2. Socioeconomic Change and Its Impact on Forest Resources in the Basin of Mexico

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Surrounded by the mountains of Mexico's Central Volcanic Axis, the Basin of Mexico remains, on all counts, the center of the nation. It is also the habitat in which one of the largest urban complexes in the world has developed (Pick and Butler 1997). Following up and summarizing previous studies (Aguilar et al. 1995; Ezcurra and Mazari-Hiriart 1996; Ezcurra et al. 1999), in this paper we shall discuss some of the socioeconomic issues related to the changes in forest ecosystems in the Basin of Mexico. The depletion of natural resources in the Basin of Mexico is not just a recent phenomenon. Rooted deep in the historic past, it has triggered massive emigration and various sociocultural collapses in the past (Ezcurra 1990a, 1990b, 1992; Whitmore and Turner 1986; Whitmore et al. 1990). Yet the scale, pace, and period of change currently under way are unprecedented, and the impact of urban growth on what remains of the surrounding forests is of primary importance.

Mexico City is a massive urban area. Originally contained within the boundaries of the Federal District (DF), during the 1950s, it spilled beyond these borders into the adjacent municipalities of the State of Mexico. The urbanized area contains 16 administrative subunits, called *delegaciones*, in the DF, as well as 29 municipalities (*municipios*) in the neighboring State of Mexico. Thus, the limit of the urban physical unit does not coincide with political administrative divisions. Larger, of course, is the Basin of Mexico, a hydrologically defined unit that encompasses 84 municipalities in the DF and the states of Mexico, Hidalgo, and Puebla. Mexico City, in which 93% of the total population is concentrated,

represents the most important socioeconomic unit within the Basin. Thus, the Basin of Mexico and Mexico City are almost synonyms in demographic terms, but the latter is a subset of the former in geographic terms (Valverde and Aguilar 1987).

Historic Forest Use in the Basin of Mexico

Teotihuacan

In approximately the year 100 AD, Teotihuacan, situated in the northeast of the Basin, had some 30,000 inhabitants. Five centuries later, in 650 AD, its population of 150,000 made it one of the largest cities in the world (Millon 1970; Parsons 1976). A century later, the population of Teotihuacan had collapsed to fewer than 10,000. The cause of this decline is not well understood. Some researchers attribute it to the rebellion of subjugated groups; others, to the exhaustion of the natural resources exploited by the Teotihuacans. Ecologically, both hypotheses point to a similar underlying problem: The need for war tribute was the result of the inability of the Teotihuacans to survive on their own natural resources and of the need to import natural resources from other areas to support their economy. In either case, the exhaustion of local resources and the conflicts for the appropriation of foreign commodities appear as the driving forces of the collapse. According to Sanders (1976a, see also Sanders; Parsons and Santley 1979), the overexploitation of the forests and shrub-lands in the semiarid environment surrounding Teotihuacan and the lack of a sufficiently developed technology to exploit the fertile but flood-prone terrains of the Basin lake beds were decisive determinants in the sudden collapse of this civilization.

Good evidence shows that the Teotihuacan area was strongly disturbed at the time of the decline and remains so even today. The area is strongly desertified and completely lacks native woody vegetation. It is possible to calculate, for example, the amount of wood needed to calcinate the mortar and stucco used to construct the gigantic pyramids of the city as on the order of tens of thousands of tons (Cook 1947). Adding to this amount the amount of wood necessary to satisfy the domestic needs of 150,000 persons (a conservative estimate is 30,000 tons per year), it becomes clear that the development of Teotihuacan brought a large-scale process of deforestation in the north of the Basin, with erosion and loss of good agricultural soils as consequences. The total amount of wood used by Teotihuacan during its last century implies the cutting of 30,000 to 60,000 ha of dry pine and oak forests (Ezcurra 1992). Everything seems to indicate that resource exhaustion in general, and deforestation in particular, were key determinants of the decline of Teotihuacan.

Forests and Aztec Agriculture

Climate was restrictive for human settlements in the temperate zones of Mexico, where the dry season, starting in October and ending in May or June, allowed

only one harvest for most crops. Many of the early inhabitants regarded the muddy bottom of the lacustrine system of the Basin as unsuitable for settlement. When the Aztec immigrants arrived in the Basin, they were displaced into the lowlands by established dominant groups already in the Basin. The lakes, however, proved to be the solution for coping with the seasonal droughts. The Aztecs developed a unique agricultural system, known as *chinampas*, consisting of artificial islands built with the rich silt of the swampy lakes. There was no soil limitation for the *chinampa* system, for as soon as soil fertility became impoverished by the crops, the silt was replaced by a new layer of rich lake-bottom sediment. Water shortages were also nonexistent throughout the year, since the shallow soil of the artificial islands absorbed water directly from the water table of the lakes. Nor were the *chinampas* washed out by water because trees with large root systems, mainly a willow (*Salix bomplandiana*), were planted along the borders to protect the plots from the eroding effects of water. Finally, the rich aquatic fauna of the canals also provided a valuable and rich source of additional food for the *chinampa* farmers.

Thus, by harvesting aquatic products and by digging the muddy sediments from the canals into the fields, the *chinampa* system was able to recycle in a very efficient manner the nutrients leached from the fertile soils of the agricultural fields. Although this system required a large amount of maintenance work (building the *chinampa*, cleaning the canals, protecting seedbeds from freezing during the cold winter mornings), it turned out to be one of the most productive Mesoamerican agricultural systems (Armillas 1971; Coe 1964; Sanders 1976a; Whitmore and Turner 1992).

