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Land Use and Land Cover Change in Highland Temperate Forests in the Izta-Popo National Park, Central Mexico

The long-term preservation of national park ecosystems requires scientific knowledge about land use/cover change (LUCC) that influences these ecosystems. LUCC in Mexican temperate mountain forests as depicted in satellite imagery was evaluated for 3 time intervals: 1970–1980, 1981–1990, and 1991–2000. Forest cover declined at an average rate of 0.35 ha per year due to timber extraction, cultivation, grazing (areas grazed by cattle), and urbanization processes. Historically, cultivation has resulted in such a high loss of plant communities in lowlands that regional diversity has been threatened. Currently, though, cultivation has been reduced due to a decline in the economic importance of corn and bean crops. By contrast, grazing has increased due to low labor costs and economic policies that provide incentives for cattle production in Mexico. The abandonment of cultivated land due to economic processes may have strong implications on the regeneration of plant communities in temperate forests. Highland temperate forest and subalpine grasslands remain relatively intact due to national park protection, which is essential to maintain species diversity at a regional scale.

Keywords: *Deforestation; land use/land cover change; cultivation; conservation; regeneration; highland temperate forest; Mexico.*

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Introduction

Several mountain ecosystems worldwide are subject to high rates of deforestation because of rapidly increasing land use (Gunilla et al 2000; Kräuchi et al 2000). The structure and function of mountain ecosystems are affected in different ways by land use and land cover change (LUCC). A considerable number of ecological studies have focused on the effects of deforestation in North American and European mountains (Smethurst 2000; Jansky et al 2002). Studies on LUCC dynamics in mountainous regions in Latin America, especially in national parks, are scarce. These types of studies are fundamental because mountains shelter a great number of endemic species and great genetic diversity (Smethurst 2000; Jansky et al 2002).

In Latin America, deforestation in mountainous areas is the result of population growth and introduction of agriculture (Byers 2000; Nagendra et al 2003). Deforestation is a complex problem due to land tenure irregularities (Nagendra et al 2003) and socio-cultural and economic factors such as migration, poverty, and marginalization (Tanner 2003; Nagendra et al 2003). National parks in mountainous regions have not escaped the accelerated processes of environmental degradation both within and outside their borders (Schelhas 1991; Byers 2000; Tanner 2003).

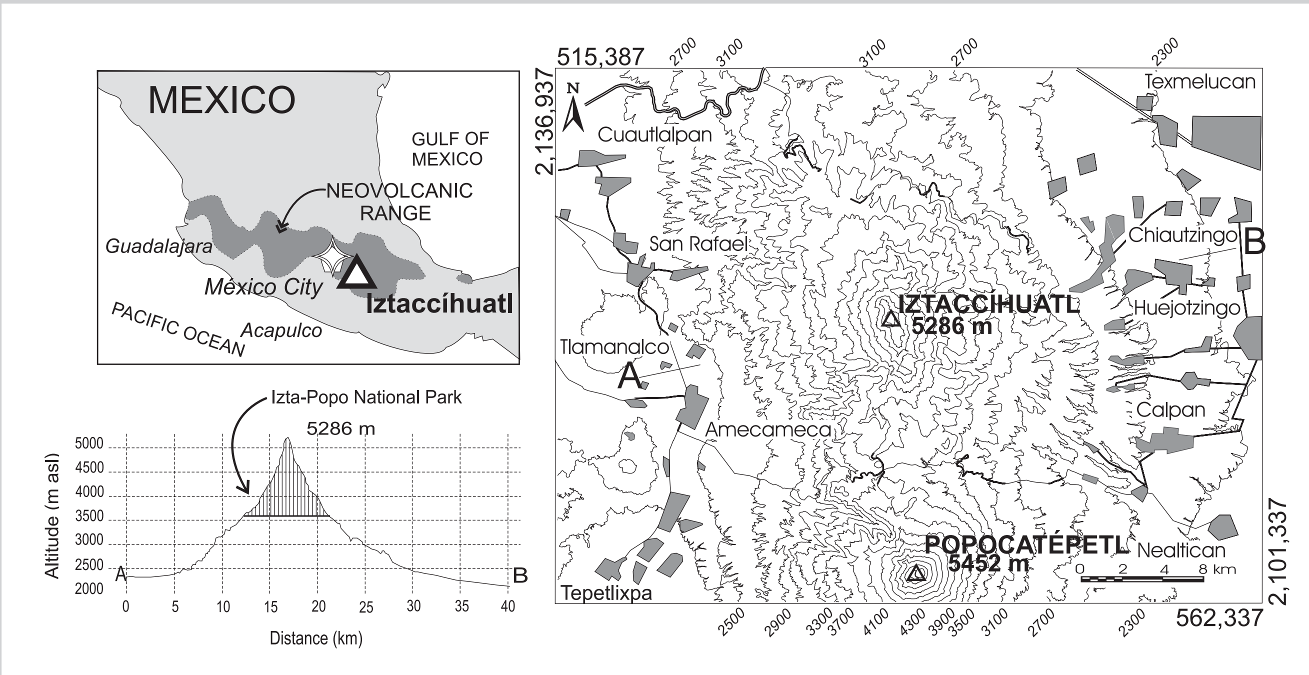
Despite widely documented studies of deforestation in Mexico's tropical lowland regions (Dirzo and García 1992; Trejo and Dirzo 2000; Turner et al 2001; Durand and Lazos 2004), there is little information about the rates of deforestation and LUCC in their highland temperate forest counterparts (Ochoa-Gaona and González-Espinoza 2000; García-Romero 2001). In Mexico, pine and oak forests are the richest ecosystems in terms of species diversity, containing 7000 species, ie about 25% of the flora in the country (Rzedowski 1991; Challenger 1998). These forests may have covered around 20% of the national territory at one time (Rzedowski 1991; Nixon 1993; Challenger 1998), with oak representing 5%, pine and oak 14%, and conifers 1% of total forest cover (Rzedowski 1991; Nixon 1993). In the last 50 years pine and oak forests have experienced a high decline rate with regard to both area coverage and species richness (Rzedowski 1978; Challenger 1998). Due to human impacts, these forests at present cover only around 17% of Mexico; the annual rate of deforestation is higher than 0.95%, without considering regeneration (Masera et al 1997).

