of particular importance to understand how these changes impact ecologically sensitive areas, such as the TRW, that are in large part comprised of ejidos (Figure 2).

The Multiple Species Conservation Program

The Endangered Species Act (ESA), passed in 1973 to mandate the protection of endangered and threatened species, is undoubtedly a powerful piece of legislation. One of its shortcomings, however, is its crisis approach, by which action is taken only when a species has already become threatened, and its single-species focus, which underemphasizes the importance of habitat connectivity and the overall geographic range of a species (Reid and Murphy 1995; Rohlf 1999; Carroll, et al. 2010). In addition, over 90% of species listed under the ESA have all or some of their habitat on nonfederal land, which is often privately owned (Government Accounting Office 1994), and enforcing the ESA on private lands presents its own unique problems. Private landowners are often resistant to cooperating with government agencies due to economic or social concerns (Brook et al. 2003), and some argue that the ESA is weakly positioned when up against the interests of private property owners in a court of law (Meltz 1994).

In an effort to deal with some of these private ownership issues, the ESA was amended in 1982 to include habitat conservation plans (HCPs). These plans are designed to provide incentives to private landowners to assist in the preservation of endangered species. However, they are often problematic and, in some cases, can lead to decreased populations. For instance, if a landowner provides for maximum habitat mitigation from the beginning, he or she then has no financial incentive for adaptive management later, as all financial incentives have been received up front. Paradoxically, if a landowner opts for minimum mitigation from the beginning, then

funding will remain for further management but initial mitigation opportunities would be neglected, possibly harming populations (Wilhere 2009).

In 1991, California passed the Natural Communities Conservation Planning Act (NCCP). NCCP does not replace the ESA or HCPs, but rather works in conjunction with them. NCCP does not provide for the listing of species as endangered or threatened; rather, it takes the listings provided under the ESA and translates them into a broad-based ecosystem conservation approach (CBI 2003). NCCP is also not a regulatory piece of legislation; instead it receives its enforcement capabilities from the ESA. The perceived efficacy of NCCP is not so much in its prohibitive power, but rather in its scope, with its shift in focus from single species to entire ecosystems (Reid and Murphy 1995). Unlike the ESA, plans developed under NCCP allow for the protection of critical habitat before an occupying species is listed, giving it the potential to avoid crisis-management and to promote planning that will avert the listing of additional species (Feldman and Jones 2000).

The passing of NCCP in California permitted the state government to enter into planning agreements with local governments and other stakeholders. One such agreement in San Diego County is the MSCP (Figure 3), which came about after six years of planning between local governments, developers, wildlife agencies, and private conservation groups (County of San Diego Department of Planning and Land Use 2010). Under the federal ESA and the state of California's Environmental Quality Act (CEQA), development projects that may cause significant adverse impacts to threatened or endangered species must mitigate these impacts either by modifying the project or by providing long-term conservation and management (White, et al. 2006). Oftentimes mitigation occurs on a project-by-project basis, with little concern for habitat connectivity. Important connecting swaths of land may then be lost to development, resulting in the fragmentation of habitats. MSCP attempts to combat this fragmentation through a system of continuous preserves. This goal is to be achieved through land acquisition by a public land agency or environmental trust, and by conservation easements that dedicate land for open space (County of San Diego Department of Planning and Land Use 2009).

The City of San Diego's MSCP Subarea Plan was officially implemented on July 17, 1997, seeking to conserve 52,012 acres of land (City of San Diego Planning Department 1997). In addition to the City of San Diego's plan, there is a separate plan for the County of San Diego, which was implemented on March 17, 1998 (County of San Diego Department of Planning and Land Use 2009). The habitat conservation goal for the County of San Diego's Subarea plan includes 98,379 acres (County of San Diego Department of Planning and Land Use 1998). Under both plans, lands can be conserved through conservation of existing public lands, land-use restrictions of property through zoning regulations, mitigation banks, as open space previously set aside on private lands for conservation as part of the development process, or through public acquisition of private lands (City of San Diego Planning Department 1997; County of San Diego Department of Planning and Land Use 2009).

Together, the plans propose to conserve over 150,000 acres of land (City of San Diego Planning Department 1997; County of San Diego Department of Planning and Land Use 2009). Of the total planned lands committed to permanent conservation, approximately 33,000 acres are owned by the federal and state governments, approximately 45,000 acres are public lands owned by the city, county, and other local jurisdictions, approximately 14,000 acres consist of negotiated open space on private lands, approximately 20,000 acres are expected to be preserved through future application of zoning regulations, and approximately 38,000 acres are anticipated to be acquired with public funds and by the application of mitigation requirements for development impacts outside the MSCP (City of San Diego Planning Department 1997; County of San Diego Department of Planning and Land Use 1998).

The 1998 Final MSCP Plan describes the program as “an historic accord established to strike a critical balance between development and the protection of valuable habitat,” all while making it “easier and less expensive for most property owners to develop their land” (County of San Diego Department of Planning and Land Use 1998). The 1998 plan strongly links the success of MSCP with economic benefits for the protected areas. With species and habitats being preserved, and with the permitting process for development streamlined to make it less expensive, the county suggests that the San Diego region will become increasingly attractive to business. With increased biodiversity and preservation there can also be increased opportunities for recreation, another important source of revenue (County of San Diego Department of Planning and Land Use 1998). Similar to the new Agrarian Law in Mexico, the goals of MSCP have the potential to alter the landscape in significant ways, and understanding these impacts is important for sensitive area such as the TRW.

RESEARCH OBJECTIVES

Characterize Current Land Cover and Land Use and Evaluate Changes Since 1994

Current land cover and land use were examined and analyzed for differences in the dominant land uses in the U.S. and Mexican portions of the watershed in order to investigate how those uses have changed since they were last mapped (Ojeda et al. 2008). Understanding the direction and extent of that change was one of the objectives of this project.

Characterize Land Ownership within the Watershed

There are large differences in land ownership patterns on each side of the border (CBI 2004), resulting in differences in current and potential land use and land management strategies. A second objective was to create a better and more up-to-date characterization of ownership that can aid in understanding who the land users are and whether changes in land use occur in association with the changes in ownership.

Evaluate the Role of Land-Use Policy Changes

A third objective was to evaluate the role of two dominant policy changes with the potential to influence land use and land cover in the TRW during the study period: MSCP in San Diego County and the Mexican Nueva Ley Agraria. While the initial objective was to focus on two to four case studies on each side of the border, the scope was greatly increased to include all ejidos in the Mexican portion of the watershed in order to provide a more comprehensive understanding. For the U.S. side, the watershed was found to be an artificial boundary that did not coincide well with an evaluation of conservation policy, so San Diego County as a whole was evaluated instead.

RESEARCH METHODOLOGY/APPROACHES

Land Use/Cover Change

In order to address the first research objective land-use/cover maps for 1994 and 2005 were created, and changes in land use between those years and relevant landscape metrics were calculated. The maps for the U.S. portion of the watershed were created using 1994 National Oceanic and Atmospheric Administration color aerial photographs (August 1: 45,000; 10 m spatial resolution), 1994 SPOT 10 m panchromatic imagery, and 2005 Aster images (May, June, and October; 15 m spatial resolution) (Ojeda-Revah et al. 2008; Ojeda-Revah, et al. forthcoming). This study is part of a long-term research program and aims to monitor trends in land-cover and land-use change in the basin from the 1930s to the present (Ojeda 2000, Ojeda, et al. 2008). Therefore, for purposes of comparison, the land-use/cover classifications developed by O'Leary (2005) were adopted, combining categories that were not discernible in the oldest aerial photographs. Aerial photo-interpretation was carried out using standard interpretation keys (tone, texture, pattern, shape, and location of land cover/use polygons as identified on the images). Every interpreted image was manually digitized onto a common-base mosaic (scale 1:50,000) and corrected using control points in a GIS. To ensure geometric consistency, the layers were overlain on a digitally enhanced 1994 SPOT panchromatic image and checked thoroughly for consistency. The accuracy of polygon labeling was tested by verifying at least 20% of the interpreted polygons in the field, and corrections were made when needed. In addition, the following landscape analyses were performed on the basis of patch number and area (Forman 1995): (1) area of each land use/cover; (2) number of patches in each land-use/cover category; (3) rates of change, calculated both for the area and for the number of patches in each land-use/cover category (rate of change calculated as [$C = (\log S_{i2} - \log S_{i1})/ (t_2 - t_1)$], where C is rate of change, S_{i2} is the area of land use/cover or the number of patches at time two, and S_{i1} is the area of the same land use/cover or number of patches at time one, t_2 and t_1 are the years), to estimate expansion or contraction of different land use/cover types and their fragmentation; and (4) land-use/cover transitions from one category to another over the study period. Transitions were evaluated in terms of both geometric and thematic consistency, and errors from tracing of polygon boundaries resulted in only small differences in polygon area (< 0.02% for the whole watershed).

