featured article

Mapping Land Degradation Factors in Mexico

María C. García and Graciela Pérez

Traditional and automated cartographic methods were used to compile a comprehensive map of environmental problems in Mexico. The map is part of the recently published *Atlas Nacional de México*. This paper outlines the procedures followed during the collection and analysis of data through to its cartographic expression. The recent increase in the publication of environmental maps at regional, national and global scales may increase awareness of the threatening effects of man-induced environmental disturbances.

INTRODUCTION

Presently, land degradation is a popular issue because it is one of the principal problems that modern societies have to face the world over. It is commonly argued that man's technological ability to bring about great changes in the environment has in many cases overwhelmed nature's system. Natural sources of pollution such as dust particles from volcanic eruptions, methane and hydrogen sulfide gases produced by decay in marshes, and cyclic forest fires are considered minor threatening factors, since these pollutants are maintained at a level that allows regulation by complex dynamic ecosystem processes (Purdom and Anderson 1980).

Environmental problems increased dramatically in Mexico during the 1950's. However, it was not until twenty years later that several institutions undertook serious projects to study and solve these problems. Information on pollution and land degradation in Mexico at national (Toledo et al 1989), state or regional levels (SEDUE 1983-1986) is often either fragmented or too general. Environmental information is published mainly in papers, books, and a profusion of brochures, but it is rarely presented in maps (SAHOP 1976).

The Environment section of the 1990 *Atlas Nacional de México* is likely to be the first extensive attempt to cartographically describe the current situation of environmental problems and policies of the country at a national level. The Ministry of Agriculture published a map on environmental problems at a very general level (SAHOP 1976). *The Atlas del Golfo y del Caribe de México* (Centro de Ecodesarrollo y Secretaria de Pesca 1988), concerned with the problems derived from oil extraction and oil spillage, is an example of a regional environmental atlas.

Devoting a special section to environmental problems in a national atlas is a new phenomenon. Czechoslovakia in 1983 and Cuba in 1989 published national atlases containing sections on environmental issues. Other atlases treat these topics but include them within several sections, as for example the *National Atlas of the United States of America* (U.S. Geological Survey 1970), and the *Hydrological Atlas of Canada* (Ministry of Supply and Environment of Canada 1978). There are some examples of regional environmental atlases such as the *Environmental Atlas of the Greater Anchorage Area Borough, Alaska* (Selkregg 1976) and of atlases on more specific environmental topics like *Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas* (Air Pollution Control Association 1970). Finally it is important to mention the recently published *Atlas of the Environment: The Most Up-to-Date Report on the Ecological State of the World* (Geoffrey 1990).

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THE ATLAS NACIONAL DE MÉXICO

More than 300 Mexican specialists from several universities and governmental institutions have contributed to the *Atlas Nacional de México*. This atlas consists of three volumes, with 163 sheets (92 x 66 cm) and 600 color maps. Topics are divided into seven sections: General Maps, History,

Society, Nature, Environment, Economy and Mexico in the World. Map scales include 1:4,000,000; 1:8,000,000; 1:12,000,000 to 1:16,000,000.

Volume I consists of a general introduction to the country in several general maps. The section on History describes the main events of the prehispanic, colonial, and the 19th century up to the Mexican revolution of 1910. Maps of the distribution of present population and of its main features (migration, urban systems, housing, education, culture and health) are grouped in the Society section.

Volume II is divided into Nature and Environment sections. The former section outlines the physical and biotic characteristics of the country. The latter shows the influence of man on the environment. It depicts the present level of disturbance of the main constituents of the environment (soil, water and vegetation). Some maps in this section describe the relationship between population and environment; others represent an evaluation of the impact on historically valued resources (cultural patrimony). Finally, one composite map evaluates the current conditions of the natural components of the environment.

Finally, **Volume III** deals with the most important economic activities of the country including agriculture, livestock raising, forestry, the oil industry and tourism. The last section of the atlas — Mexico in the World — depicts the international relations of the country.