Because deforestation is still continuing and the risk of major biodiversity loss in Mexico is high, evaluation of LUCC has begun in these temperate forests (Velázquez et al 2003), though with only a slow increase in knowledge about the processes explaining LUCC dynamics. Understanding the patterns, causes, and consequences of land use change will help predict the dynamics of landscape change and help to develop effective conservation and management strategies for highland temperate forests in Mexico. The objective of the present study was therefore to evaluate the magnitude of forest LUCC and recognize factors and processes that determine land use change in temperate forests in the Mexican tropics.

Study area

In central Mexico pine and oak forests are mainly distributed in the highlands of the main mountains such as the Iztaccíhuatl (5286 m), the Nevado de Toluca (4690 m), the Popocatepétl (5432), and the Cofre de Perote (4682 m). These mountains are strategic sites for obtaining valuable resources (food, water, minerals, and fuelwood) for several rural communities. The study

FIGURE 1 Location of the study area in the Izta-Popo National Park area, Mexico. (Map by authors)



site covers an area of 1085 km^2 located in the center of the country (5286 m, 18° 59' N and 109° 04' W), straddling the boundaries of the states of Mexico, Morelos, and Puebla (Figure 1). This region is representative of the processes that drive land use change in highland temperate forests in Mexico and in national parks that protect forest communities above 3600 m. Thus, the results of the present study may be relevant for other national parks in mountain areas in central Mexico (Nevado de Toluca and Cofre de Perote). The Iztaccíhuatl volcano is a Quaternary strata volcano. It is part of the Sierra Nevada range, which runs from north to south through the region. The volcano has 3 principal summits: the "head" (5140 m), "chest" (5286 m), and "knees" (5000 m) (Lugo 1984), with a local height difference of 3000 m. Due to great topographic diversity, the study site shows a great diversity of species, physiographic conditions, and patterns of temperate forest representative of similar sites in Mexico.

The vegetation is distributed on altitudinal belts (Rzedowski 1978), with oak on lower slopes up to 2800 m; fir (*Abies religiosa*), mixed conifers (*A. religiosa* and *Pinus* spp.), and oak up to 3000 m; mixed conifers up to 3400 m; and pine (*P. hartwegii*) up to 4000 m. Subalpine grassland (*Festuca tolucensis*, *Calamagrostis tolucensis*, and *Muhlenbergia* spp.) ranges from 3600 to 4200 m. According to the climatic classification system developed by Köppen, modified by García (1987), the climate in this upper zone is cold, with annual temperatures below 10°C; annual precipitation is 1000 mm. In the volcano remainder, the predominant climate is temperate and sub-humid, with an average temperature of 18°C and annual precipitation of 800–1000 mm. The Izta-Popo National Park was created in 1935 and was included in the United Nations' Natural Protected Areas list in 1967. This park protects 25,679 ha of temperate forest, including subalpine grasslands and high-elevation coniferous forests (3600–4100 m) that include *Pinus hartwegii* as the principal species.

Methods

Elaboration of land cover maps and database

The analysis of land cover dynamics from aerial photographs (1983) and Landsat MSS satellite images (1970) and TM (1990 and 2000) was made using a visual classification method. As Mas and Ramírez (1996), Arnold (1997) and Slaymaker (2003) argue, visual methods are particularly useful for detailed analysis of land cover series over time. The reliability of results depends on the interpretation of plant community crown structures, fieldwork, and wide knowledge of the environment in the study area, as well as use of the literature and cartography.