Land-use/cover change was then calculated for each individual ejido in the watershed. Change was calculated in two ways: total area (km^2) and as percent change in relation

to ejido area. In order to compare ejidos, an impact index was constructed and normalized to values between zero and one. Distances from highways and main cities to each ejido were also measured from the center of each ejido. Distance to the cities of Tijuana and Tecate was also calculated following available roads, with terrain roughness being calculated for each ejido as a slope percentage.

Policy Analysis

For the Mexican portion of the watershed, data were gathered from INEGI and RAN on the size of each ejido and the amount of parceled land that is in *dominio pleno*. Data were also gathered from Terra Peninsular, a conservation organization, for comparison. These included qualitative data that categorized land sales in each ejido on a scale from very high to low (Table 1). In-depth, structured interviews were conducted with 55 ejidatarios, representing one to five interviews in each of the 18 ejidos. Eight ejidos were completely urbanized and no ejidatarios could be located, and therefore no interviews were conducted there (Table 2). Particular focus was given to ejidatarios who had lived on the land for at least twenty years and could speak of land-use change over time. A second set of interviews was conducted with policy officials from the following organizations: Procuraduría Agraria, the agency responsible for the land titling process, the Comision de Regulariacion de la Tenencia de la Tierra (CORETT), officials from the conservation organizations Terra Peninsular and Pronatura, which are both very active in the region, and real estate attorneys from Baker & McKenzie, LLC, in Tijuana, a firm that represents Americans who are interested in purchasing land in Mexico. Questions included how ejido land has been historically used and whether there have been significant changes in land use and tenure since the implementation of the new Agrarian Law.

For the U.S. portion of the watershed, eighteen in-depth, semi-structured interviews were conducted with representatives from various stakeholder groups. These groups included policy officials, environmental professionals, nonprofit conservation groups, recreation groups, and groups who have a substantial financial stake in the land. Due to the contention over MSCP in the region, these groups remained anonymous in order to elicit a more open dialogue. Following these interviews, 300 surveys were mailed to members of these groups. These surveys included both open and close-ended questions aimed at gauging attitudes towards MSCP and conservation in general in the region, as well as the effects MSCP has had on land use, cover, and tenure. Out of the 300 surveyed, 136 replied, representing a 45% response rate. In addition, several public meetings were attended. Land ownership data were then obtained for San Diego County from the San Diego County Association of Governments (SANDAG) for 1995 and 2009 in order to understand how land tenure has changed.

PROBLEMS/ISSUES ENCOUNTERED

Watershed as Boundary for U.S. Research

It was difficult to discuss MSCP's effect on the watershed due to the fact that it is not used as a boundary for conservation. The County MSCP is divided in to three areas: North County, South County, and East County. South County is the only area that has been fully implemented. North County will most likely be implemented in the near future. However, East County is currently on hold due to the economic situation and lack of current development pressure. The vast majority of the watershed falls within the East County MSCP with a much smaller portion falling within the South County MSCP (Figure 3). The portion that falls within the South County MSCP is heavily urbanized and was so before the implementation of MSCP (Figure 3). Therefore, it is difficult to attribute land-use/cover change to MSCP directly.

Due to this challenge, the policy aspect of the project was expanded to include all of San Diego County. Ideally, it would have been preferred to expand the land-use/cover change component to the entire county as well, but it was beyond the scope of this project due to various constraints, in particular obtaining imagery for the whole county for the appropriate dates. Nonetheless, MSCP has the potential to affect the TRW in the future, especially after the East County plan is implemented (see Recommendations for Further Research below).

RESEARCH FINDINGS

Land-Use/Cover Change

In the Mexican portion of the watershed for the period between 1994 and 2005 land-use/cover change was dominated by an increase in urban areas and grasslands and a decrease in coastal sage scrub, chaparral, and agriculture (Table 3). Urban areas saw the greatest increase, nearly 75%, while grasslands more than tripled in area. This is significant, as grasslands are a mix of natural and anthropogenic origin and previous research in the TRW has suggested that grasslands constitute an early stage of the process towards urbanization (Ojeda, et al. 2008). Grassland increase and coastal sage scrub decrease between Tijuana and Valle de las Palmas could be indicative of recent clearing and a transition to urban areas in the future. A large urban development project was approved in 2008 in Valle de las Palmas and promoted as an area where Tijuana, Tecate, and Playas de Rosarito could grow (IMPLAN 2008). Urban and grasslands also decreased in number of patches, 6% and 9% respectively, suggesting growth and a merging of patches. Urban area primarily transitioned from grasslands, chaparral, and coastal sage scrub while grasslands primarily transitioned from coastal sage scrub, chaparral, and rain-fed agriculture (Table 4).

Two patterns of urban growth have been seen in the TRW between 1972 and 1994: (1) growth around already-established urban areas in the south and the east along major highways, and (2) increased fragmentation and patchiness among areas of coastal sage scrub and chaparral due to a discontinuous pattern of urban growth (Ojeda, et al. 2008). The first pattern continued between 1994 and 2005, while the second pattern, although present, had slowed. However, the increase and merging of urban areas has formed a near-complete barrier between the coastal sage scrub in the United States

and that in Mexico (Figure 4). In terms of the new Agrarian Law, patchy urban areas that saw substantial growth were located within ejido land.

In order to understand trends of change among individual ejidos, land-use/cover change and change in number of patches were calculated for each ejido (Tables 5 and 6). Based on this information, as well as distance from highways, main cities, and topography, it was found that spatial patterns of impact can be classified into four areas that could represent different responses to the new Agrarian Law (Table 7). The groups are as follows:

- Group One: Categorized by urban growth and grassland decrease. Spatially, there are two areas of group one: one on the periphery of Tijuana and Tecate near the main highways and roads, and one that borders the Tijuana-Mexicali highway east of the watershed

- Group Two: Categorized by increased grasslands but no notable urban growth

- Group Three: Categorized by very slight urban and grassland changes. Although there is not a clearly defined spatial pattern to this group, most of the ejidos are further away from cities (more than 30 km)

- Group Four: Categorized by no significant change in land use/cover and comprised of ejidos in remote areas of the watershed

Overall, most of the urban changes that occurred within ejido land followed a trend of growth close to cities or along main highways and over flat areas. Many authors have identified as main drivers of deforestation accessibility through the construction of highways (Parker 1995; Aguayo, et al. 2007; Geist and Lambin 2002) and proximity to cities, as they provide employment sources and markets for agricultural products and facilitate capital flow (Garcia, et al. 2005). These results suggest that similar drivers are important in land-use change in the TRW.

The Mexican portion of the watershed as a whole underwent some agricultural change during the study period. The new Agrarian Law sought to revitalize the rural economy and increase agricultural production. However, rain-fed agriculture decreased by nearly 65% of its area and saw a loss of 48 patches (Table 3), most transitioning to grasslands (Table 4). This differs from a previous period from 1972 to 1994, when the TRW saw an increase in rain-fed agriculture and a decrease in irrigated agriculture (Ojeda, et al. 2008). This also could be due to higher average annual precipitation in the period from 1989 to 1994 (309 mm) than during the period the period from 2000 to 2005 (254 mm) (NOAA 2006).

As for ecologically sensitive areas, chaparral comprised the largest area in the watershed, followed by coastal sage scrub. Both saw losses during the study period, with coastal sage scrub losing a dramatic 27% of its total area while chaparral lost 7% (Table 3). Both also became significantly more fragmented, with chaparral seeing a

63% increase in number of patches while coastal sage scrub saw a 75% increase in number of patches. These trends are consistent with those observed during the previous period between 1972 and 1994. Most of this lost area was converted to grassland, which is significant because, as discussed above, grasslands are often a precursor to urbanization.

In general, the land use and cover in the U.S. portion of the watershed did not change dramatically (Figure 5). The largest trend was increased urbanization, which is consistent with Ojeda-Revah et al.'s (2008) study and population growth in the area (Table 8). It can be seen how increased urbanization is affecting specific habitats and land covers. Chaparral saw the greatest decrease in land cover, shrinking by about 13 square kilometers. Urbanization accounts for over 65% of this loss, while the rest was converted to grasslands, although grasslands overall saw a decrease in land cover which was again due to increased urbanization (Table 9). Coastal sage scrub, in contrast, has seen very little change, losing only a small amount of land cover and becoming marginally more fragmented. This differed from chaparral, grasslands, and riparian vegetation, which all saw a marked increase in fragmentation.

Land Tenure Change

Changes in land tenure could also be seen during the study period. Twenty-two ejidos in the TRW were in some stage of the certification and titling process (Table 1). Of those, about half contained land that had been converted to *dominio pleno*— which is needed in order to receive full title to the land—although the amount of land that had been parceled in each ejido varied greatly, from as low as 0.2% to 100%. Similar patterns could be seen at the level of ejidatarios. Of those interviewed, 52 had obtained certificate while only three-fifths had received title to the land.

Forty-three of the ejidatarios interviewed said that they agreed with the law and cited reasons such as improved security, the ability to obtain credit, and the ability to enter into partnerships with outside investors. Previous research in northern Baja California conducted shortly after the new Agrarian law was implemented showed that 44% of respondents opposed the law, which is in contrast to those questioned in this study (Whiteford and Bernal 1996). Reasons given included mistrust of the government and lack of information. Eleven interviewees in this study opposed the law over concerns that land would become concentrated, taxes could be imposed, or that land could be taken by the bank if it had been used as collateral for a loan. This fear of property loss has been seen in previous research (Goldring 1996).