The Colonial Period

After the Aztec conquest in 1521, the Mexican colony became a synthesis of both Aztec and Spanish traditions. Some persistent cultural differences, however, led to transformations of the landscape in general, and of the Basin of Mexico's forests. From early colonial times, it became clear that the Spanish city plan was not compatible with the lacustrine landscape of the Basin (Sala Catalá 1986). The conquest of Mexico by the Spaniards brought, among many other things, an introduction of alien plant and animal species as well as unfamiliar techniques for the use of natural resources. With the introduction of cattle came the first use of animals for labor and transportation. The filling of the Aztec canals and the *chinampa* fields to build elevated roads obstructed the surface drainage of the city and created large expanses of stagnant water. At the same time, the grazing and intensive logging of the slopes surrounding the Basin resulted in increased surface runoff and silting during the rainy season (de Humboldt 1811). The colonial city began to be troubled by severe floods. The first one occurred in 1553; floods recurred in 1580, 1604, 1629, and thereafter at shorter intervals. Growing deforestation was, to a large degree, responsible for these floods. Although many scientists warned the colonial authorities of the consequences of

forest loss, the governmental response was to drain the Basin through the construction of an ever-growing, complex, and immensely expensive system of canals and tunnels. The works to drain the basin began in the early colony and have never stopped.

The Twentieth Century

After the end of the Mexican Revolution, in 1924, Mexico City began to grow rapidly. The pace of environmental deterioration increased rapidly with the development of the modern city. As in many other parts of Latin America, industrialization during this century accelerated migration towards the city, where job opportunities were higher. In its rapid growth, Mexico City began to engulf the satellite towns that surrounded the old Aztec capital, transforming itself into the immense megalopolis of today. Even the forests in the mountain ranges south and west of the city, little affected by the process of urbanization until the 1970s, began to suffer the consequences of explosive urban growth.

Realizing the environmental importance of the surrounding forests, President Lázaro Cárdenas (1934–1940) created various national parks in the mountains enclosing the basin. Two national parks, Desierto de los Leones and Cumbres del Ajusco, were created to the west and south as a way of restricting the deforestation of the basin slopes. Unfortunately, during the presidency of Miguel Alemán (1946–1952) a good part of the Ajusco park was given to a paper mill, which embarked on an ambitious timber–logging program (DDF 1986). The consequent elimination of the park and the ensuing deforestation of neighboring areas opened the way for urban expansion. The measure was again reversed in December 1988 when President Miguel de la Madrid decreed the ecological corridor Ajusco–Chichinautzin a protected area, justifying the measure on the need to maintain the recharge of the basin's aquifers, among other reasons.

Although substantial forested areas were logged during the colonial period, it was during the late twentieth century that accelerated deforestation began to have noticeable and dramatic impacts. More than 9000 hectares of trees disappeared in only 15 years between 1985 and 2000, and some insect pests that thrive on the trees debilitated by air pollution are attacking the protected forests. The widespread use of introduced and often invasive species such as *Eucalytus* to reforest the Basin has resulted in a loss of the native plant communities (Segura-Burciaga and Martínez-Ramos 1994) and of the animal species that relied on the native plants for food or shelter.

In its rapid growth, the city occupied land unsuitable for urbanization, such as the desiccated lake bed of Texcoco to the east and the forested mountain slopes in the south and southwest of the Basin (Figs. 2.1 and 2.2). To some extent the physical barriers imposed by the mountain ranges in the south and west have restricted urban growth. Extension of the urban expansion to the mountain slopes, however, has resulted in forest disturbance and deterioration of the important environmental services they provide.

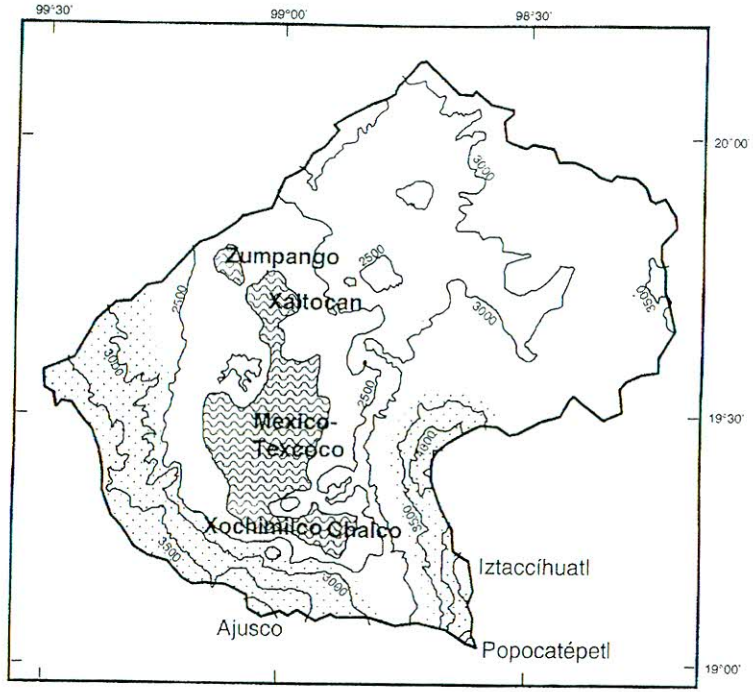

Figure 2.1. Map of the Basin of Mexico. The hatched area in the center of the Basin represents the original extension of the lakes at the time of the Spanish Conquest; the dotted areas in the southwest and southeast represent the forested areas of the Basin. The three highest volcanic peaks (Ajusco, Popocatépetl, and Iztaccíhuatl), which mark the boundary of the Basin, are indicate for references. (Modified from Ezcurra et al. 1999.)

Urban Growth and Social Distribution

Demographically, the Basin of Mexico concentrates almost 25% of Mexico's population, but its economic importance is even greater. In the 1940s, Mexico City constituted an economically optimal location for industrial development. Its extensive urban infrastructure, a concentrated market for industrial products, a variety of professional and financial services, and its abundant facilities for administrative transactions as seat of the federal government were all reinforced by a flow of government investments and fiscal incentives that stimulated and enhanced the concentration of economic development in the area.

In the early 1950s, industrial activity in the Basin became especially dynamic and, at a national level, reflected a clear trend towards concentration in the capital

city. The dramatic industrial concentration in the capital during the present century has generated a situation in which the capital city produces almost half of the national industrial production. Recent efforts to redistribute industry elsewhere have apparently produced a relative decline in industrial growth in Mexico City and may have decreased the above percentages of concentration, but nevertheless the area remains heavily industrialized.