This article describes the cartographic procedure followed during the production of the 1:4,000,000 scale Land Degradation Map which appears in the the Environment section of Volume II in the 1990 *Atlas Nacional de México*. It focuses on man's impact on the land while other maps in this section address hydrologic and atmospheric pollution.

Environmental degradation brought on by deforestation, forest fires, erosion, livestock grazing, oil, thermoelectric, chemical and other industries, as well as the effect produced by the infrastructure of human settlements and tourism have been mapped. The distribution of these elements and their environmental impact are addressed in cartographic form for the entire Mexican Republic.

METHODOLOGY

Evaluating land degradation factors and their consequences requires a holistic consideration of multiple interrelations between nature and society. However, owing to the complexity of the topic and the national scale at which it was to be treated we found it became necessary to select only the main factors affecting natural resources. Quality and amount of available information determined which factors were included and which had to be ignored.

Statistical data were provided by several governmental institutions including the Ministry of Ecology and Urban Development (SEDUE), Ministry of Agriculture and Water Resources (SARH), Institute of Forestry Research (INIF), and the Oil Company (PEMEX). Cartographic sources included various thematic maps dealing with industry (Perez 1984), transport (Chias *et al* 1989) and population (Gutierrez and Gonzalez 1989) as well as the analysis of information provided by newspapers on this topic covering a five year period.

Available information was analyzed, processed, and compiled on four main maps: a base map, a vegetation map, a point symbol map, and a polygon map representing degradation factors. Selection of the type of cartographic symbol to use for the different factors was based on the amount and accuracy of the available data and was constrained by a concern for visual clarity. During the printing process, these four maps were integrated into one.

Computer-assisted methods were used in several stages: to draw the vegetation map, to analyze the effect of several disturbance factors on a specific area, and to measure deforested and eroded areas, as well as the surface occupied by different vegetation types. The main software used was MICROMAP and AU220. However, the final map was produced conventionally.

Description of maps

To reduce complexity, we decided to depict only state boundaries and major main rivers on the base map.

Vegetation map

Existing recent vegetation maps of Mexico contained serious contradictions, owing mainly to the variety of scales and classification criteria. Taking into account that it was not possible to update vegetation data in a short term, and that there were no valid criteria for selecting a primary map source, we decided to compile a new map from information derived from other existing map sources: Flores *et al* 1971; Rzedowski 1978; SAHOP 1981; INEGI 1980-1985; and SARH 1976. These maps were digitized to standardize scale and to make comparison possible. Subsequently they were analyzed and a new version of the vegetation map at a scale of 1:4,000,000 was compiled. The vegetation classification used for this new map consisted of: rainforest; tropical subdeciduous forest; dry deciduous forest; thorny forest; xerophytic shrub; temperate forest; grassland; and low evergreen cloud forest (after Rzedowski 1978). Crops, grasslands, and secondary vegetation are also indicated on this map since they are important indicators of vegetation disturbance.

Available information was analyzed, processed, and compiled on four main maps. During the printing process these were integrated into one.

Point symbol degradation map

This map contains information on the distribution and magnitude of forest fires, industry, and the main urban settlements of Mexico. Forest fires are considered a direct impact factor (affecting land cover directly) while industry and urban settlements are indirect factors.

Forest fires

The available data on forest fires was so detailed (at the county level) and important to highlight, we decided to represent the distribution of fires as well as their level of impact on the forest.

Dot symbols were used to represent this factor; the size of the dots indicates the number of forest fires per year (1-10, 11-100 and 101-300) and colors show the surface affected (5-500, 501-10,000 and 10,000-30,000 hectares). Combining these data affords the user a general overview of the effect of fire. One can easily appreciate that most of the fires of Mexico have a low to medium impact on resources. Colors were selected such that lighter tones represent low impact and darker tones represent high levels of impact (Figures 2 and 4).

Industrial impacts

Different types of symbols were used to represent the distribution of highly polluting industries. In order to be systematic and for the sake of clarity, the same color gradient used for forest fires was used for the industry map legend (pink for low, orange for medium and red for a high level of impact). Oil, thermoelectric and nuclear power industries are indicated in black since they represent the most hazardous type of industry.