The majority of those interviewed (41 respondents) were in support of the ability to obtain certificate to a parcel and thought that it directly benefited them. The most commonly cited reason (19 respondents) was greater land tenure security. As previously discussed, obtaining title to the land is not necessarily an indicator of an intent to rent or sell the land (Perramond 2008). In this study, only five of the ejidatarios responded that it benefited them by giving them the ability to sell their land, although most (39 respondents) agreed with the idea of being able to rent or sell land. Instead,

land tenure security appeared to be the primary reason for participating in PROCEDE. Many also acknowledged negative effects of the new Agrarian Law, such as a decline in ejidatarios working the land, speculation, corruption, lower land prices, and loss of identity or patrimony associated with the loss of ejido land. Others (15 respondents) claimed that the new Agrarian Law had little to no effect, which is likely a reflection of illegal land sales occurring around Tijuana before the reform.

Two groups in particular were in favor of the ability to sell land: posesionarios, or people who use ejido land but have not been recognized as ejidatarios, and avecindados, or people who reside on the ejido but do not have any ejidal rights (Table 10). The new Agrarian Law has the potential to provide these groups with a way to purchase land, which is especially relevant in the municipio of Tijuana where there are 3,500 posesionarios (Table10). This, in combination with proximity to urban areas, may provide additional demand for land. Although this study suggests that the primary driver of participation in PROCEDE is not land sales, ejido land belonging to 15 ejidos in the TRW, totaling 59 km^2 has been sold during the study period (INEGI 2009). Most was sold near Tecate and to people outside the ejidos, however, there was some ejido land purchased by avencindados or posesionarios (INEGI 2009).

In the U.S. portion of the watershed, where one of the tenets of MSCP is land acquisition, public land tenure for the county between 1995 and 2009 was examined (Table 11). Public land included all city, county, state, and federally owned land as well as sanitation, school, and water districts and the Port of San Diego. Overall, public land ownership only increased by 16.116 km^2, which represents an increase of 0.26%. The more significant change was in land tenure. Land owned by the Bureau of Land Management (BLM) decreased by 322.492 km^2 which represented almost 45% of their land in San Diego County. The County of San Diego, on the other hand, gained over 141 km^2, representing a 57% increase. A large number of survey respondents and interviewees mentioned the county acquiring large amounts of private land, a perception that may be false given these changes in land tenure.

Those who participated in the written survey were able to express opinions regarding conservation in general, as well as MSCP in particular. Participants were asked if they believed that environmental conservation was important and should be a priority. Sixty three percent replied “absolutely”, while another 27% replied “somewhat yes.” There was some disagreement over the level of conservation needed, with 53% calling for increased effort while 35% responded that the current level of conservation in San Diego County was adequate. Most (67%) also believed that trade-offs between economic opportunities and conservation needs should be evaluated on a case-by-case basis, with less (25%) holding the view that conservation should always be a priority. Surprisingly few (8%) believed that economic opportunities should always take priority. These results display a generally positive attitude towards conservation in the county.

During interviews many had speculated on the overall public awareness of MSCP. However, surveys indicated that familiarity with MSCP was high, with the majority of respondents (106) having heard of it. This high number could be a product of targeting

specific groups who are active in the county. Of the 106 who had heard of MSCP there was much variation in levels of familiarity and perceived level of impact the program has had. An overwhelming majority (88%) believed that conservation is best accomplished through a mix of public policy and education. Very few believed it should be left entirely up to regulation or private citizens. Several participants viewed recreational access to the land as a way to increase public education and stewardship, with 28% replying that land purchased with public money should always include public access while, 69% believing that public access should be given when it is compatible with conservation goals.

CONCLUSIONS

For the Mexican portion of the watershed, the findings of this project support previous predictions regarding the continuing expansion of urban growth from existing urban areas (Ojeda, et al. 2008). Tijuana has continued to grow to the south and the east, converting land that was previously grassland, chaparral, and coastal sage scrub. A small amount of agricultural land was also urbanized, which shows similarities with other regions in which urban growth consumes surrounding agricultural land (Seto and Fragkias 2005). Interviews conducted suggest the same pattern, with the new ability to sell land putting agricultural land at risk for urbanization. In the TRW, sensitive natural ecosystems are also facing the same threat. Mapping also indicates that grasslands can be a precursor to urbanization, with urban land having expanded in areas that were grasslands in 1994 and grasslands expanding into areas that had been mostly coastal sage scrub in 1994 (Figure 4). This suggests that much of the area surrounding Tijuana that was converted to grasslands between 1994 and 2005 will likely convert to urban areas in the future.

A trend of increased physical fragmentation of the natural landscape is also present and of concern. This is especially true regarding the loss of coastal sage scrub, which is a unique binational habitat, home to numerous threatened and endangered species as well as a host of endemic plants and animals (Reimann and Ezcurra 2005; Davis et al. 1994). Estimates regarding coastal sage scrub in California indicate that 40%–66% has been lost and that potentially only 15% is in good health (Klopatek et al 1979; Westman 1987; O'Leary et al. 1992). This landscape has also become severely fragmented. This research shows that while this is now happening at a slower pace in the U.S. portion of the watershed, there are now only remnants of coastal sage scrub left that are providing some of the last remaining habitat for endangered species (Syphard et al. 2005). The same urban growth patterns that led to this dire situation in the United States are now occurring in Mexico with less government protection. Potential outcomes of this trend include loss of vertebrate species within a few decades, disappearance of plant species, decreased viability of bird and mammal populations, and isolation of reptiles and small mammals by roads or urbanization (Beier 1993; Alberts et al. 1993; Soulé et al. 1992; Quinn 1990).

This study contradicts the expectation that land closest to urban areas is the most likely to obtain full title (Galeana 2004), and studies done of other ejidos such as in Oaxaca,

where most full privatization occurred adjacent to cities where land values were higher (Brown 2004). While obtaining full title can be seen as an intent to sell (Assies 2008), this appears not to be the case in the TRW, where primary motivation to obtain full title is to secure land tenure. This is not to say that no ejido land is changing hands in the watershed. High land sales in the municipality of Tecate suggest continued urban growth and a decrease in area with an increase in fragmentation for chaparral. The proximity to the U.S. border of these growing urban zones must also be considered, as Whiteford and Bernal (1996) noted in their Mexicali Valley study, that the new Agrarian Law is "…only part of a larger set of changes transforming the region and Mexico in general…Being a border region magnifies some of the forces of change and mitigates others."

This study also illustrates that policies can have effects that are counter to their original goals. Although the primary purpose of the new Agrarian Law was to revitalize the agricultural sector, in the case of the TRW more land has moved out of the agricultural sector than has moved into it. Instead, the new Agrarian Law appears to be facilitating urbanization.

While it is too early to tell if MSCP is accomplishing its intended goals, results from this study suggest that MSCP's immediate impacts are often misunderstood, as shown by the perception that the county is acquiring large tracts of private land. It is clear, however, that attitudes towards conservation in the county are generally positive and most people believe that conservation should include public education. This suggests a window of opportunity for policymakers and environmental professionals to increase public support for MSCP and conservation in general in the county. This is not to say that all participants were in favor of MSCP. Some believed it does not do enough to secure ecosystem preservation while others saw it as another unnecessary impediment to development. Most, however, were somewhere in the middle, citing the good and the bad of the program.

RECOMMENDATIONS FOR FURTHER RESEARCH

While the new Agrarian Law has affected land-use/cover change and land tenure change in the TRW, there are other trends that deserve future research. These include the growing importance in the watershed of active conservation organizations, and the relatively new practice of selling conservation easements. These trends have the potential to counter current trends in native vegetation fragmentation.

While the increase in urbanization is not surprising on the U.S. side of the border, given previous research (Ojeda-Revah et al. 2008) and population growth in the area, the loss of chaparral in relation to urbanization is of import. Out of all of the habitats converted for urbanization, chaparral accounts for 40%. Given that this rare plant community is home to many endangered and threatened species (O'Leary 2005), this loss is of concern. Further research is needed to understand how this change in land cover is affecting those species.

Continued research is also needed to understand changes in the U.S. portion of the watershed, and San Diego County in general, since 2005. Given the current economic climate, it can be expected that the rate of urbanization has slowed, but it is unclear exactly how the landscape is changing today, especially in relation to grassland and chaparral. Since the majority of the watershed falls under the East County portion of MSCP, which has yet to be enacted, it is not possible to ascertain how MSCP has affected land cover in the watershed between 1994 and 2005. It will be interesting to see how MSCP will affect the watershed once the East County portion is enacted. Also, given the misconception that large amounts of private land are being purchased, further research is needed to see how land use and cover are changing in the entire county, especially in those areas where MSCP has been in effect for some time.

Research is also needed to examine ways in which public knowledge could be effectively increased in order to ease tension among stakeholder groups. There were stakeholder groups, such as developers, who either chose not to participate in this study or simply did not reply to requests for interviews. More research is needed among these groups in order to form a more complete picture of attitudes in the county.