The city holds an enormous share of the major financial exchanges, private businesses, and central offices in Mexico. Mexico City also has the largest number of institutions of higher education and centers of culture. Indeed, compared with industry, services show an even higher tendency to concentrate in Mexico City. Many industrial firms that have relocated their manufacturing operations to outlying cities have kept their administrative headquarters in the capital.

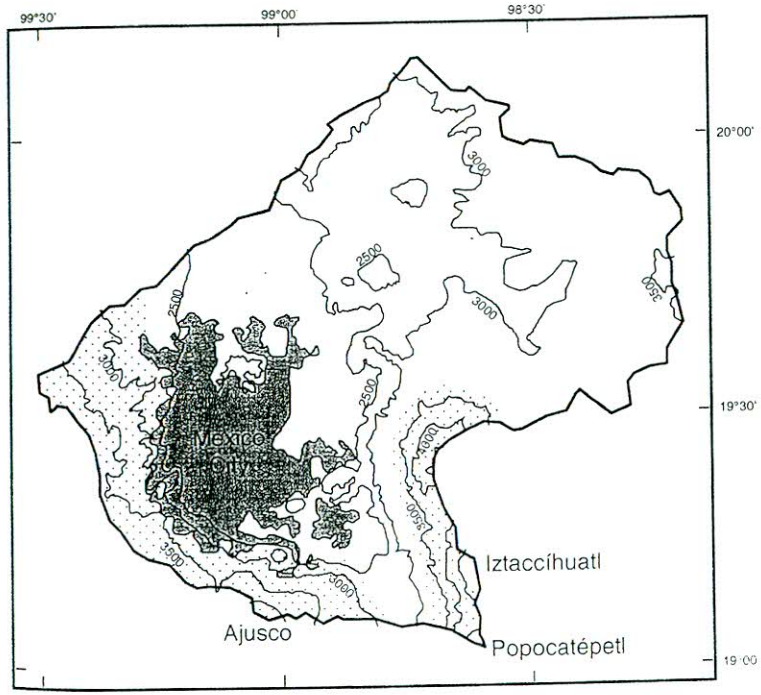

Figure 2.2. Map of the Basin of Mexico. The shaded area in the center represents the extension of the urbanized area in 1990; the dotted areas in the southwest and southeast represent the forested areas of the Basin (see for reference Fig. 2.1). Note the encroachment of the city's growth on the forested slopes of the southwest of the Basin. (Modified from Ezcurra et al. 1999.)

Urban Growth

With more than 15 million inhabitants in 1990, Mexico City is at present one of the largest cities in the world (Table 2.1). And despite a diminished population growth rate (Table 2.1, lower part), its total population is approaching 17 million. In the present century, the city has experienced a remarkable growth characterized by a great centralization of economic activities, notably industry, and high rates of population growth, driven to a large extent by migration of people from rural areas into the city. The population of the city reached one million inhabitants in 1930, more than 5 million in 1960, and more than 15 million in 1990.

However, the lure of the capital, a favorite destination for immigrants from rural or urban areas alike in 1940, gradually lost its appeal. The population began to notice that the concentration of economic, cultural, and political decisions was accompanied by negative side effects, perceived as a deterioration in the overall quality of life. In fact, the migration flows formerly destined for Mexico City now head for smaller metropolitan areas, where they represent an important component of rapid growth. Concomitantly, the capital city tends to export inhabitants, particularly of the middle class, into the periphery of the city or into other cities in the central region of the country, where the quality of life is perceived as more agreeable (Izazola and Marquette 1995).

Even so, the urban area still presents an active process of metropolitanization especially in neighboring territory of the State of Mexico. Although the growth

Table 2.1. Population in Mexico City 1519–2000, and growth rates 1950–2000

	Population (millions)		
Year	Federal District	State of Mexico	Total
1519 (Conquest)	0.3		0.3
1620 (Colony)	0.03		0.03
1810 (Independence)	0.1		0.1
1910 (Revolution)	0.7		0.5
1940 (Cardenist period)	1.8		1.8
1950	3.0		3.0
1960	4.8	0.4	5.2
1970	6.8	1.9	8.7
1980	8.8	5.0	13.8
1990	8.2	6.5	15.0
2000	8.6	9.1	16.7
	Mean annual growth rates per decade (%)		
1950–1960	4.7		5.5
1960–1970	3.5	15.6	5.1
1970–1980	2.6	9.7	4.6
1980–1990	−0.7	2.6	0.8
1990–2000	0.5	3.4	1.1

Source: DDF (1986), Ezcurra et al. (1999), DGE (1990), and INEGI (2000).
Pre-1950 dates have been chosen as approximate indicators and correspond with the important historical dates indicated in parentheses.

rate for the DF and, notably, the central city was negative over the years of 1980 to 1990, the municipalities in the neighboring State of Mexico are still growing at high rates (2.6% per year on average), and some of them have growth rates higher than 10% per year (Ezcurra et al. 1999). It is in these peripheral areas that urban growth is currently causing the stronger impacts on forests and natural ecosystems in terms of land occupation.

In spite of the lagging growth of the city itself, as other nearby metropolitan areas like Cuernavaca, Puebla, Tlaxcala, Pachuca, and Querétaro consolidate their functional integration to the country's capital, the urbanized areas around Mexico City will continue to grow (Garza 1987). In 1990, the metropolitan area concentrated 93% of the inhabitants of the Basin. In later years, however, population in the rest of the Basin has grown at a higher rate than in Mexico City itself (Ezcurra et al. 1999). Should this pattern persist, it may unfold a future characterized by more disperse settlements throughout the Basin. This more extensive pattern of land use may in turn put more pressure on the Basin's natural ecosystems and especially on the peripheral forests.

Physical Expansion

The spatial development of Mexico City until 1950 was characterized by a pattern of concentration in the four central *delegaciones* of the DF which contained around 70% of the urban area at that time. Thereafter the expansion of the city underwent rapid suburbanization that affected the surrounding *delegaciones* and finally produced a spill-over of population into the adjacent municipalities of other states. In this process, the city absorbed agricultural land. Land unsuitable for urbanization, such as the desiccated lake bed of Texcoco to the east, a group of abandoned sand quarries and open-cast mines to the west, and the forested mountain slopes in the south of the Basin, were also converted. To some extent, physical barriers in the south and west have contributed to the restriction of urban growth, because the large and flat valley of the Basin (approximately 2250 meters above sea level) is surrounded by volcanic mountain ranges that open only to the north and the southeast.