The evaluation of the three levels of degradation (low, medium and high) was based on records of emission volume and the number of industries. Industry types were selected according to the type of pollutant they were discharging into the environment.

Urban settlements

The impact of urban settlements is expressed by graduated circles (numbers of inhabitants in 1980, the year of the last census). The area of these settlements is indicated by two tones of blue.

Area symbols/degradation map

This map contains information on the environmental impact of erosion, atmospheric pollution and tourism. Of these three elements, the erosion problem was the most difficult to represent since it affects about 75 percent of the country. A fine hachure pattern was thus chosen to identify

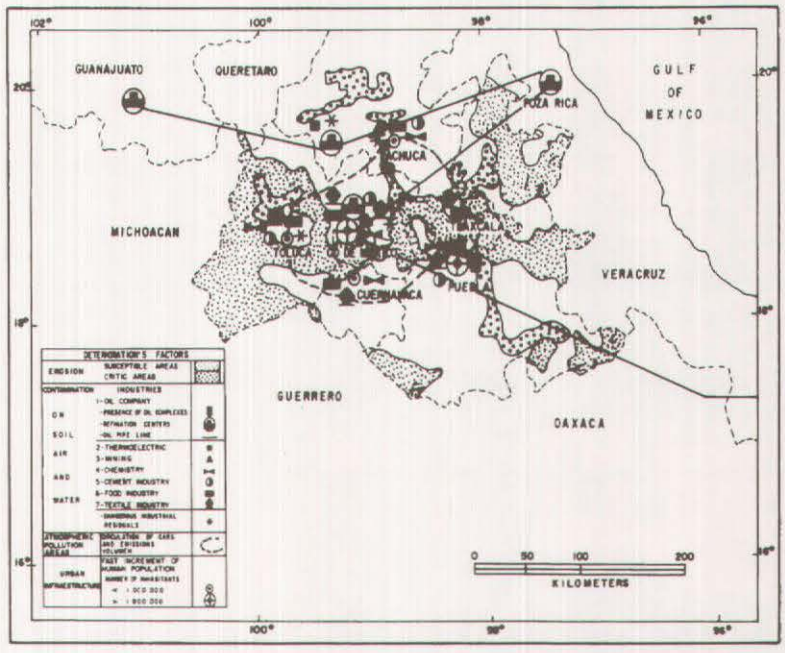


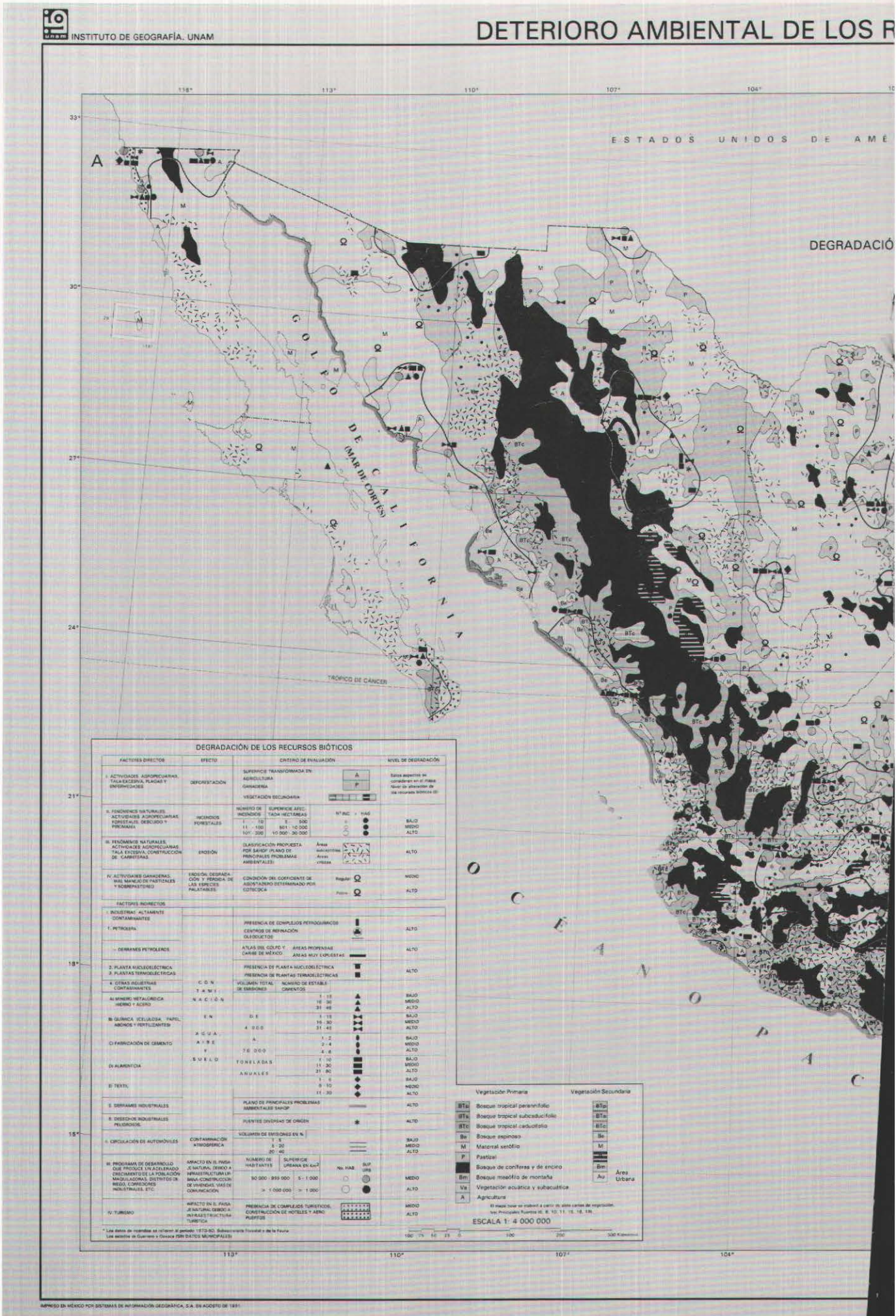
Figure 1: Compilation worksheet of erosion susceptibility, industrial impacts, atmospheric pollution and urban population in central Mexico.

eroded areas (Figures 1 and 3). Two different tones of brown were used to indicate either moderate or strong impact on the landscape.