RESEARCH BENEFITS

This research has given those residing or active in the TRW an opportunity to express their ideas and opinions about important policies that have the potential to affect their everyday lives as well as drastically alter the landscape. This project also provided a base of current, up-to-date information for decision-makers involved in land-use planning in the watershed. The information generated can be useful to government agencies involved in land-use planning in the watershed, as well as to nongovernmental organizations working in the area on land use and conservation. Policy officials in Mexico and the United States have already expressed interest in the data produced by this project.

This project has also lead to a number of paper presentations at conferences by both the project PIs and graduate students whose thesis research has been supported by the project, as listed below:

- Atkinson EE, Farley KA, Ojeda-Revah L, Eaton R. Understanding the links between land-use change and policy: an analysis of the Tijuana River Watershed. Annual Meeting of the Association of American Geographers, Las Vegas, NV, 23 March 2009

- Atkinson EE, Farley KA, Ojeda-Revah L, Eaton-González BR. Linking land use and policy: San Diego's Multiple Species Conservation Program (MSCP). Annual Meeting of the Association of Pacific Coast Geographers, San Diego, CA, 2 October 2009

- Ojeda-Revah L, Eaton-González BR, Farley KA, Atkinson EE. Land-use change in the Tijuana River Watershed: one basin, two patterns. Annual Meeting of the Association of Pacific Coast Geographers, San Diego, CA, 2 October 2009

- Eaton-González BR, Ojeda-Revah L, Atkinson EE, Farley KA. Impacts of the change in the Ley Agraria on the development of ejidos within the Tijuana River Watershed. Annual Meeting of the Association of Pacific Coast Geographers, San Diego, CA, 2 October 2009

- Farley, KA, Ojeda-Revah L. Land use change in the ejidos of the Tijuana River Watershed. Southwest Consortium for Environmental Research and Policy Technical Conference, Tempe, AZ, 24 January 2011

- Rossiter, JS. Environmental Perceptions Regarding the Multiple Species Conservation Program. San Diego State University Student Research Symposium, San Diego, CA, 4 March 2011

- Rossiter, JS. Environmental Perceptions Regarding the Multiple Species Conservation Program. Annual Meeting of the Association of American Geographers, Seattle, WA, 13 April 2011

In addition, this research has resulted in one journal article that is currently under review and two that are under preparation:

- Farley KA, Ojeda-Revah L, Atkinson EE, Eaton-González BR. Changes in land use, land tenure, and landscape fragmentation in the Tijuana River Watershed following the reform of the ejido sector. In review (Land Use Policy)

- Ojeda-Revah L, Farley KA, Eaton-González BR, Atkinson EE. Changing patterns of land use and tenure within the ejidos of the Tijuana River Watershed. In preparation

- Rossiter JS, Farley KA, Ojeda-Revah L. Public or private?: Negotiating conservation space in San Diego County. In preparation

This project also made a significant contribution to the education of several Master's students in the Department of Geography at San Diego State University. One Master's student, Emily Atkinson, completed her thesis with support from this project, earned an M.Sc. degree, and is now a Ph.D. student at the University of Wisconsin-Madison. A second master's student is currently analyzing data for her thesis and will defend and graduate in spring 2011. In addition, substantial cross-border collaboration occurred in the course of this project, including conducting joint field research and the training of a Mexican research assistant who assisted in conducting interviews in the Mexican portion of the watershed.

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APPENDIX

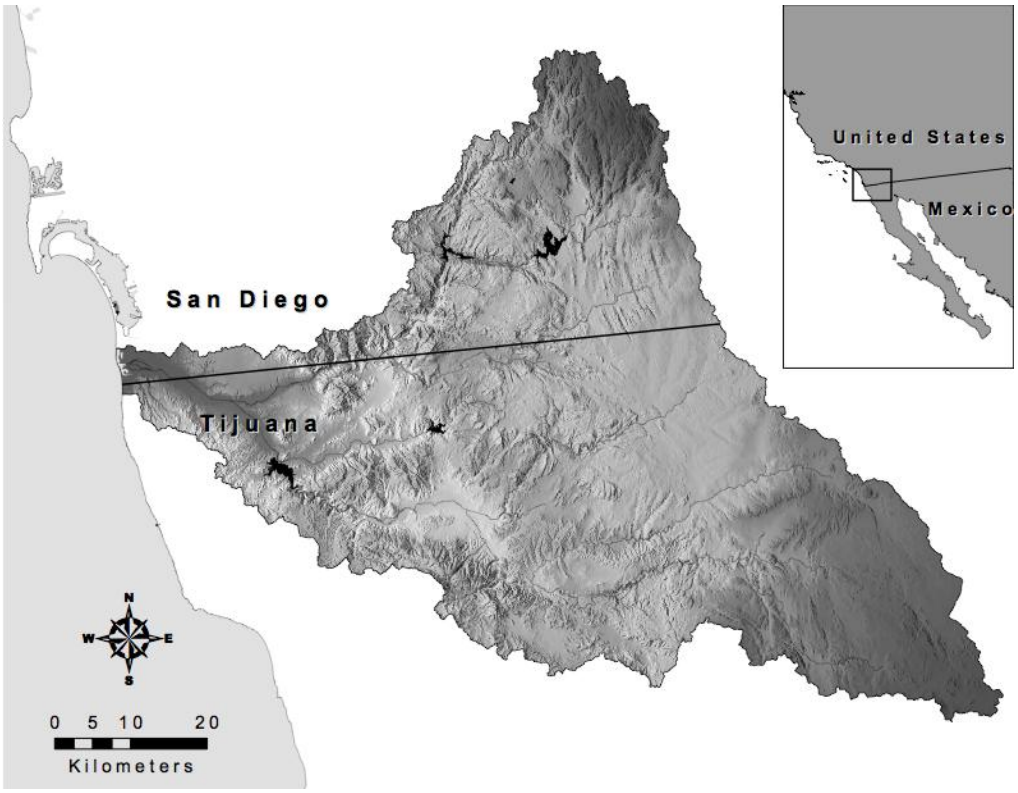

Figure 1. Map of the Tijuana River Watershed, Including the Cities of San Diego, CA, USA and Tijuana, Baja California, Mexico

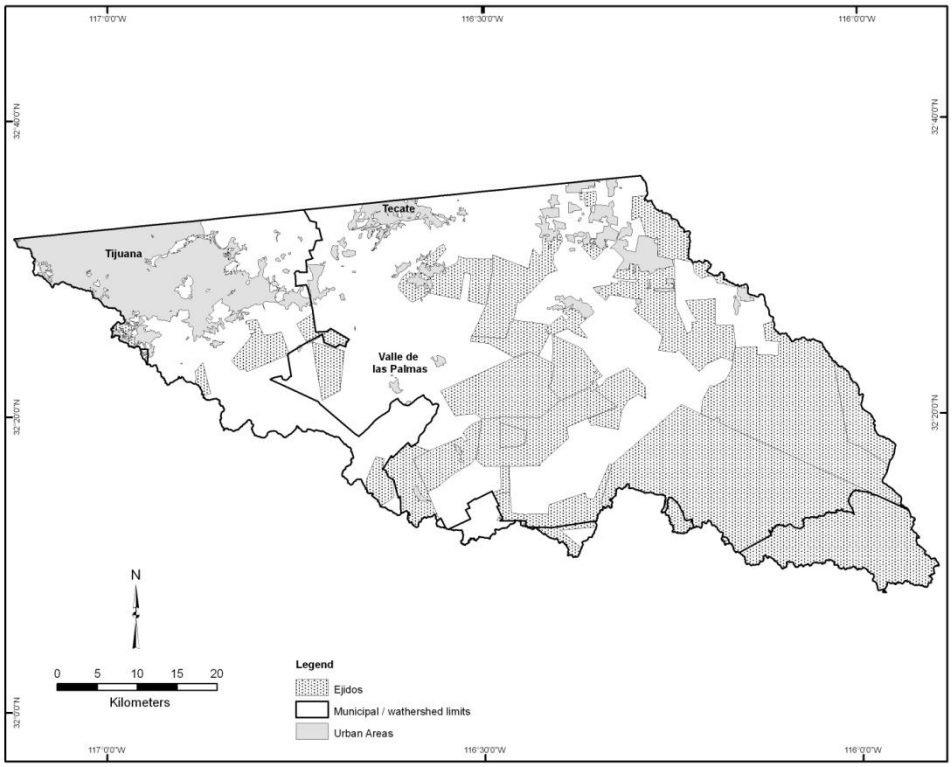

Figure 2. Map of the Area Covered by Ejidos in the Tijuana River Watershed Created with Data Obtained from Registro Agrario Nacional (RAN 2010)

Table 1. Total land area of each ejido within the Tijuana River Watershed (km^2), area of each ejido within the watershed boundaries (km^2), amount of parceled land in each ejido (in km^2, and as a percentage of total land), and land in *dominio pleno* in each ejido (km^2, and as a percentage of total land). These data were obtained from the Registro Agrario Nacional (RAN 2009). Land sales ranking is a qualitative ranking of the amount of land sales in the ejido (Very High, High, Medium, Low), based on observation by the organization Terra Peninsular. *These ejidos are located partially within the Tijuana River Watershed. Note: Two ejidos, Maclovio Rojas and Tampico, appear in the RAN list, but contain no data, so are not included in this list; Valle de las Palmas was also excluded because it is a colonia rather than an ejido.