The Spanish established the colonial spatial structure of the city with their square grid layout for the central urban area organized around a central square (the *Zocalo*), which had formerly been the ceremonial center of the Aztec city. During colonial times, and even through most of the nineteenth century, this basic structure suffered only minor alterations. The nationalization of the large church landholdings in 1856, however, set important changes in motion. Land around the city was subdivided and sold off, and the upper classes moved to the periphery from their mansions in the city center. The downtown area, in turn, gradually deteriorated and became subdivided for low-income groups. The movement of the rich classes, largely towards the western forested slopes of the Basin, was accelerated by the purposeful construction of roads and avenues (Bataillon and Rivière d'Arc 1973).

The urban area of the Basin expanded dramatically from 360 km^2 in 1960 to 650 km^2 in 1970 (a 57% increase), and to 1114 km^2 in 1980 (an additional increase of 71%) (Graizbord and Salazar 1987). Accelerated urban growth led to the proliferation of illegal, usually poorly urbanized, settlements either in the State of Mexico or in the outskirts of the DF (Ward 1981). Between 1970 and 1975, some southern and western *delegaciones*, such as Tlalpan, Xochimilco, and Cuajimalpa, that harbor a large proportion of the Basin's forests, doubled or tripled their urban area (DDF 1986). This expansion has been in part stimulated by governmental decisions such as the construction of a paved highway to the Ajusco mountain range and the massive construction of large lower-middle-income housing units (mostly for governmental workers) in peripheral locations (DDF 1986). With these new urban expansions, Mexico City began to become connected across the mountain slopes with the states of México, Morelos, Puebla, and Hidalgo.

In its outward growth, the city is also changing internally. The central city is experiencing a depopulation process that started slowly in the 1970s and has continued at progressively higher negative growth rates. In a similar way, the inner ring of the city (but outside of the central city), after receiving a considerable population increase in the 1940 to 1960 period, has began to show the first signs of a depopulation process with negative growth rates after 1980. The same decade reveals particularly high growth rates in the intermediate and outer rings, with the former registering a growth rate of 12% and the latter a rate of 7%. Although these high rates decreased to between 4% and 6% in the following decade, the peripheral municipalities still have the fastest-growing populations of the megalopolis, enhancing the trend to incorporate contiguous municipalities (Ezcurra et al. 1999).

Changes in the Basin's Forests

Broad-Leafed Montane Forests

According to Sanders (1976b), by the time humans colonized the Basin of Mexico, particularly in the Texcoco region, a conifer forest covered the mountain ridges and the higher piedmont, whereas a moist broad-leafed (mesophyllous) forest, rich in oaks, probably covered the lower. Rzedówski (1969) reports that many of the moist ravines in the south and southeastern parts of the basin might have been occupied by this type of forest. Nowadays, the mesophyllous forest is best represented on the lower western slopes of Iztaccíhuatl, as well as on some of the eastern slopes of the Sierra de las Cruces at elevations between 2500 and 3000 m, but not more than 2 km^2 are occupied by this type of vegetation (Ezcurra 1990b). Near Amecameca, a relatively large town in the lower part of the Sierra Nevada, a small forested slope known as Sacromonte (the "Sacred Mount") rises from the alluvial plain. Though it has been deeply disturbed, some elements (e.g. *Quercus rugosa* and *Cupressus lindleyi*) of the original mesophyllous forest still grow on the slope. In contrast to most forests in the Basin of Mexico, this one is rich in epiphytes and ferns. Rzedowski (1969) is of the opinion that this type of vegetation must have been better represented and more continuously distributed in the Basin of Mexico in the past. As a consequence of the deep disturbance it has suffered, probably many of the original elements have been lost.

Pine/Oak Forests

According to Rzedowski (1978) and Domínguez (1975), it is probable that many of the pine communities present in the Basin are of secondary origin, and their characteristic co-occurrence with tussocky grasses known as "*zacatón*" (*Muhlembergia* sp.) is a symptom of disturbance. Wood is cut in these forests for burning and building and also for producing paper. Although today oaks (*Quercus* spp.) cover only dispersed patches of different sizes, they were once very abundant in the Basin. Communities characterized by different species of *Quercus* covered the lower parts of the mountains and some patches of the volcanic substrate formed after the eruption of the Xitle Volcano (Álvarez del Villar 1971; Rzedowski 1975, 1978).

Conifer and oak forests have been deeply disturbed. Since the first settlements appeared in the Basin, these forests have been used as sources of wood for building and burning. Oak trees were also a main source for coal. Wood extraction had already been going for a long time when the Spaniards arrived in the Basin of Mexico. During the Colonial period, however, the rate of extraction increased significantly, because increasingly large amounts of wood were needed to build the new European-style houses of the conquerors. In the first half of the twentieth century, these forests were intensively utilized by three paper factories that established south and west of the city: San Rafael, Loreto, and Peña Pobre. Even zones officially designated as protected areas were given as concessions to the paper factories, as happened in San Rafael.

The Chapultepec Forest

Located to the west of the old downtown, Chapultepec Park is the largest forested section within the urbanized area of Mexico City. A recreational place as early as 1280, Chapultepec had, in Aztec times, a temple for the god Huitzilopochtli. Aztec emperors visited the area for its dense forest and its natural springs, which the ruling class used for bathing. At that time, the Chapultepec Forest was already planted with introduced, non-native plants. During the early colonial period, the Spanish conqueror of Mexico, Hernán Cortés, owned Chapultepec, but by 1530 the colonial government had designated it the public property of Mexico City and granted free entrance to everyone. Today, only 230 hectares of the 438 ha occupied by the original forest remain as a park, and a large proportion of this area has been invaded by exogenous species such as *Eucalyptus* spp.