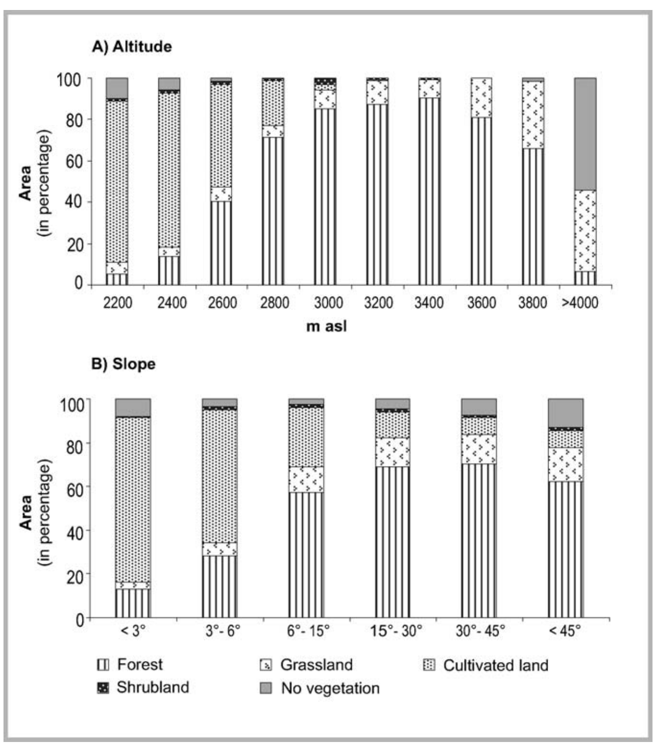
The study used a geographic information system (ILWIS 3.0). The images and photographs were corrected geometrically and georeferenced to topographic maps at a scale of 1:50,000 (RMSE or Sigma= 2) (Mas and Ramírez 1996), with a minimum cartographical area of 50 m^2. Finally, tests were made to verify the correct superposition of the images. The first interpretation was made over more recent (1983) and detailed

TABLE 1 Land use and land cover types considered in image classification and highland temperate forest change detection in Izta-Popo National Park (Mexico).

Land use	Land cover	Land cover characteristics
Forestry	(i) Fir forest, (ii) pine–evergreen oak forest, (iii) pine and fir forest, (iv) oak forest, and (v) high-elevation pine forest (*Pinus hartwegii* forest)	Areas covered by trees with closed canopies (estimated at 75% or more crown cover by the respective species (pine, oak, fir, and *Pinus hartwegii*)
Grazing	(i) Subalpine grassland, and (ii) grassland with dispersed trees	Natural grassland with poor tree cover, used by livestock
Cultivation	(i) Non-irrigated crops, (ii) irrigated crops, and (iii) cultivated forest	Corn and beans: principal non-irrigated crops
Regeneration	(i) Shrubland, (ii) shrubland with dispersed trees	Land covered by scattered shrubs, bushes, and young broadleaf regeneration
Intensive use or no use	(i) Urban settlement, (ii) water body, and (iii) barren	Roads, construction sites, and other built-up areas, as well as other areas without vegetation

(1:37,000) aerial photographs of the area. To verify the units and identify new classes (forest plantations and types of forests), various indicators were consulted (Slaymaker 2003): digital maps of slopes, altitude and exposition of hillsides; land use and vegetation maps of the National Institute of Statistics, Geography and Informatics (INEGI 1986). In addition, 60 sites were set up to verify georeferenced fields with GPS technology.

FIGURES 2A AND 2B Distribution of land cover types in the Izta-Popo National Park area, Mexico, in relation to (A) altitude and (B) slope.



The previously interpreted photographs and the field sites were introduced into the GIS; to confirm the results a map with the sites of known covers was elaborated.

The land cover map for 1983 was the basis on which the other maps were elaborated. This was possible because the other images (with the exception of the October 2000 images) were from the dry period (MSS of February 1973 and TM of February of 1993), ie the most appropriate season for cover differentiation. For these, sub-scenes of images and several multiband color composite images (red, green, blue) were elaborated.

The images that allowed us to better differentiate between types of land cover were 2, 3, 4 in Landsat MSS, and 3, 2, 1 (color natural) / 4, 5, 7 (false color) in Landsat TM images. Land cover for 1983 was superposed on 1970, 1990, and 2000 images to apply direct, associative, and deductive techniques for analyzing traits (texture, size, shadow, density, location) to differentiate land cover classes (Enciso 1990; Mas and Ramírez 1996). The TM images for 1990 and 2000 have better spatial, spectral, and radiometric resolution, so the interpretation was easier, with support from fieldwork and sources of edited information (IG-UNAM 2000). In the case of the MSS images for 1970, interpretation was supported by land use and vegetation maps (scale 1:50,000) by INEGI (1986).