Municipio	Ejido Name	Total Land	Area within the Watershed	Parceled Land		Land in *Dominio Pleno*		Land Sales Rankings
		km²	km²	km²	%	km²	%	
Tecate	Baja California	101	101	39	38	17	17	Very High
Tecate	Carmen Serdán*	62	48	0	0	0	0	Low
Tijuana	Chilpancingo	4	4	0	9	2	37	Very High
Tecate	El Encinal	58	58	13	22	0	0	Very High
Tijuana	El Ojo de Agua	45	45	0	0	0	0	
Tecate	General Felipe Ángeles	5	5	4	87	0	0	
Tijuana	General Francisco Villa	19	19	1	5	2	12	Very High
Tecate	Guadalajara II	32	32	22	66	13	41	Low
Tecate	Gustavo Aubanel Vallejo*	352	36	26	7	21	6	Medium
Tecate	Héroes del Desierto	38	38	17	46	0	0	Low
Ensenada	Ignacio Zaragoza	105	105	5	5	0	0	
Tecate	Jacume*	250	36	21	9	8	3	Medium
Tijuana	Javier Rojo Gomez	1	1	1	100	1	100	Very High
Tecate	José María Pino Suárez*	265	231	2	1	0	0	Low
Tecate	Juntas de Nejí	106	106	0	0	0	0	Low

Table 1 Continuted.

Playas de Rosarito	Lázaro Cárdenas*	51	4	35	69	4	7	
Tijuana	Matamoros	12	12	6	47	4	35	Very High
Tijuana	Mesa Redonda*	15	5	11	73	0	0	Very High
Tecate	Mi Ranchito	4	4	4	100	2	40	High
Tecate	Nueva Colonia Hindú	66	66	56	85	0	0	High
Tecate	Nuevo Porvenir	10	10	5	51	2	24	
Playas de Rosarito	Plan Libertador*	32	2	21	66	14	45	
Ensenada	San Marcos *	54	46	9	17	0	0	
Ensenada	Sierra de Juárez*	1,730	452	1369	79	309	18	High
TOTAL		**3,415**	**1,465**	**1,667**	**49**	**399**	**12**	

Table 2. Number of Interviews per Ejido (interviews were not conducted in ejidos that have been completely urbanized since ejidatarios could no longer be located)

Municipality	**Ejido**	**Number of interviews**
Tecate	Baja California	2
Tecate	Carmen Cerdan	4
Tijuana	Chilpancingo	0 (urbanized)
Tecate	El Encinal	3
Tijuana	El Ojo de Agua	1
Tecate	General Felipe Angeles	3
Tijuana	General Francisco Villa	0 (urbanized)
Tecate	Guadalajara II	2
Tecate	Gustavo Aubanel Vallejo	5
Tecate	Héroes del Desierto	4
Ensenada	Ignacio Zaragoza	4
Tecate	Jacume	4
Tijuana	Javier Rojo Gonez	0 (urbanized)
Tecate	José María Pino Suárez	4
Tecate	Juntas del Neji	3
Playas de Rosarito	Lazaro Cardenas	0 (urbanized)
Tijuana	Maclovio Rojas	0 (urbanized)
Tijuana	Matamoros	0 (urbanized)
Tijuana	Mesa Redonda	2
Tecate	Mi Ranchito	2
Tecate	Nueva Colonia Hindu	4

Table 2 Continued.

Tecate	Nuevo Porvenir	1
Playas de Rosarito	Plan Libertador	0 (urbanized)
Tecate	San Marcos	2
Tecate	Sierra de Juárez	4
Tijuana	Tampico	0 (urbanized)
Tecate	Valle de las Palmas	1 (colonia)
TOTAL		**55**

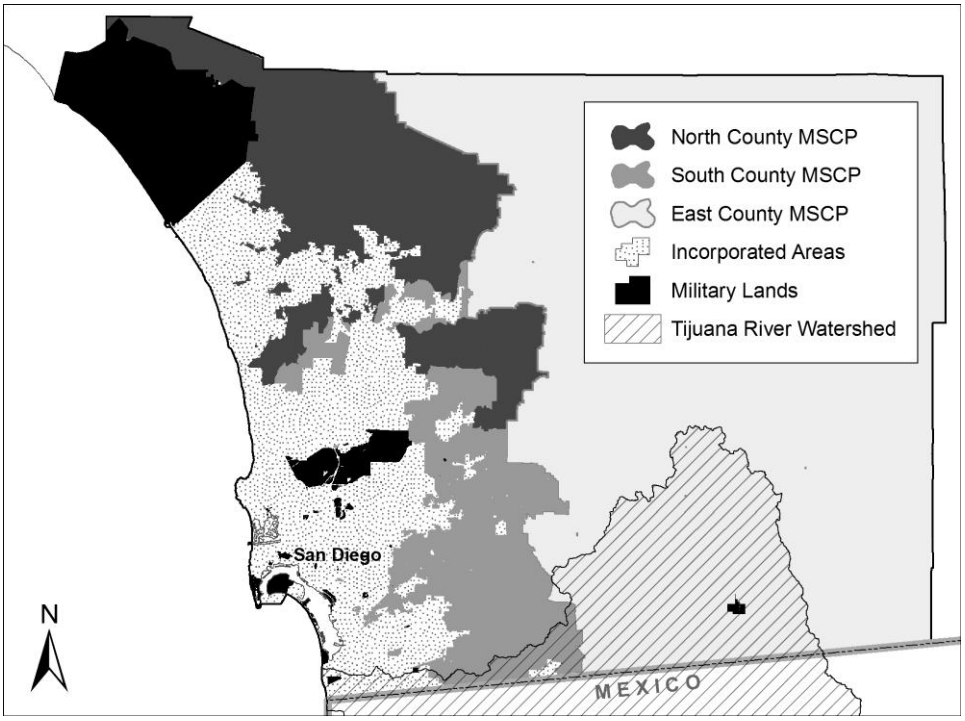

Figure 3. Map of the Area Covered by the Multiple Species Conservation Program and its Relation to the Tijuana River Watershed (data obtained from the San Diego Association of Governments (SANDAG))

Table 3. Changes in Land-Use and Land Cover Change in the Mexican Portion of the Tijuana River Watershed between 1994 and 2005

Land cover /use	1994		2005		1994-2005		
	Area (km^2)	Number of patches	Area (km^2)	Number of patches	Change in land cover/use, in km^2 (and change in # of patches)	Rate of change, area	Rate of change, patches
Juniper scrub	228.52	81	226.11	84	-2.41 (+3)	-0.10	0.33
Chaparral	1,467.96	57	1,360.55	93	-107.41 (+36)	-0.69	4.45
Coastal sage scrub	950.48	47	690.13	82	-260.35 (+35)	-2.91	5.06
Riparian vegetation	79.86	590	76.21	550	-3.65 (-40)	-0.43	-0.64
Mountain meadows	31.14	84	30.35	74	-0. 79 (-10)	-0.23	-1.15
Grassland	132.39	414	401.30	377	269.91(-37)	10.08	-0.85
Irrigated agriculture	34.22	53	33.09	43	-1.13 (-10)	-0.30	-1.90
Rain-fed agriculture	87.25	121	31.12	73	-56.13 (-48)	-9.37	-4.59
Urban	221.09	86	387.32	81	166.23 (-5)	5.10	-0.54
Reservoirs	7.39	2	4.08	3	-3.30 (+1)	-5.39	3.69

Table 4. Land Cover/Use Transitions (area converted from one land use/cover in 1994 to another in 2005, in km^2) in the Mexican Portion of the Tijuana River Watershed (1994-2005)

		2005									
	Land cover/use	**Juniper Scrub**	**Chaparral**	**Coastal Sage Scrub**	**Riparian vegetation**	**Mountain Meadows**	**Grasslands**	**Irrigated Agriculture**	**Rain-fed Agriculture**	**Urban**	**Reservoirs**
1994	**Juniper Scrub**	225.63	0.06	-	0.04	0.54	0.29	0.04	0.01	1.90	-
	Chaparral	0.33	1,359.31	0.02	0.67	0.15	59.46	0.06	0.08	47.85	-
	Coastal Sage Scrub	-	0.04	689.28	0.31	-	212.30	0.27	0.02	47.99	0.28
	Riparian vegetation	0.00	0.20	0.13	73.75	0.00	0.51	0.75	0.18	4.34	-
	Mountain Meadows	0.11	0.27	-	0.00	29.35	0.34	0.08	0.06	0.93	-
	Grasslands	0.03	0.36	0.04	0.08	0.26	73.01	2.33	0.05	56.21	-
	Irrigated Agriculture	0.00	0.06	0.07	0.26	0.04	4.69	22.25	2.79	4.05	-
	Rain-fed Agriculture	0.00	0.23	0.04	1.07	0.00	47.15	7.26	27.94	3.57	-
	Urban	-	0.02	0.46	0.02	0.01	0.18	0.05	0.00	220.28	0.05
	Reservoirs	-	-	0.08	0.02	-	3.38	-	-	0.16	3.76