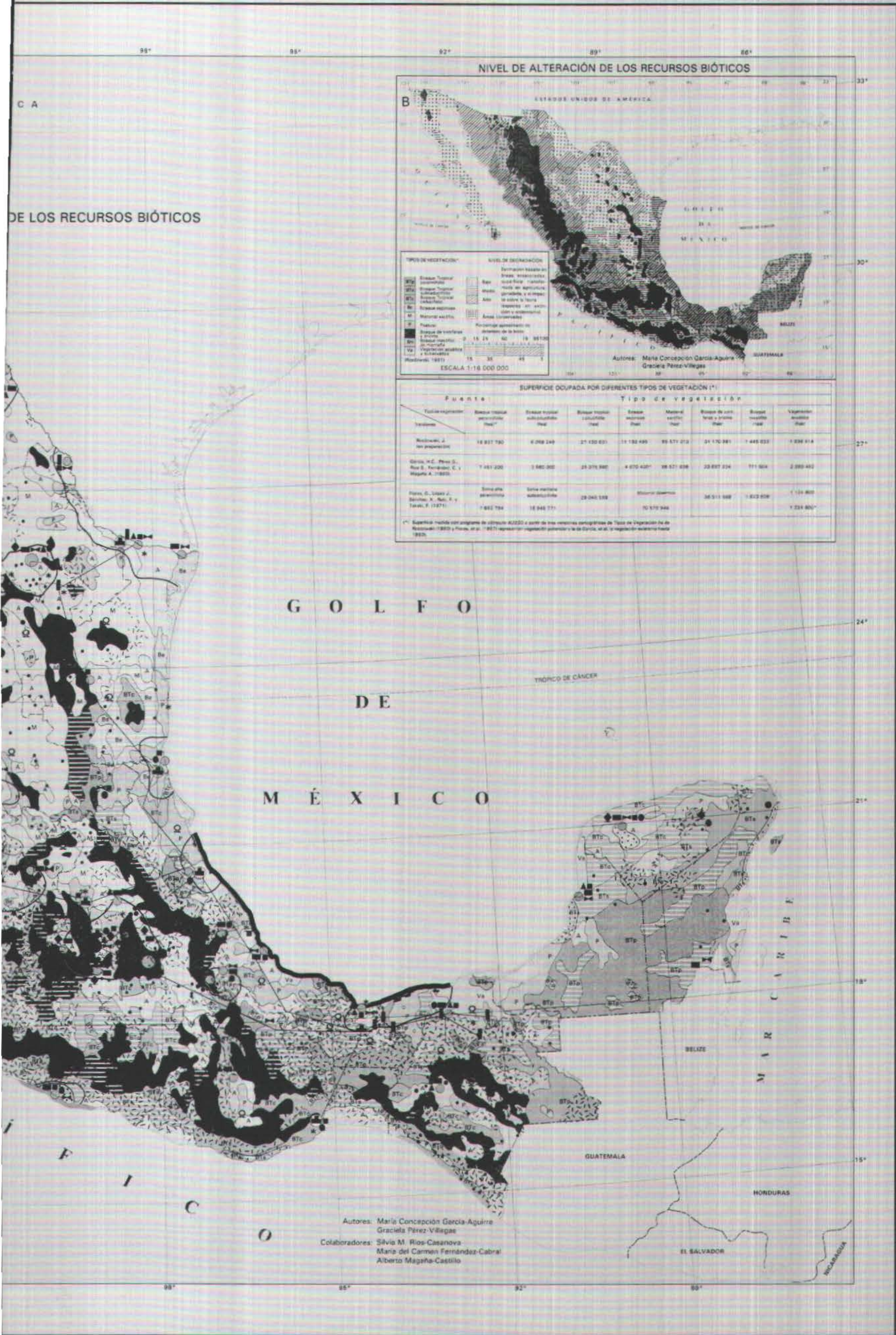
Erosion problems in Mexico are related to the strongly dissected topography that dominates the country (about 75 percent of the landscape is volcanic). Climate, the mismanagement of crops and grazing activities, and highway construction also contribute to the problem.

The impact of tourism is closely related to urban settlements. This element has hardly been addressed as an important degradation factor in environmental literature. However, the recent trend to build giant resort centers has adversely affected the environment and thus this element was included in the map.

Finally, a general estimate of atmospheric pollution was included to focus attention on the lethal effects of some of these pollutants on the health of population. Areas immediately affected by atmospheric pollutants produced by cars and industries are depicted by three different types of lines. Considering that the reported emission volumes are not very



Original in color, 92cm x 66cm.


C A
DE LOS RECURSOS BIÓTICOS
NIVEL DE ALTERACIÓN DE LOS RECURSOS BIÓTICOS
B
ESTADOS UNIDOS DE AMÉRICA
ESCALA 1:16 000 000
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BELICE
GUATEMALA
GOLFO
DE
MÉXICO
TRÓPICO DE CÁNCER
MAR CARIBE
BELIZE
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María del Carmen Fernández-Cabral
Alberto Magaña-Castillo
98°
95°
92°
89°
86°
33°
30°
27°
24°
21°
18°
15°

SUPERFICIE OCUPADA POR DIFERENTES TIPOS DE VEGETACIÓN (*)