To determine the typology, we used the classification of land use systems and vegetation published by INEGI (1986). This provided the most suitable tool for updating and assessments. Table 1 shows the 15 types of land cover we identified (see also García-Romero et al 2004). The land cover segments from different dates were digitized in GIS to obtain polygons, including the description of the perimeter, area, and land cover attributes.

Rates of deforestation in temperate forests

The method developed by Trejo and Dirzo (2000) was used to estimate the rate of deforestation between 1970 and 2000:

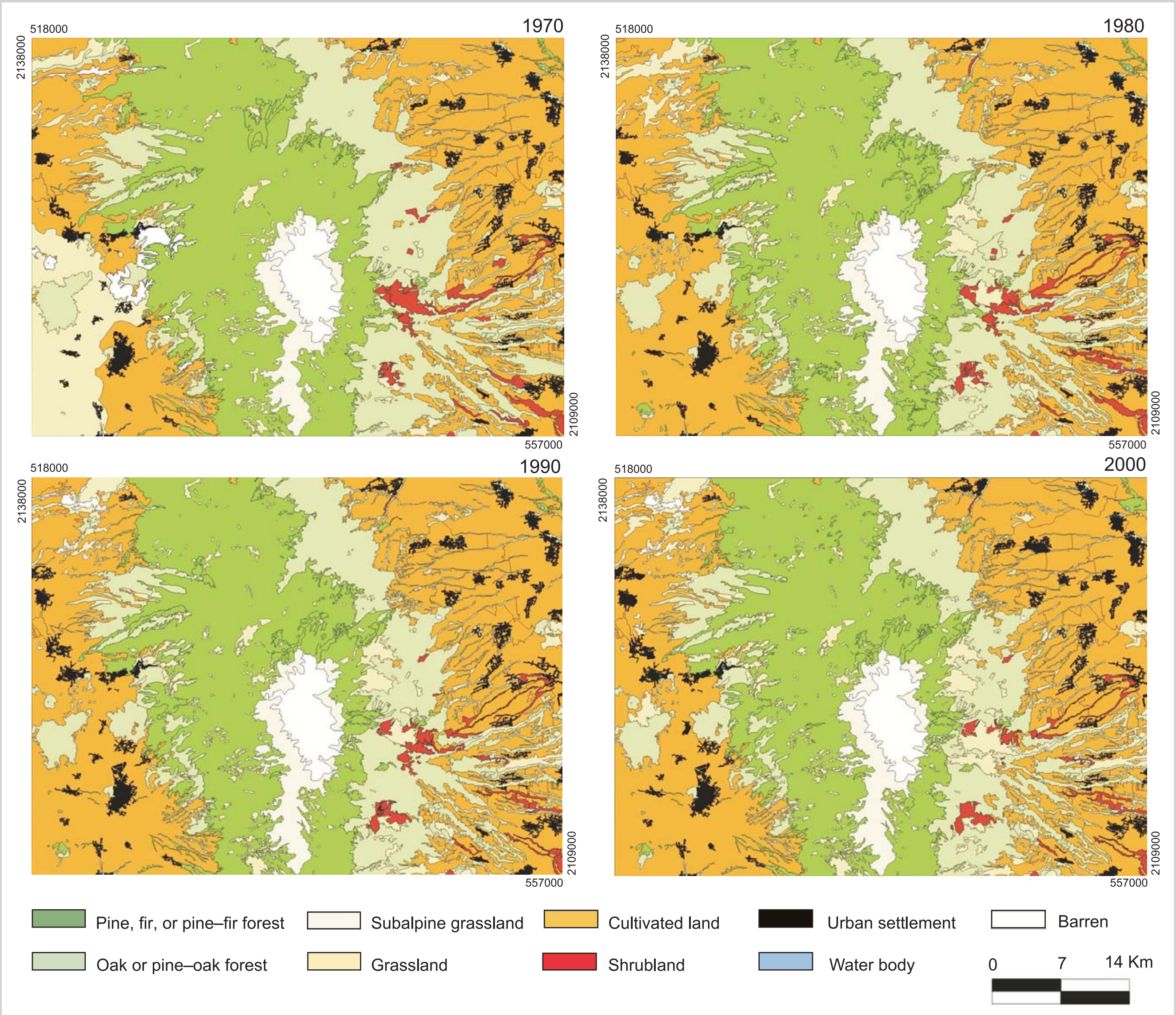
$$r = 1 - \left(\frac{1 - A_1 - A_2}{A_1} \right)^{1/t}$$

where r is the deforestation rate, A_1 is the natural forest cover area at the beginning of the period, A_2 is the natural forest cover area at the end of the period, and t is the number of years covered by the analysis.