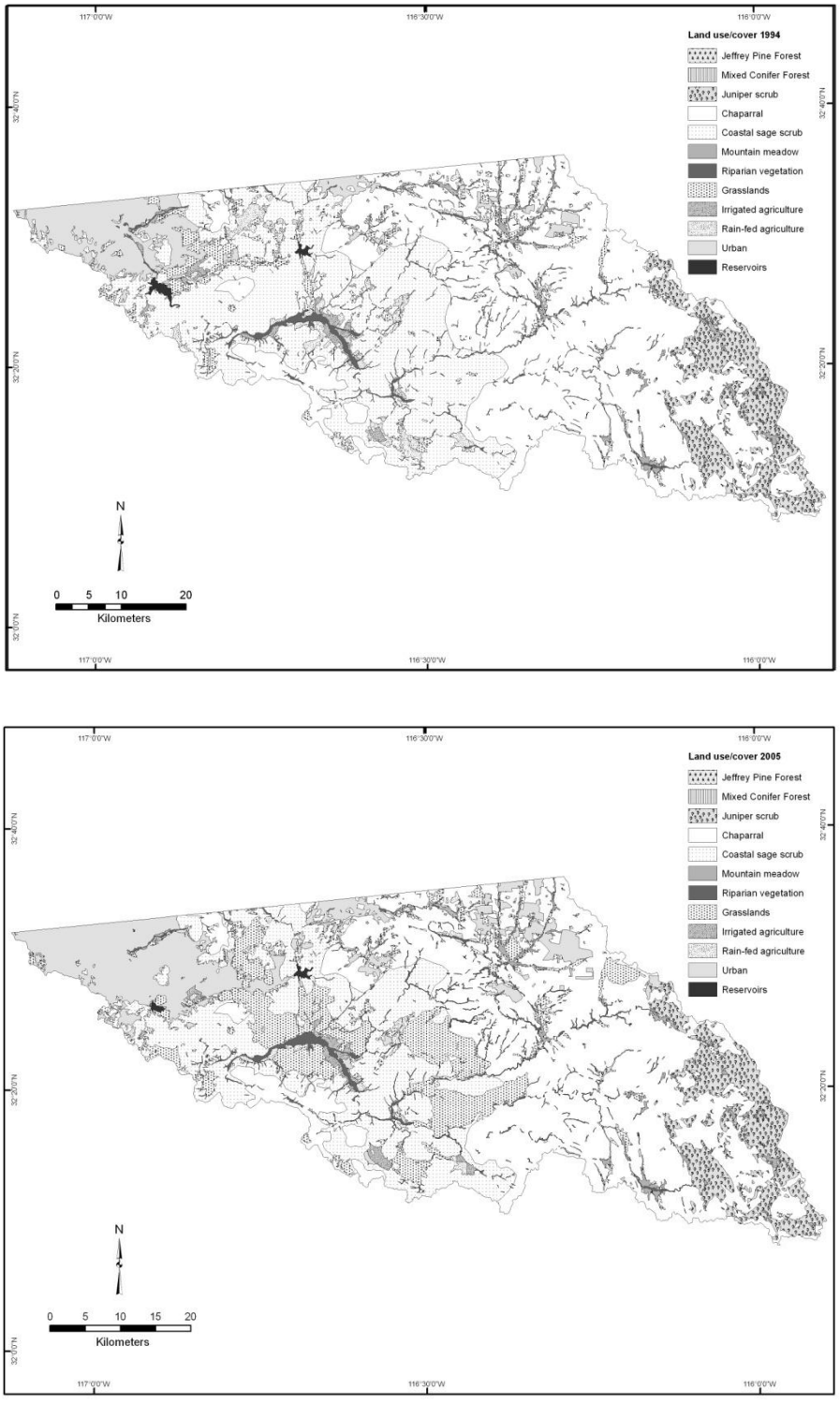

Figure 4. Maps of Land Use/Cover in the Mexican portion of the Watershed in 1994, and Land Use/Cover in the Watershed in 2005

Table 5. Area in km^2 per Land Use/Cover and Ejido in 1994 and 2005

Ejido	Juniperus scrub		Chaparral		Coastal sage scrub		Mountain meadows		Riparian vegetation		Irrigation agriculture		Rain fed agriculture		Grassland		Urban	
	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005
Altiplano					3.27	0.68			0.24	0.15	0.01	0.00	0.60	0.53	0.79	0.08	0.32	3.79
Aubanel	31.39	31.35	3.25	3.25			1.13	1.18							0.19	0.19		
Baja California			93.35	86.04					2.02	2.08			0.22	0.00	4.55	3.15	2.66	10.60
Carmen Serdán			18.60	18.60	25.47	24.74			0.42	0.42	0.49	1.79	1.30	0.00	0.89	1.10	0.79	1.32
Colonia Nueva Hindú I			25.98	22.20	17.01	17.01			1.00	0.87	0.14	0.00			1.32	1.02	1.40	5.74
Colonia Nueva Hindú II			16.94	15.73	5.72	1.38			0.74	1.14					0.49	5.63		
El Encinal			35.62	35.04	16.87	13.65			1.97	1.97			0.64	0.00	2.05	5.86	0.53	1.17
El Mezquital					0.11	0.11							0.08	0.08				
El Pedregal											0.22	0.15			0.25	0.07	0.12	0.38
Felipe Ángeles I			2.46	1.92			0.04	0.04							0.93	0.84	0.00	0.60
Felipe Ángeles II			1.04	0.42											0.04	0.02	0.27	0.91
Francisco Villa															0.84	0.00	0.20	1.04
Guadalajara II			30.46	29.72					1.53	1.50			0.41	0.17	0.00	0.81	0.04	0.23
Héroes del Desierto I			0.23	0.23	27.53	26.73			2.09	2.08	0.70	1.54	2.56	0.34	0.00	1.95	0.39	0.63
Héroes del Desierto II					4.08	3.58			0.16	0.16					0.00	0.50		
Ignacio Zaragoza			21.62	13.30	51.34	17.56			1.22	1.13					0.40	42.58		
Jacumé			36.23	34.44			0.14	0.12	0.10	0.10					0.67	2.14	0.05	0.39
Javier Rojo Gómez					10.62	3.19			0.11	0.11					0.25	7.68	0.00	1.45
La Joya			3.13	3.13	19.67	19.22			0.10	0.10					0.68	1.13		
Lázaro Cárdenas					2.17	1.95			0.00	0.00					1.38	0.56	0.41	1.35
Mesa Redonda					1.95	1.70			0.02	0.02			2.39	0.00	0.00	2.64		
Mi Ranchito I			0.86	0.13											0.20	0.06	0.00	0.86
Mi Ranchito II			1.83	1.83			0.16	0.16	0.01	0.01					0.96	0.96		
Neji I			24.01	22.95					0.53	0.53			0.02	0.02	0.00	1.09		
Neji II			26.47	5.88	51.98	36.18			2.67	2.53					0.47	36.99		
Nuevo Porvanir			9.09	8.81					0.43	0.47					0.04	0.04	0.27	0.52
Ojo de Agua					14.23	0.08			3.25	3.29			1.60	1.19	0.12	14.63		
Pino Suarez	84.90	84.72	135.89	135.51			4.85	5.11	0.79	0.86	2.77	0.26	0.17	0.16	2.07	4.82		
Plan Libertador					0.66	0.62									1.19	0.43	0.24	1.03
Real de San Francisco			0.01	0.01	0.48	0.45									1.09	0.00	0.16	1.27
Resta Zaragoza					7.68	0.00			0.06	0.06					0.25	7.94		
San Marcos			15.20	15.20	30.13	29.93			0.58	0.78			0.05	0.00	0.25	0.00		
Sierra de Juárez	97.00	96.76	336.45	336.45			12.28	12.47	3.75	3.77	0.01	0.00	0.12	0.12	3.84	3.84	0.03	2.33
Villa Fontana					0.01	0.00									2.51	0.00	0.07	2.59
Total	**213.29**	**212.83**	**838.71**	**790.78**	**290.99**	**198.77**	**18.60**	**19.09**	**23.77**	**24.14**	**4.34**	**3.73**	**10.18**	**2.61**	**28.71**	**148.79**	**7.95**	**38.20**