The zone that surrounds what is now Chapultepec gained economic value towards the end of the Revolution (*circa* 1920), as people from the rural *haciendas* of the Mexican highlands fled from the violent struggle dominating the countryside and sought security in the Basin of Mexico. Many of the workers from

the *haciendas* also fled the Revolution and crowded into the center of the city, prompting the upper classes to seek out and retreat to relatively secluded places. In fact, these migratory forces were one of the major factors giving rise to the incorporation into Mexico City of towns such as Coyoacán, Tacubaya, San Angel, Tizapán, and Tlalpan. By 1930, the pursuit of suburban plots in Mexico City had driven people into the green, mild zones west and south. One of the first manifestations of this preference was Lomas de Chapultepec, a trendy district developed in the 1920s by the new and wealthy postrevolutionary classes, built on lands surrounded or still occupied by the conifer forests that originally characterized the Chapultepec forest. As its name indicates, Lomas de Chapultepec emerged in the gently sloping hills where conifers such as sacred firs (*Abies religiosa*) and the native *ahuehuetes* (*Taxodium mucronatum*) originally grew (Suárez 1974).

Woody Shrub-Lands

Until the beginning of this century, the lava badlands of *El Pedregal*, in the southern part of the Basin, and their shrubby plant communities (see Rzedowski 1954) were considered a hostile environment, and no urban developments were attempted in them for many years. The lack of water flows or lakes, the high permeability of the rocky uneven substrate, and the abundance of dangerous animals, especially snakes, kept people away from *El Pedregal* for centuries. During colonial times, a few important *haciendas* (rural estates) were established in the parts where some soil had developed. The most important *haciendas* were located in zones with oaks and pines. The surrounding zones, like Coyoacán and San Angel, became wheat producers during the colonial period, and the occupation of these lands by large tenants forced the original inhabitants to move to the less favorable environments of *El Pedregal* (Carrillo 1995).

In the early 1950s, an affluent residential district, characterized by large houses of modern architecture with big gardens, began to emerge in *El Pedregal*, which still enjoyed a reputation as a secluded urban district, removed from the turmoils of the growing city. In fewer than 20 years, the original shrubby vegetation cover of the lava flow almost disappeared. Today fewer than 3 km^2 of the original *Pedregal* remain. Small patches can be found on some slopes and even in some gardens, but most of what is left is on the grounds of the campus of the National University (UNAM). The campus was built in the 1950s directly on *El Pedregal*, despite the protests of a small group of citizens that were already aware of the biological importance of this ecosystem. Paradoxically, it has proven crucial that the remnants of *El Pedregal* are on University grounds, because in 1983, a group of students and professors reacted firmly to a proposed urban development of this zone and succeeded in having it declared a protected area, only used for education and research (Rojo 1994). This is one of the few cases in the Basin of Mexico in which the construction of streets and commercial centers has been stopped or redesigned in order to protect a natural zone. Today, the natural reserve harbored by UNAM is the largest natural protected area to be found within an urban area in Mexico. Though small, and insufficient as a formal natural reserve, this area has become extremely important for the conservation and protection of the diversity that evolved around the Xitle lava flows (Rojo 1994). Six years after the area was protected, in 1989, a higher part of *El Pedregal*, in which deep disturbance had already taken place, was declared a protected area, the *Parque Ecológico de la Ciudad de México*. As a result, patches of open and dense oak forests, as well as some well-preserved patches of the characteristic *Sedum* shrubs, enjoy protection. Other patches, colonized by *Buddleia* or covered only by naked basalt and some rare rock vegetation, are also frequent in this region. In the Sierra de Guadalupe, a small representation of the natural xerophilous shrub-lands and some patches of *Eisenhardtia polystachia*, once an abundant dominant species, are still present. As in *El Pedregal*, this shrubby vegetation is rapidly disappearing as urban and industrial settlements appropriate the land.

Riparian and Lacustrine Forests

The lower regions of the Basin were covered by discontinuous vegetation types, including willows and other riparian trees along the borders of the lake, oak forests in the drier soils, and seasonally flooded patches occupied by aquatic species. Aquatic vegetation was once abundant in the Basin of Mexico; Rzedowzki (1975) presumes the existence of several endemic species that are now locally extinct. Some of these inferences are based on pollen profiles for the Teotihuacan Valley (Sanders et al. 1979), where the first large Mesoamerican urban settlement was established (Niederberger 1987a, 1987b). In these profiles, pollen of arboreal genera such as *Pinus*, *Abies*, *Quercus*, *Alnus*, and *Salix* was found together with that of herbaceous species. The abundance of pollen of sedge species (family Cyperaceae) in the older sediments is especially important, because it highlights the large original extension of the lake system.

However, the abundance of the pollen of aquatic species tends to diminish as corn records increase. This suggests that the shores of Lake Texcoco were gradually occupied by cornfields which replaced the riparian forests and the aquatic vegetation of the seasonally flooded shores. That is, the decline of riparian and lacustrine forests started far before the arrival of the Spaniards to Mexico. The ancestral springs and water-flows of Teotihuacan allowed intensive cultivation of the adjoining lands (Millon 1970; Sanders 1976a). The loss of these springs was probably related to the environmental degradation induced by human overuse of the natural resources, which seems to have played an important role in the decline of Teotihuacan (Ezcurra 1992, 1995; Sanders 1976a).

The Driving Forces of Environmental Change

The rapid rise and the enormous power of the Aztec state were based on the political control of much of Mesoamerica and on the subordination of hundreds of different groups that paid tribute to the emperor. Aztec wealth depended to some

with the depressed rural areas from which most of the immigrants come. It is evident that such public services as education, drinking water, and drainage are rare in the poorer areas of central and southern Mexico that provide at a cheap price many of the products that are consumed in the Basin. These areas also generate most of the new immigrants that move into the area. In the Mixtec Region of Oaxaca, for example, the proportion of houses with drinking water is less than 4%, most of the towns do not have drainage, and the mean literacy and educational levels reach only elementary (primary school) level (Ezcurra et al. 1999).