Land use changes trajectories

To identify natural resource use (land use) that characterized the different types of land cover, we analyzed an agricultural census and cartographic information (Fuentes-Aguilar 1975; Rzedowski 1978; INEGI 1986; Toledo et al 1989; Challenger 1998; Chávez et al 2001; Ramírez-Ramírez 2001; García-Romero 2002; Works and Hadley 2004). We also conducted interviews and fieldwork. To analyze the processes and extent of land use change, transition matrix analysis was performed (Aaviksoo 1995; Bocco et al 2001). We defined the following types of land use change processes: (1) *Deforesta-*

FIGURE 3 Land cover in 1970, 1980, 1990, and 2000 in the Izta-Popo National Park area, Mexico. (Maps by Arturo García-Romero and Leopoldo Galicia, based on aerial photographs [1983] and Landsat MSS satellite images [1970] and TM [1990 and 2000])



tion is the change from forest to cultivation and grazing. (2) *Permanence* is the persistence of cultivation and grazing between 2 dates. (3) *Replacement* represents the transformation from grazing to cultivation or vice versa. (4) *Regeneration* represents the change from temperate forest to shrubland due to forest use or to abandonment of grazing and cultivation. (5) *Urbanization* is the change from forest, cultivation, and grazing to residential and industrial use. (6) *Conservation* is the persistence of subalpine grasslands (ungrazed) and forests between 2 dates.

Results

Spatial LUCC distribution in 2000

Different types of cover associated with forest were found mainly between 2600 and 3800 m; by contrast, cultivated land was mainly distributed between 2200 and 2800 m, and subalpine grassland between 3600 and 4000 m. The distribution of areas without vegetation is not homogeneous: barren areas were located at very high elevations (> 4400 m), while urban areas were distributed between 2200 and 2400 m (Figure 2A). Forest and grasslands were distributed primarily on gradients between 6° and 30°; by contrast, cultivated land and urban zones were distributed primarily on gradients between 3° and 6° (Figure 2B).

LUCC dynamics

The analysis of LUCC between 1970 and 2000 in former temperate forests indicated that these were neither unidirectional nor homogeneous. LUCC showed moderate changes: an expansion of cultivated land, a reduction of forest, and a strong decrease of pastureland followed by a recent increase from the 1st to the 4th period evaluated (Figure 3). Thus, in 1970 about 59,369 ha were occupied by natural forest, 34,907 ha by cultivated land, and 10,148 ha by pastureland. In 1980, natural forest covered 56,211 ha, followed by cultivated land (42,072 ha) and pastureland (5901 ha). By 1990, natural forest cover occupied 53,862 ha, while cultivated land covered 43,989 ha and pastureland 5768 ha of the total area. In 2000, the surface covered by forests was 53,187 ha, followed by cultivated land (43,149 ha) and pastureland (7295 ha). Subalpine grasslands (~3500 ha), barren land (~2700 ha), and urban zones (~3000 ha) occupied comparatively (though not unvarying) small areas during the 4 periods.

Forest cover decreased from 1970 to 2000. Temperate forest cover loss was 6181 ha in 30 years at a mean rate of 0.35 ha per year. However, this loss was not constant, with decreases of 3157 ha (1970–1980), 2349 ha (1980–1990), and 674 ha in 1990–2000. Nor was loss the same for all temperate forests; the greatest was for pine and oak, with 3200 ha lost by 1980, 400 ha by 1990, and 100 ha more by 2000. High-elevation temperate forests did not show great change during any of the 3 periods (Figure 4A), nor did ungrazed subalpine grassland and barren land (Figure 4B).

Cultivation increased in the periods 1970–1980 (+8007 ha) and 1980–1990 (+1660 ha), and decreased slightly in the period 1990–2000 (–424 ha) (Figure 4C). Changes in cultivated area differed according to types of use: non-irrigated crops grew in the periods 1970–1980 (+6362 ha) and 1980–1990 (+1684 ha); on the other hand, neither tree plantations (10,851 ha in 2000) nor irrigated crops (1861 ha in 2000) changed a great deal from 1970 to 2000 (Figure 4C). Pastureland lost 4246 ha between 1970–1980, however, it increased again between 1990–2000 (1527 ha). More specifically, within this category the greatest loss was from 1970 to 1980, for grassland with remnant trees used for cattle grazing (decrease from 8221 ha to 4362 ha; Figure 4B). Shrubland with dispersed trees decreased from 1117 ha in 1970 to 447 ha in 2000, whereas open shrubland increased from 242 ha in 1970 to 1020 ha in 1980, then decreased again to 590 ha by 2000 (Figure 4D). Urban settlements showed a continual increase from one period to the next (Figure 4E): +30 ha by 1980, +361 ha by 1990, +266 ha by 2000. The rate of increase was less for barren land (from +30 ha by 1980 to +218 ha by 1990) and stabilized in 1990 (Figure 4F).