Table 6. Number of Patches per Land Use/Cover and Ejido in 1994 and 2005

Ejido	Juniperus scrub		Chaparral		Coastal sage scrub		Mountain meadows		Riparian vegetation		Irrigation agriculture		Rain fed agriculture		Grassland		Urban	
	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005	1994	2005
Altiplano					1	6			5	1	2		1	1	1	2	1	1
Aubanel	2	2	1	1			3	3							4	4		
Baja California			4	4					20	19			2		9	7	2	8
Carmen Serdán			3	3	2	3			8	7	2	2	2		5	4	1	1
Colonia Nueva Hindú I			3	5	1	1			18	16	1				9	7	3	3
Colonia Nueva Hindú II			1	4	1	3			9	8					3	4		
El Encinal			2	4	1	4			22	21			2		8	7	2	3
El Mezquital					1	1							1	1				
El Pedregal									1	1	1	1			1	1	1	1
Felipe Ángeles I			3	4			1	1						1	6	4		2
Felipe Ángeles II			1	2			1								1	1	1	2
Francisco Villa															1		1	1
Guadalajara II			4	1					21	17			5	4		2	1	2
Héroes del Desierto I			1	1	3	3			16	16	3	2	7	1		5	1	1
Héroes del Desierto II					1	1			2	3						2		
Ignacio Zaragoza			3	1	2	2			17	13					2	1		
Jacumé			2	1			2	2	1	1					8	8	2	2
Javier Rojo Gómez					1	2			1	1					3	1		1
La Joya			1	1	1	1			7	2					2	3		
Lázaro Cárdenas					1	3									7	1	2	6
Mesa Redonda					2	2			2	2			1			1		
Mi Ranchito I			1	3											2	2		1
Mi Ranchito II			2	4			1	1	1	1					2	2		1
Neji I			1	1					13	13			1	1		1		
Neji II			3	2	2	3			35	34					6	2		
Nuevo Porvanir			1	1					7	7					3	3	1	1
Ojo de Agua					1	2			6	6			4	2	2	2		
Pino Suarez	20	20	3	3			25	21	7	7	8	4	2	3	33	29		
Plan Libertador					1	1									1	6	1	7
Real de San Francisco			1	1	1	1									1		2	1
Resta Zaragoza					1				1	1					2	1		
San Marcos			1	1	1	1			14	15			1		2			
Sierra de Juárez	58	60	12	12			32	26	20	20	1		1	1	21	23	1	1
Villa Fontana					1	1									1		1	1
Total	80	82	54	60	26	41	65	54	254	232	18	9	30	15	146	136	24	47

Table 7. Ejido Groups Based on Urban and Grassland Change, with Distances to Cities and Slopes less than 20%

				Urban change		Grassland change		Access (distance to cities km)								Slope <20%	
	ID	Ejidos LUCC 1994-2005	Area km²	(km²)	relative to ejido (%)	(km²)	relative to ejido (%)	1994	dirt 94	paved 94	2005	dirt 05	paved 05	nearest highway	nearest city	km²	relative to ejido (%)
Group 1	34	Villafontana*	2.59	2.51	97.01	-2.51	-96.90	0.75	1.05	0.75	0.00	0.00	0.00	Bldv. 2000	Tijuana	2.59	100.00
	22	Mi Ranchito I	1.06	0.86	81.67	-0.13	-12.65	35.50	8.89	26.61	27.16	8.89	18.27	Tijuana-Mexicali	Tecate	1.04	99.32
	12	Francisco Villa*	1.04	0.84	81.11	-0.84	-81.11	0.94	1.56	0.94	0.00	0.00	0.00	Bldv. 2000	Tijuana	1.04	100.00
	30	Real de San Francisco*	1.73	1.12	64.60	-1.09	-62.80	1.28	1.01	1.28	0.00	0.00	0.00	Bldv. 2000	Tijuana	1.39	80.70
	1	Altiplano*	5.23	3.47	63.89	-0.70	-19.21	2.35	1.74	0.61	0.00	0.00	0.00	Bldv. 2000	Tijuana	5.17	98.75
	11	Felipe Angeles II	1.36	0.65	47.61	-0.02	-1.81	27.16	0.55	26.61	18.82	0.55	18.27	Tijuana-Mexicali	Tecate	1.09	100.00
	9	El Pedregal*	0.60	0.26	43.03	-0.18	-30.31	0.19	0.68	0.19	0.00	0.00	0.00	Tijuana- Tecate	Tijuana	0.60	100.00
	29	Plan Libertador	2.09	0.80	38.07	-0.76	-36.29	0.42	3.40	0.42	0.00	0.00	0.00	Tijuana-Rosarito	Tijuana	1.95	93.43
	20	Lazaro Cardenas	3.96	1.04	26.25	-0.82	-20.66	1.78	7.33	1.78	0.00	0.00	0.00	Bldv. 2000	Tijuana	3.59	90.52
	10	Felipe Angeles I	3.43	0.60	17.45	-0.09	-2.62	28.52	1.91	26.61	20.18	1.91	18.27	Tijuana-Mexicali	Tecate	3.43	100.00
	5	Colonia Nueva Hindu I	46.84	4.34	9.27	-0.29	-0.63	13.04	2.44	10.60	11.41	2.44	8.97	Tecate-Ensenada	Tecate	36.81	78.57
	3	Baja California	101.88	7.93	7.78	-0.47	-0.45	43.44	7.19	36.24	35.09	7.19	27.90	Tijuana-Mexicali	Tecate	98.32	96.51
Group 2	15	Heroes del Desierto II	4.24	0.00	0.00	0.50	11.79	60.02	9.96	50.06	58.39	9.96	50.06	Tecate-Ensenada	Tecate	3.15	74.25
	6	Colonia Nueva Hindu II	23.88	0.00	0.00	5.14	21.55	49.77	18.20	31.56	48.13	18.20	29.93	Tecate-Ensenada	Tecate	20.21	84.63
	25	Neji II	81.59	0.00	0.00	36.52	44.77	44.19	12.63	31.56	42.56	12.63	29.93	Tecate-Ensenada	Tecate	68.30	83.71
	16	Ignacio Zaragoza	74.57	0.00	0.00	42.18	56.56	58.50	14.75	43.75	56.87	14.75	43.75	Tecate-Ensenada	Tecate	58.69	78.69
	21	Mesa Redonda	4.36	0.00	0.00	2.64	60.59	17.48	8.74	17.48	10.51	8.74	1.77	Bldv. 2000	Tijuana	4.15	95.10
	18	Javier Rojo Gomez	10.98	0.00	0.00	7.43	67.70	24.22	3.37	20.85	7.90	3.37	4.53	Tijuana-Valle de las Palmas	Tijuana	3.94	35.91
	27	Ojo de Agua	19.19	0.00	0.00	14.52	75.65	26.29	5.44	20.85	9.97	5.44	4.53	Tijuana-Valle de las Palmas	Tijuana	17.47	91.01
	31	Resta Zaragoza	8.00	0.00	0.00	7.68	95.98	54.26	10.51	43.75	52.63	10.51	42.12	Tecate-Ensenada	Tecate	7.99	99.92
Group 3	26	Nuevo Porvenir	9.83	0.25	2.50	0.00	0.00	38.86	15.76	23.10	30.52	15.76	14.76	Tijuana-Mexicali	Tecate	9.83	100.00
	4	Carmen Serdan	47.97	0.53	1.10	0.21	0.44	57.89	9.05	48.84	56.26	9.05	47.21	Tecate-Ensenada	Tecate	25.63	53.42
	7	El Encinal	57.69	0.64	1.10	3.81	6.71	38.93	17.13	21.80	30.59	17.13	13.46	Tijuana-Mexicali	Tecate	50.18	86.97
	17	Jacume	37.19	0.39	1.06	2.14	5.75	38.40	3.52	34.88	30.06	3.52	26.54	Tijuana-Mexicali	Tecate	34.07	91.61
	14	Heroes del Desierto I	33.51	0.24	0.72	1.95	5.82	47.42	2.24	45.17	45.79	2.24	45.17	Tijuana-Mexicali	Tecate	24.12	71.99
	13	Guadalajara II	32.44	0.20	0.60	0.81	2.50	46.19	23.09	23.10	37.85	23.09	14.76	Tijuana-Mexicali	Tecate	27.16	83.72
Group 4	2	Aubanel	35.96	0.00	0.00	0.00	0.00	81.38	24.89	56.48	73.03	24.89	48.14	Tijuana-Mexicali	Tecate	35.96	100.00
	8	El Mezquital	0.20	0.00	0.00	0.00	0.00	45.56	0.39	45.17	43.93	0.39	45.17	Tecate-Ensenada	Tecate	0.20	100.00
	23	Mi Ranchito II	2.96	0.00	0.00	0.00	0.00	30.48	7.38	23.10	22.14	7.38	14.76	Tijuana-Mexicali	Tecate	2.96	100.00
	33	Sierra de Juarez	453.49	0.00	0.00	2.10	0.46	90.36	44.73	45.63	82.02	44.73	37.29	Tijuana-Mexicali	Tecate	411.34	90.71
	32	San Marcos	45.97	0.00	0.00	0.25	0.54	63.80	13.74	50.06	62.17	13.74	50.06	Tecate-Ensenada	Tecate	29.05	63.21
	28	Pino Suarez	231.43	0.00	0.00	2.75	1.19	72.37	26.74	45.63	64.03	26.74	37.29	Tijuana-Mexicali	Tecate	222.90	96.31
	19	La Joya	23.58	0.00	0.00	0.45	1.91	28.28	7.43	20.85	11.96	7.43	4.53	Tijuana-Valle de las Palmas	Tijuana	9.46	40.11
	24	Neji I	24.56	0.00	0.00	1.07	4.36	61.45	25.20	36.24	53.10	25.20	27.90	Tijuana-Mexicali	Tecate	19.37	78.88