In short, the population growth rate emerges as the main driving variable of environmental change. Between 1940 and 1980, with a growth rate of approximately 4% to 5%, the population doubled every 15 years, and with it the demand for water, electricity, transportation, housing, and other services. The number of cars has grown at a rate even higher than the population, doubling every decade. These accelerated growth rates have exacted a huge environmental toll, as more people necessarily use more resources and generate more waste and pollution.

Economic Development and Environmental Degradation

For nearly 2000 years, the Basin of Mexico has been one of the most densely populated areas of the world. During most of these 2000 years, the inhabitants of the Basin have used their political power to obtain advantages over other areas of the nation. The economic development of Mexico City after the Mexican Revolution (1930–1997) was promoted by governmental policies, local private enterprises, and foreign capital. The main objective has been massive industrial development, frequently at the expense of social equality. The direct driving force of urban growth has been the use of public resources allocated to the industrial and financial sectors. As a result of the rapid but highly unbalanced growth, the Basin now confronts an unsustainable pattern of urbanization and land use as well as an uneven and socially conflictive distribution of population and wealth.

Despite the existence of a wealthy social sector that includes government officials, private executives, public bureaucracy, and a large middle class with a high capacity to consume, most of the city consists of poor quarters inhabited by workers and underemployed people. These social groups consist mainly of immigrants that arrived in the metropolis in the decades between 1960 and 1980 and previously formed part of rural Mexico. They came to Mexico City in search of employment and some of the services and goods that the Basin seems to promise.

The concentration of wealth and the rapid development of the Basin was not accompanied by a concurrent emphasis on environmental protection. Decision-makers prioritized economic growth at all costs, while taking, in general, a complacent view in regard to environmental deterioration under the assumption that the technological development associated with rapid economic growth would eventually be able to restore degraded ecosystems and remediate environmental damage.

The Vulnerability of the Basin's Forests

Mexico City now spreads over approximately 1300 km^2 and has a population of around 17 million. The city now spills over the mountains into areas beyond the boundaries of the Basin, like the adjacent cities of Toluca and Querétaro and to a lesser extent Cuernavaca and Puebla, forming an immense conurbation complex. The accelerated peripheral expansion of the city has meant the deforestation of many of the surrounding areas which formerly acted as hydrological regulators for the severely disrupted water cycle of the basin.

Most (some 90%) of the megalopolis is occupied by built-up or paved urban spaces, whereas less than 10% of it is occupied by parks, private gardens, and public spaces. Taking into account the whole conurbation that forms this megacity, some 20 million people live in the Basin, enjoying only 5 m^2 of green area per person (Ezcurra et al. 1999). In some parts of Mexico City the situation is substantially worse; many inhabitants have less than 1 m^2 per person of open public spaces for recreational use. This is the case in Atzcapotzalco, a northern industrial quarter, and many other industrial areas. Mexico City has changed from the patchy mixture of urban and rural environments that was typical of the first half of the twentieth century to an overcrowded urban environment with little vegetation and open space for its inhabitants.

Unless new and more efficient wastewater treatment and recycling methods are adopted soon, meeting the growing demands for domestic water will require in the long term either a higher rate of pumping from the basin's aquifer (further increasing the current problem of subsidence) or, alternatively, the pumping of some 40 $m^3 s^{-1}$ of water from outside the Basin. Other external basins have been studied as potential water sources, but all these plans imply an enormous energy expense (on the order of 1.5 million MW-hour per year) to pump such vast volumes of water. Additionally, the extraction of water from other regions will necessarily generate significant ecological alterations and water shortages in the basins from where the water is to be pumped.

Factors Leading to Forest Endangerment

Most of the Basin's 20 national parks and protected areas were established between 1936 and 1939. Only one national park, Desierto de los Leones, had been established before this period (1917). Additionally, in 1983, a protected area was created in a small part of El Pedregal de San Angel, to protect the remnants of the vegetation and fauna that are endemic to the *pedregales* (lava flows) of the southern part of the Basin.

Other recently protected zones include part of the central region of the El Ajusco range, in the south of the metropolis in Lomas del Seminario. Illegal settlements had begun to be established there in the 1980s, endangering these humid southern ranges which are the most important source of water recharge into the Basin's aquifers, largely regulated by the existing remnants of the original vegetation. The area is now a reserve (*Parque Ecológico de la Ciudad de México*)

with a center for research and educational activities. Other zones, such as El Cerro de Guadalupe, had also been colonized by squatters (*paracaidistas*), a process that in the past has been the spearhead of irregular urban expansion. The squatters have been moved, and the Cerro de Guadalupe is now being reestablished as a protected zone. The future of these reserves is not assured because population pressure on these areas is strong, and both economic and political interests could at some point acquiesce to their occupation by squatters. If this were to happen, the circle of unbridled growth and environmental destruction would recommence.

Most of the reserves in the Basin no longer represent true natural protected areas. Many are so deteriorated they can hardly be considered "green" areas anymore. Some of them have lost all their vegetation and been incorporated into the urbanized area. The deterioration of the national parks of the Basin of Mexico commenced almost immediately after their creation. For example, during the years of 1946 to 1952, one of Mexico's most important paper factories was officially allowed to log the forests in the protected parts of El Ajusco. Desierto de los Leones, Cumbres del Ajusco, Dinamos de Contreras, and Miguel Hidalgo are among the few zones that can still be considered effective protected zones, although they face the problem of increasing human use for recreation with increasing erosion from hiking trails and the additional problem of tree dieback owing to high levels of atmospheric pollution. The new reserves of *El Pedregal* and *Lomas del Seminario* have also managed to persist without being invaded or overly degraded by human use, although from a conservationist point of view, their size is much smaller than it should be for such a protected zone.

Most of the green areas in the Basin of Mexico are treated as recreational zones, with no ecological or conservationist purpose. Their management, design, and spatial distribution has been strongly dependent on recreational considerations. Green areas contain many nonindigenous species. This is the case with many of the most common tree species such as *Eucalyptus* sp., an Australian genus; *Schinus molle*, a South American tree; *Jacaranda mimosaefolia*, from Brazil; or *Ligustrum lucidum* from Asia. The original species of the Basin are only rarely used for planting, because the alien species frequently have higher growth rates, fewer predators, or both. These are important considerations, but this practice is accelerating the depletion of the original richness of environments and species in the Basin. The region is progressive losing its fauna because herbivores can no longer find the native plants from which they feed.