Fuente / Tipo de vegetación	Bosque tropical perennifolio (ha)	Bosque tropical subcaducifolio (ha)	Bosque tropical caducifolio (ha)	Bosque espinoso (ha)	Matorral xerófilo (ha)	Bosque de coníferas y encino (ha)	Bosque mesófilo (ha)	Vegetación acuática (ha)
Rzedowski, J. (en preparación)	16 837 780	6 058 249	27 130 631	11 132 495	95 571 213	31 170 381	1 445 833	1 836 914
García, H.C., Pérez G., Ruiz E., Fernández, C. y Magaña A. (1993)	7 451 200	3 580 300	25 375 980	4 070 420*	98 571 638	33 837 334	771 904	2 280 402
Flores, O., López J., Sánchez, X., Ruiz, F. y Takaki, F. (1971)	Selva alta perennifolia 7 682 794	Selva mediana subcaducifolia 16 946 771	29 040 539	Matorral desértico 70 570 946		36 511 568	1 623 608	1 124 800 / 1 224 800*

(*) [illegible]

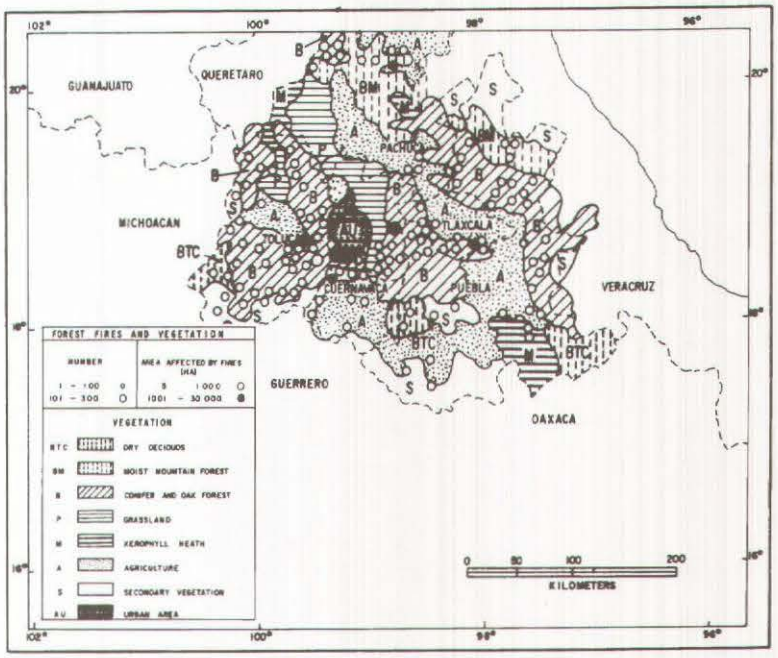

Figure 2: Compilation worksheet depicting vegetation types and forest fire locations in central Mexico.

accurate, an estimate was made on the basis of size of the urban settlements and the number of industries therein (Figures 1 and 3).

Integration of the land degradation map

As indicated above, these four maps were integrated during the printing process. A black and white halftone version of the final color map is reproduced as an insert to this publication at forty percent of original size.

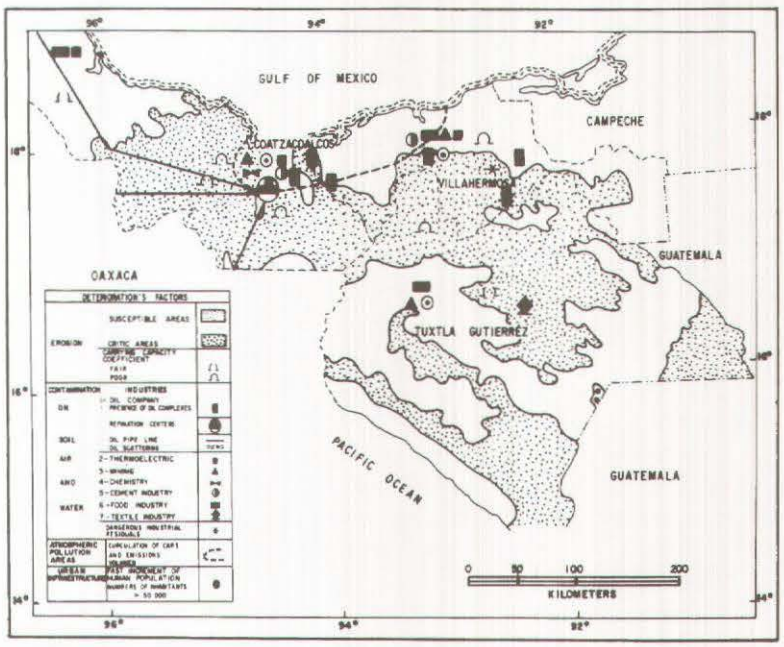

Figure 3: Compilation worksheet of erosion susceptibility, industrial impacts, atmospheric pollution and urban population in the isthmian area of Mexico.