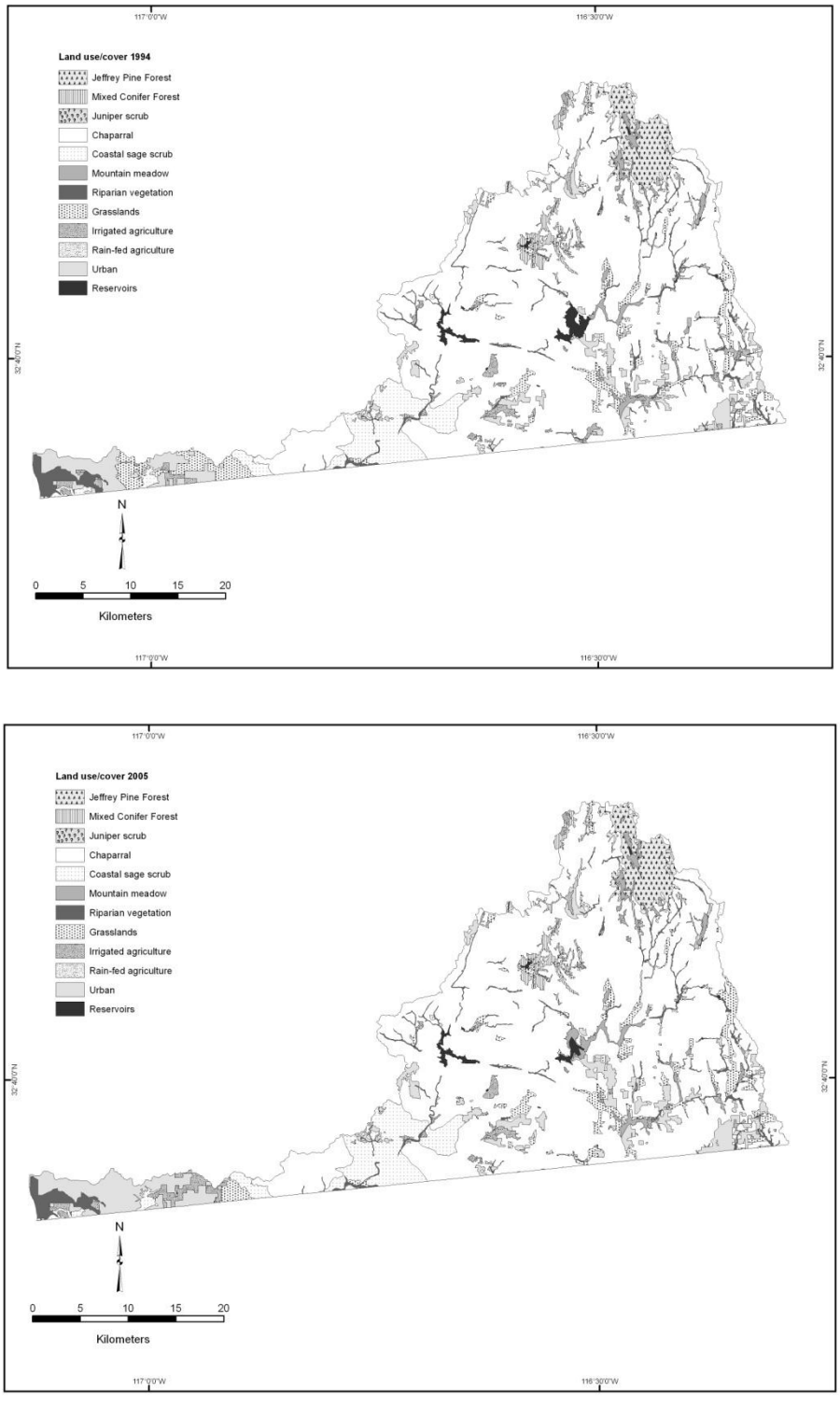

Figure 5. Maps of Land Use/Cover in the U.S. Portion of the Watershed in 1994, and Land Use/Cover in the Watershed in 2005

Table 8. Changes in Land-Use and Land Cover Change in the U.S. Portion of the Tijuana River Watershed, 1994-2005

Land cover /use	1994		2005		1994-2005		
	Area (km²)	Number of patches	Area (km²)	Number of patches	Change in land cover/use, in km² (and change in # of patches)	Rate of change, area	Rate of change, patches
Irrigated Agriculture	27.587	68	23.897	43	-3.688 (-25)	-0.10	0.33
Jeffrey Pine	39.165	3	39.387	6	0.222 (+3)	-0.69	4.45
Mixed Conifer Forest	21.313	20	21.291	20	-0.022 (0)	-2.91	5.06
Chaparral	855.901	30	842.861	51	-13.040 (+21)	-0.43	-0.64
Coastal Sage Scrub	71.218	7	70.637	8	-0.581 (+1)	-0.23	-1.15
Grasslands	59.921	66	53.939	99	-5.981(+33)	10.08	-0.85
Mountain Meadows	17.467	33	22.196	33	+4.729 (0)	-0.30	-1.90
Reservoirs	10.189	18	6.332	18	-3.857 (0)	5.10	-0.54
Urban	75.180	90	98.893	90	+23.713 (0)	-5.39	3.69
Riparian Vegetation	31.361	71	30.026	84	-1.335 (+13)		

Table 9. Land Cover/Use Transitions (area converted from one land use/cover in 1994 to another in 2005, in km^2) in the U.S. Portion of the Tijuana River Watershed (1994-2005)

		2005									
	Land cover/use	**Irrigated Agriculture**	**Jeffrey Pine**	**Mixed Conifer Forest**	**Chaparral**	**Coastal Sage Scrub**	**Grasslands**	**Mountain Meadows**	**Reservoirs**	**Urban**	**Riparian Vegetation**
1994	**Irrigated Agriculture**	16.918	-	0.013	0.131	-	7.194	0.978	-	2.338	0.003
	Jeffrey Pine	-	38.580	-	0.031	-	-	0.092	-	0.459	-
	Mixed Conifer Forest	-	0.140	21.132	0.012	-	-	0.020	-	-	<0.001
	Chaparral	0.093	0.651	0.100	842.223	-	3.951	0.152	0.059	8.635	0.042
	Coastal Sage Scrub	0.007	-	-	-	70.579	0.113	-	-	0.507	0.001
	Grasslands	6.549	-	0.104	0.005	-	42.478	0.111	-	10.649	.001
	Mountain Meadows	0.063	0.011	0.061	0.009	-	0.006	17.107	-	0.206	-
	Reservoirs	-	-	0.002	0.109	-	0.210	3.729	6.280	0.027	-
	Urban	0.046	-	0.010	0.115	0.050	0.013	<0.001	<0.001	74.906	<0.001
	Riparian Vegetation	0.209	-	-	<0.001	-	0.001	-	-	1.131	30.000

Table 10. Number of Ejidatarios,Comuneros, Posesionarios and Avecindados in Tecate and Tijuana Ejidos (ejidatarios are those with ejidal rights; posesionarios are people who use either individual or common ejido land but have not been recognized as ejidatarios; avecindados are people 18 and older who have resided for one or more years on ejido land and have been recognized by the ejido); INEGI 2009

	Tijuana	**Tecate**	**Total**
Ejidatarios	302	931	1,233
Ejidatarios with individual parcels	106	702	808
Posesionarios	3,500	132	3,632
Posesionarios with individual parcels	0	103	103
Avecindados	11,000	3,953	14,953

Table 11. Public Land Tenure Change in San Diego County between 1995 and 2009; data obtained from the San Diego Association of Governments (SANDAG)

Owner	1995 (km^2)	2009 (km^2)	Gain/Loss	%Change
City of San Diego	351.509	404.378	52.869	15.041
San Diego County	89.629	141.005	51.376	57.321
Fire Districts	16.931	17.476	0.545	3.218
Port of San Diego	0.224	0.291	0.067	30.036
Sanitation Districts	0.958	0.484	-0.474	-49.502
School Districts	44.278	21.941	-22.337	-50.447
Water Districts	225.926	236.900	10.974	4.858
Other Special Districts	11.438	21.030	9.591	83.852
California State Land Commission	41.904	42.296	0.392	0.937
State of California	92.575	133.767	41.192	44.495
California State Parks	2201.211	2300.385	99.174	4.505
California Department of Transportation	74.562	81.472	6.910	9.268
California Department of Fish and Game	18.540	48.609	30.069	162.184
Bureau of Land Management	718.600	396.108	-322.492	-44.878
U.S. Forest Service	1152.265	1169.791	17.525	1.521
Military Reservations	673.239	671.068	-2.171	-0.322
Indian Reservations	511.745	522.134	10.389	2.030
U.S. Fish and Wildlife Service	12.742	44.808	32.066	251.659
Other Federal	7.256	7.706	0.449	6.193
Total	**6245.533**	**6261.649**	**16.116**	**0.26**