Summary

The urbanization process affects forests directly through the occupation and destruction of naturally vegetated areas. In the Basin of Mexico, air pollution, another consequence of urbanization, is also a debilitating stress on sensitive species of both natural and cultivated vegetation. Forest dieback in the surrounding mountains, triggered by atmospheric pollution, can in some places increase the degradation of the system of water recharge of the Basin's aquifer and hence its long-term hydrological sustainability.

The protection of these remaining reserves is of the utmost importance and must be achieved at all costs. Vegetated spaces are relevant not only to the quality of life of city dwellers but also to the hydrological cycle of the Basin. In the design of programs intended to rescue reserves invaded by urban settlements, the social factor merits consideration. People who are forced to leave these zones need an alternate place to settle without again damaging the environment. Their quality of life must also be improved with the move; otherwise, the occupation of the forested slopes of the Basin and the subsequent degradation of the Basin's forests will continue. It is evident that the protection of the few remaining forests in the Basin of Mexico and the restoration of as much as possible of those that have been affected by urban development should be a priority in any government program intended to rescue the Basin of Mexico from the ecological crisis it faces.

References

Aguilar, A.G., Ezcurra, E., García, T., Mazari-Hiriart, M., and Pisanty, I. 1995. The Basin of Mexico. In *Regions at Risk: Comparison of Threatened Environments*, eds. J.X. Kasperson, R.E. Kasperson, and B.L. Turner II, pp. 304–366. Tokyo: The United Nations University Press.

Álvarez del Villar, J. 1971. Panorama ecológico del Valle de México. In *IMERNAR, Mesas Redonadas Sobre Problemas de Ecología Humana en la Cuenca del Valle de México*, pp. 3–41. México, D.F.: Instituto Mexicano de Recursos Naturales Renovables.

Armillas, P. 1971. Gardens on swamps. *Science* 174:653–661.

Bataillon, C., and Rivière d'Arc, H. 1973. *La Ciudad de México*, Colección SepSetentas, no. 99, Translators C. Montemayor and J. Anaya. México, D.F.: Secretaría de Educación Pública.

Calderón, E., and Hernández, B. 1987. Crecimiento actual de la población de México. *Cienc. Desarrollo* 76:49–66.

Carrillo, C. 1995. *El Pedregal de San Ángel*. Mexico, D.F.: Coordinación de la Investigación Científica, Universidad Nacional Autónoma de México.

Coe, M. 1964. The chinampas of Mexico. *Sci. Am.* 211:90–98.

Cook, M. 1947. The interrelation of population, food supply, and building in pre-Conquest Central Mexico. *Am. Anti.* 8:45–52.

Corona, V.R. 1991. Confiabilidad de los resultados preliminares del XI Censo General de Población y Vivienda de 1990. *Est. Demográficos y Urbanos (El Colegio de México)* 6:33–68.

de Humboldt, A. 1811. *Essai Politique sur le Royaume de la Nouvelle–Espagne. (Avec un Atlas Physique et Géographique, Fondé sur des Observations Astronomiques, des Mesures Trigonométriques et des Nivellements Barométriques)*. 5 Vols. Paris: F. Schoell.

DDF. 1986. *Manual de Planeación, Diseño y Manejo de las Áreas Verdes Urbanas del Distrito Federal*. México, D.F.: Departamento del Distrito Federal.

DGE. (Dirección General de Estadística). 1990. *VI a XI Censo General de Población y Vivienda, Estados de Hidalgo, Mexico, Tlaxcala y el Distrito Federal, 1940–1990*. México, D.F.: Secretaría de Industria y Comercio e Instituto Nacional de Estadística, Geografía e Informática (INEGI).

Domínguez, V. 1975. *Estudio Ecológico del Volcán Popocatépetl, Estado de México.* Unpublished B.Sc. Thesis. México, D.F.: Facultad de Ciencias, Universidad Autónoma Nacional de México.

Ezcurra, E. 1990a. *De las Chinampas a la Megalópolis: El Medio Ambiente en la Cuenca de México.* Serie La Ciencia desde México. México, D.F.: Fondo de Cultura Económica.

Ezcurra, E. 1990b. Basin of Mexico. In *The Earth as Transformed by Human Action: Global, and Regional Changes in the Biosphere over the Past 300 Years*, eds. B.L. Turner II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, and W.B. Meyer, pp. 577–588. New York: Cambridge University Press with Clark University.

Ezcurra, E. 1992. Crecimiento y colapso en la Cuenca de México. *Ciencias* 25:13–27.

Ezcurra, E. 1995. Demographic, and resource changes in the Basin of Mexico. In *Global Land Use Change: A perspective from the Columbian Encounter*, eds. B.L. Turner II, A. Gómez Sal, F. González Bernáldez, and F. di Castri, pp. 377–396. Madrid: Consejo Superior de Investigaciones Científicas.

Ezcurra, E., and Mazari-Hiriart, M. 1996. Are megacities viable? A cautionary tale from Mexico City. *Environment* 38:6–15, 26–35.

Ezcurra, E., Mazari-Hiriart, M., Pisanty, I., and Aguilar, A.G. 1999. *The Basin of Mexico. Critical Environmental Issues and Sustainability.* Tokyo: The United Nations University Press.

Garza, G. 1987. Introducción. In *Atlas de la Ciudad de México*, ed. G. Garza, pp. 11–15. México, D.F.: Departamento del Distrito Federal—El Colegio de México.

Goldani, A.M. 1977. Impacto de los inmigrantes sobre la estructura y el crecimiento del área metropolitana. In *Migración y Desigualdad Social en la Ciudad de México*, eds. H. Muñoz, O. de Oliveira, and C. Stern, pp. 129–137. México, D.F.: Instituto de Investigaciones Sociales, Univ. Nac. Aut. de México, and El Colegio de México.