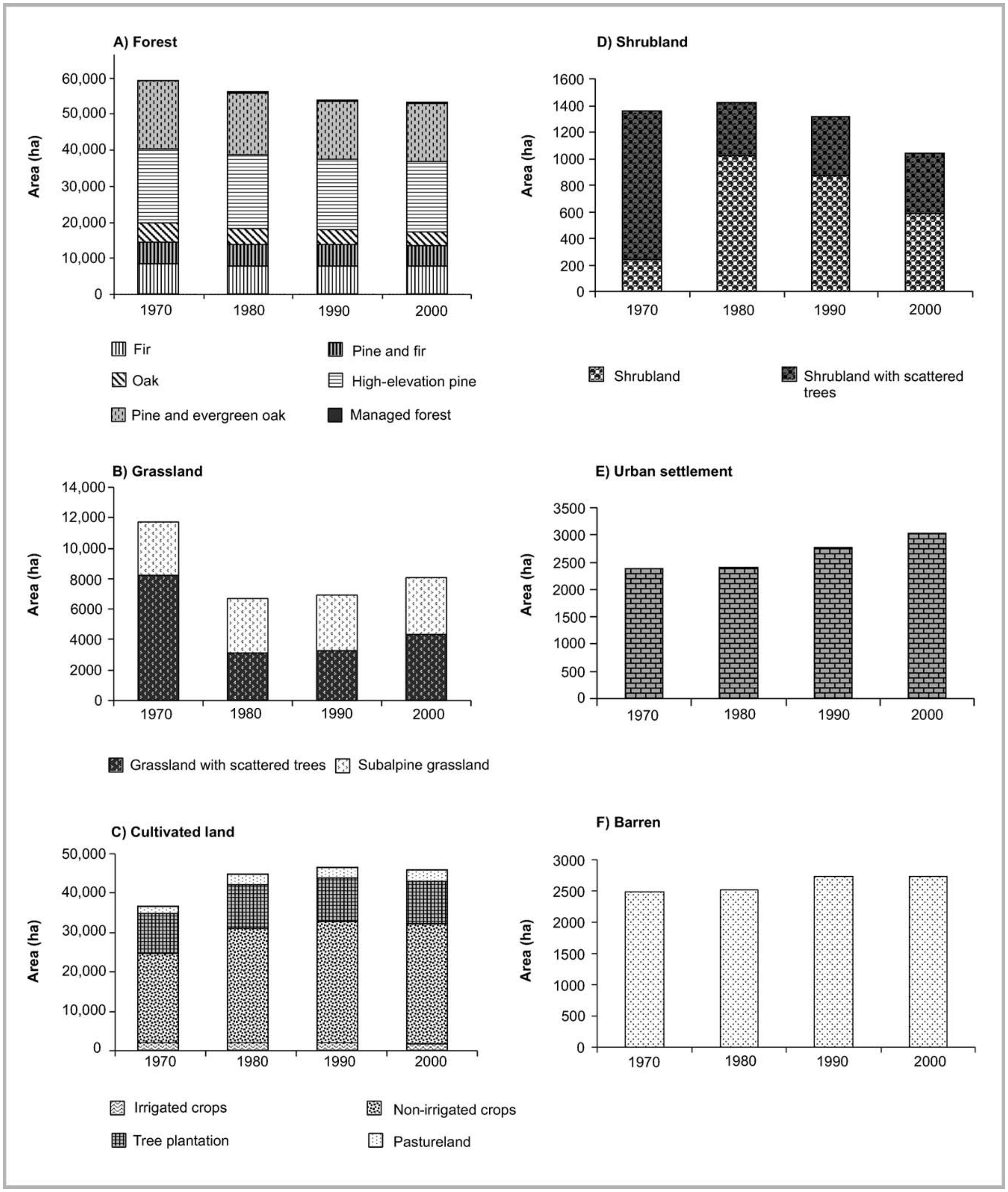
Land use change processes

Processes of land use change are shown in Table 2. Deforestation during the 1970–1980 period (3157 ha) was caused by grazing (1865 ha) and cultivation (1044 ha). Proportionally, cultivation was more permanent than grazing; also, the replacement of grazing by cultivation was very high (6809 ha) by comparison with the replacement of cultivation by grazing (596 ha). Some forest recovery is indicated by the nature of certain forest recovery patterns (forest to shrubland: 648 ha).

The process of land use change during the period 1980–1990 was characterized by slightly less forest loss (2349 ha). Most replacement of forest was by cultivation (2171 ha) and grazing (606 ha). In this period as well, cultivation remained proportionally far more permanent than grazing. Forest recovery was minor (only 165 ha). The process of replacement between cultivation and grazing was less important: only 210 ha went from cultivation to grazing and 572 ha from grazing to cultivation.