The Central and the Isthmian regions of Mexico are most affected by human activities. Figure 1 shows the major industrial complexes of the country that are concentrated near the capital. Figure 2 shows the distribution of forest fires in this area and the type of vegetation they affect.

The main oil industry complexes are located in the Isthmian region (Figure 3). The impact of this industry is a more important environmental deteriorating factor in this area than forest fires (Figure 4).

CONCLUSIONS

The increasing awareness of environmental impact problems has brought about a major demand for information on this topic. This paper describes how this task can be accomplished cartographically.

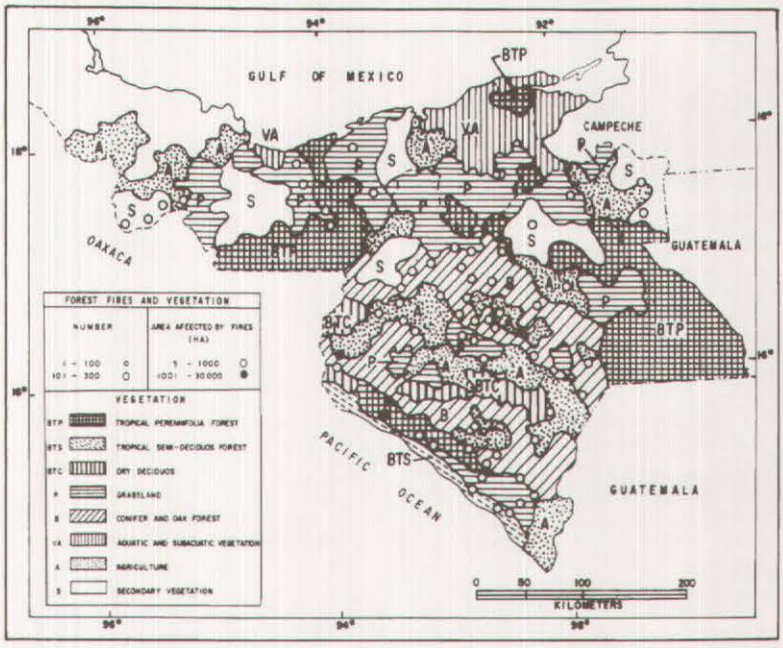

Figure 4: Compilation worksheet depicting vegetation types and forest fire locations in the isthmian area of Mexico.

Environmental maps are suitable both for informing general users about threatening agents and helping local and regional planning committees and environmental groups to identify the regions that require immediate attention.

The recent development of geographic information systems may be very helpful in the collection, ordering and analysis of data. This technology is especially useful for analyzing environmental problems that require a comprehensive approach to the multiple interrelationships between nature and mankind. However, in some cases computer generated maps have not been able to provide the same level of detail and information as those produced by conventional means. Therefore both automated and conventional methods of production were utilized for mapping land degradation factors in Mexico. Φ

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RESUMEN

Un mapa de los problemas ambientales en México fue elaborado utilizando métodos cartográficos tradicionales y computarizados. Dicho mapa forma parte del nuevo Atlas Nacional de México, recientemente publicado. El presente artículo señala el procedimiento seguido desde la colección y análisis de la información hasta el momento de su expresión cartográfica. La difusión amplia de mapas ambientales a escala regional, nacional y global que se observa en los últimos años, puede influir de manera determinante en una mayor concientización de los efectos negativos en el medio ambiente debido al uso inadecuado de los recursos naturales.