Graizbord, B., and Salazar, H. 1987. Expansión física de la Ciudad de México. In *Atlas de la Ciudad de México*, ed. G. Garza, pp. 120–125. México, D.F.: Departamento del Distrito Federal—El Colegio de México.

INEGI. 2000. *XII Censo General de Población y Vivienda, 2000.* Aguascalientes, México: Instituto Nacional de Estadística, Geografía e Informática (INEGI).

Izazola, H., and Marquette, C.M. 1995. Migration in response to the urban environment: Out-migration by middle-class women and their families from Mexico City after 1985. *Geog. Polonica* 64:225–256.

Millon, R. 1970. Teotihuacan: Completion of a map of the giant ancient city in the Valley of Mexico. *Science* 170:1077–1082.

Niederberger, C. 1987b. *Paléopaysages et Archéologie Pré-urbaine du Bassin de Mexico (Mexique)*, 2 Vols. Mexico, D.F.: Centre d'êtudes Mexicaines et Centraméricaines, Etudes Mésoaméricaines.

Niederberger, C. 1987a. De la prehistoria a los primeros asentamientos humanos en la Cuenca de México. In *Atlas de la Ciudad de México*, ed. G. Garza, pp. 40–43. México, D.F.: Departamento del Distrito Federal—El Colegio de México.

Parsons, J.R. 1976. Settlement, and population history of the Basin of Mexico. In *The Valley of Mexico: Studies in Prehispanic Ecology, and Society*, ed. E.R. Wolf, pp. 69–100. Albuquerque, New Mexico, USA: University of New Mexico Press.

Partida, V. 1987. El proceso de migración a la Ciudad de México. In *Atlas de la Ciudad de México*, ed. G. Garza, pp. 134–139. México, D.F.: Departamento del Distrito Federal—El Colegio de México.

Pick, J.B., and Butler, E.W. 1997. *Mexico Megacity.* Boulder, Colorado, USA: Westview Press.

Rojo, A. (ed.) 1994. *Reserva Ecológica "El Pedregal" de San Ángel: Ecología, Historia Natural y Manejo.* México, D.F.: Universidad Nacional Autónoma de México.

Rzedowski, J. 1954. Vegetación del Pedregal de San Ángel. *An. Esc. Nac. Cienc. Biol.* 8: 59–129.

Rzedowski, J. 1969. Notas sobre el bosque mesófilo de montaña en el Valle de México. *An. Esc. Nac. Cienc. Biol.* 18:91–106.

Rzedowski, J. 1975. Flora y vegetación en la cuenca del Valle de México. In *Memoria de las Obras del Sistema del Drenaje Profundo del Distrito Federal*, Vol. I, pp. 79–134. México, D.F.: Talleres Gráficos de la Nación.

Rzedowski, J. 1978. *Vegetación de México.* México, D.F.: Ed. Limusa.

Sala Catalá, J. 1986. La localización de la capital de Nueva España, como problema científico y tecnológico. *Quipu* 3:279–298.

Sanders, W.T. 1976a. The agricultural history of the Basin of Mexico. In *The Valley of Mexico: Studies in Prehispanic Ecology and Society*, ed. E.R. Wolf, pp. 101–159. Albuquerque, New Mexico, USA: University of New Mexico Press.

Sanders, W.T. 1976b. The natural environment of the Basin of Mexico. In *The Valley of Mexico: Studies in Prehispanic Ecology and Society*, ed. E.R. Wolf, pp. 59–67. Albuquerque, New Mexico, USA: University of New Mexico Press.

Sanders, W.T., Parsons, J.R., and Santley, R.S. 1979. *The Basin of Mexico: Ecological Processes in the Evolution of a Civilization.* New York: Academic Press.

Segura-Burciaga, S.G., and Martínez-Ramos, M. 1994. La introducción de especies a comunidades naturales: El caso de *Eucaliptus resinifera* Smith (Myrtaceae) en la reserva "El Pedregal" de San Ángel. In *Reserva Ecológica "El Pedregal" de San Ángel: Ecología, Historia Natural y Manejo*, ed. A. Rojo, pp. 177–186. México, D.F.: Universidad Nacional Autónoma de México.

Stern, C. 1977. Cambios en los volúmenes de migrantes provenientes de distintas zonas geoeconómicas. In *Migración y Desigualdad Social en la Ciudad de México*, eds. H. Muñoz, O. de Oliveira, and C. Stern, pp. 115–128. Mexico, D.F.: Universidad Nacional Autónoma de México, and El Colegio de México.

Suárez, L. 1974. *De Tenochtitlan a México*, Series Archivo del Fondo 16. México, D.F.: Fondo de Cultura Económica.

Unikel, L. 1974. *La dinámica del crecimiento de la Ciudad de México. Colección SEP–Setentas.* México, D.F.: Secretaría de Educación Pública.

Valverde C., and Aguilar, A.G. 1987. Localización geográfica de la Ciudad de México. In *Atlas de la Ciudad de México*, ed. G. Garza, pp. 19–22. México, D.F.: Departamento del Distrito Federal, and El Colegio de México.

Ward, P. 1981. Mexico City. In *Problems and Planning in Third World Cities*, ed. M. Pacione, pp. 124–147. London: Croom Helm.

Whitmore, T.M., and Turner II, B.L. 1986. *Population Reconstruction of the Basin of Mexico: 1150 B.C. to Present.* Technical Paper 1, Millennial Longwaves of Human Occupance Project. Worcester, Massachusetts: Clark University.

Whitmore, T.M., and Turner II, B.L. 1992. Landscapes of cultivation in Mesoamerica. In *The Americas before and after 1492: Current geographical research*, ed. K.W. Butzer. Special edition, Annals of the *Assoc. Am. Geog.* 82:401–425.

Whitmore, T.M., Turner II, B.L., Johnson, D.L., Kates, R.W., and Gottschang, T.R. 1990. Long-term population change. In *The Earth as Transformed by Human Action. Global, and Regional Changes in the Biosphere over the Past 300 Years*, eds. B.L. Turner II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, and W.B. Meyer, pp. 25–39. New York: Cambridge University Press with Clark University.