During the period 1990–2000, deforestation was less intense by comparison with the 2 previous periods (only 674 ha): 492 ha of forest were lost to grazing and 269 ha to cultivation. Both cultivation and grazing were characterized by permanence, with proportionally very little surface lost to other land uses. More cultivated land went to grazing (875 ha) than pastureland to cultivation (only 76 ha).

FIGURES 4A TO 4F Temporal land use change dynamics for (A) forest, (B) grassland, (C) cultivated land, (D) shrubland, (E) urban settlement, and (F) barren land in the Izta-Popo National Park area, Mexico.



Discussion

Deforestation

The deforestation rate for temperate forest in the study area was low (0.35%) compared to the 0.95% reported by Masera et al (1997) for Mexican coniferous forests, and by Ochoa-Gaona and González-Espinoza (2000) for the southeast of Mexico (3%) in non-protected areas. This considerable decrease was due to protection through national park status, and to physical characteristics such as gradient and altitude that restrict the extraction of wood and increase the cost of access and mechan-

TABLE 2 Cross-tabulated trajectories of land use change in the Iztaccíhuatl area (in ha): (A) 1970–1980, (B) 1980–1990, and (C) 1990–2000. Losses from one category to another are expressed in the rows, and gains in one category at the expense of another in the columns.

A

1970–1980	1980							Total in 1970
	Forest	Ungrazed	Shrubland	Grazed	Cultivated	Urban	Barren	
Forest	**55,669**	134	648	1865	1044	3	7	**59,369**
Ungrazed	28	**3355**	0	0	0	0	0	**3383**
Shrubland	28	0	**702**	301	327	0	0	**1358**
Grazed	164	0	14	**3140**	6809	5	15	**10,148**
Cultivated	323	13	55	596	**33,889**	22	10	**34,907**
Urban	0	0	0	0	0	**2373**	0	**2373**
Barren	0	0	0	0	2	0	**2488**	**2490**
Total in 1980	**56,212**	**3503**	**1418**	**5902**	**42,071**	**2403**	**2519**	**114,029**

B

1980–1990	1990							Total in 1980
	Forest	Ungrazed	Shrubland	Grazed	Cultivated	Urban	Barren	
Forest	**52,956**	253	165	606	2171	21	38	**56,211**
Ungrazed	164	**3339**	0	0	0	0	0	**3503**
Shrubland	57	0	**1132**	48	182	0	0	**1419**
Grazed	307	1	14	**4902**	572	4	101	**5901**
Cultivated	373	0	4	210	**41,061**	338	85	**42,072**
Urban	0	0	0	0	3	**2400**	0	**2403**
Barren	4	0	0	2	0	0	**2513**	**2519**
Total in 1990	**53,862**	**3593**	**1316**	**5768**	**43,989**	**2764**	**2737**	**114,029**

C

1990–2000	2000							Total in 1990
	Forest	Ungrazed	Shrubland	Grazed	Cultivated	Urban	Barren	
Forest	**53,101**	0	0	492	269	0	0	**53,862**
Ungrazed	0	**3593**	0	0	0	0	0	**3593**
Shrubland	5	0	**1036**	245	26	3	0	**1315**
Grazed	10	0	0	**5683**	76	0	0	**5768**
Cultivated	71	0	1	875	**42,775**	266	0	**43,989**
Urban	0	0	0	0	3	**2761**	0	**2764**
Barren	0	0	0	0	0	0	**2737**	**2737**
Total in 2000	**53,188**	**3593**	**1037**	**7295**	**43,149**	**3030**	**2737**	**114,029**

ical operation (Apan and Peterson 1998; Helmer 2000). Thus, approximately 47% of temperate forest areas remain intact, located mainly at high altitudes due to enclosure in the Izta-Popo National Park. This is particularly the case for high-elevation *Pinus hartwegii* forest. However, timber and firewood extraction have been threatening *Abies religiosa* forest, evergreen oak forest, and pine–evergreen oak forest. Though reduced, the loss of forest in this park is worrying because temperate forest and subalpine vegetation comprises a group of ecosystems with limited distribution in tropical areas worldwide. It is therefore important to protect them; the smallest changes in these areas may have profound consequences, such as the loss of endemic species (Smethurst 2000; Jansky et al 2002; Velázquez et al 2003).

Today, the loss of forest cover in the National Park is due to illegal logging, intensive extraction of pine resin, and the production of oak coal mainly by local communities, for whom the forest is the main source of income and the only source of energy (Challenger 1998; Toledo et al 1989). Legislation to regulate the use and exploitation of resources inside the park exists but is not fully applied. Communal landholders exploit forest resources, ignoring the legislation; they even lease the land to third parties—with or without a government license—for illegal destruction of forest. Schelhas (1991) and Stevens (2003) point out that one of the main threats to conservation in national parks is uncontrolled access to resources that are a very important source of livelihood for local communities.

The deforestation rate in the study area has mainly been due to 4 land use types: timber extraction (Challenger 1998), expansion of cultivation, recent expansion of grazing (Rzedowski 1978; Challenger 1998), and urbanization (Gómez-Pompa 1985; Challenger 1998). Timber extraction has been high in the region's temperate forest since 1990 when the timber industries were given concessions in Mexico (Challenger 1998). For example, in the period between 1990 and 2000, 110,975 m^3 of timber were extracted (INEGI 2000). However, timber extraction was selective—78% (86,560 m^3) concerned pine, accounting for the majority of forest loss during the 3 periods. Around 18% (19,975 m^3) corresponds to fir and 4% to cedar (4980 m^3), while a great number of other species represented only about 5% (5548 m^3). Similarly, Works and Hadley (2004) suggest that recent wood and logging extraction patterns have led to degradation of forests in Michoacan, Mexico, due to short harvest cycles and substitution of forest by avocado plantations—a process also perceptible at our study site.

Historically, the combination of cultivation and grazing has been the main cause of reduction of temperate forests in Latin American mountains, because they are the base of the economy and a source of food for highland mountain communities (Byers 2000; Preston et al 2003; Quiroga-Mendiola 2004; Velázquez et al 2003). Toledo et al (1989) suggest that 40% of temperate forestland in Mexico has been dedicated to corn production, while 35% of national corn production is in temperate forest areas. In the present study, cultivation was the land use that contributed most to the loss of forest cover and transformation of landscape (35%), particularly in zones with low altitude. According to INEGI (2000), agricultural land use is practically dominated by temporal crops (corn and bean) (82%); this caused the cultivation area to grow from 22,623 ha in 1970 to 30,669 ha in 1991. This type of cultivation is especially dominant because it plays a fundamental role in the economy of these areas due to the fact that corn is the main ingredient in the food of these rural areas (Fuentes-Aguilar 1975). This explains the permanence and extension of this land use.

Additionally, one of the main explanations for the extension of cultivation activity is population increase (Ochoa-Gaona and González-Espinoza 2000; Trejo and Dirzo 2000). The number of settlers in this zone grew considerably: from 168,689 people in 1970 to 260,624 people in 1980, and to 493,992 people in 1990 (INEGI 2000). The net population increase was 150% from 1970 to 1980, and 190% from 1980 to 1990, coinciding with larger extensions of land dedicated to cultivation at the expense of forestland cover (Toledo et al 1989; Challenger 1998). These results are similar to those in the mountains of Ethiopia (Tekle and Hedlund 2000) where the area covered by urban settlement increased 100% in 28 years. This urban growth represents greater economic, environmental and social degradation in ecosystems as a result of greater demand for areas to sustain basic resources and elevated rates of deforestation in the Izta-Popo National Park (Jansky et al 2002).

In mountain regions of Latin America rural communities have relied on goat and bovine production for meat, wool, and manure (Preston et al 2003). Also, grazing in Mexico has been one of the principal economic activities in both wet and dry tropical forests since 1960 (Toledo et al 1989; Lazos-Chavero 1996). Replacement of cultivation by grazing gained importance between 1990 and 2000 in the Izta-Popo National Park; for example, the number of cattle increased by 38% in 1997 (INEGI 2000). Ochoa-Gaona and González-Espinoza (2000) have reported that sheepherding on cultivated land is a common phenomenon, because the abandonment of cultivation encourages pasturing, at least initially.

The main cause of increase in cattle production is that local people consider livestock to be an ambulant bank that is a buffer against poverty and minimizes the risk of food insecurity (Byers 2000; Preston et al 2003; Quiroga-Mendiola 2004). This is in addition to the fact that economic policy in Mexico encourages cattle production; settlers are officially forced to take credits for cattle production (Lazos-Chavero 1996). Market forces also play a part: replacement of seasonal agriculture for pastures was due to low prices of corn and the insecurity provoked by the absence of—technical—development programs and government subsidies (Toledo et al 1989). Moreover, temporal cultivation land requires extensive care during the period of crop development, while grazing is cheaper and less labor-intensive, as it is based on an extensive system that only requires intentional burning of pasturelands, which generates renewal every 2 years. This result is contrary to what happens in mountainous environments in developed countries in Europe. Tasser and Tappeiner (2002) suggest that a growing abandonment of cattle activities exists that is related to socioeconomic acceleration in the cities.

In this study, regeneration areas proliferated during the period of study due to abandonment of lands and less productive cultivation, migration, etc. (Challenger 1998). Forest recovery of cultivated land was most pronounced between 1991 and 2000, due to the reduction of economic support for agricultural activities. This reduced the intensity of agriculture in Mexico (Ochoa-Gaona and González-Espinoza 2000; Velázquez et al 2003). Thus, the abandonment of cultivation lands may have positive implications for the rehabilitation of plant communities and recuperation or maintenance of plant diversity in this region.

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