

# MEXICO

## FIRST NATIONAL COMMUNICATION FOR THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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## INTRODUCTION

Humankind begins its transition to the 21<sup>st</sup> century with new challenges, such as that of intensifying efforts aimed at studying and mitigating global climate change.

Today, the international community, spurred by the need for greater scientific knowledge concerning the causes and the consequences climate change will have on most of the Earth's inhabitants, faces this phenomenon with more cooperation and an attitude of greater commitment.

The United Nations Framework Convention on Climate Change stipulates that developing countries are to present their first national communication three years after this instrument goes into effect for these Parties, under articles 4.1 (Commitments) and 12 (Transmission of information related to application). In the case of Mexico, the Framework Convention went into effect in 1994, which means that in 1997 it hereby responds to the requirements mentioned above with this report, which constitutes a first national communication. It was prepared according to the guidelines for Communications of the Convention Parties not included in Annex I, according to decision 10/CP.2, formed during the Second Conference of Parties (COP II) in 1996.

The fundamental objective of this report is to provide an overall view of the national situation regarding climate change, studies that have been carried out and (direct and indirect) measures being taken with respect to climate change.

Specifically, in drawing up the preliminary version of the National Inventory of Anthropogenic Greenhouse Gas Emissions, according to Sources and Sinks, financial support was received from the United Nations Environment Program (UNEP) through the Global Environment Facility (GEF).<sup>1</sup>

For its preparation, Mexican emission data were taken for the year 1990, and the methodology prepared by the Intergovernmental Panel on Climate Change (IPCC), Organization for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA) was used.

Using this methodology, the information was systematized so as to be able to compare the results obtained with those of other countries and to feed a United States IPCC database that would enable overall evaluations to be carried out.

The results of the inventory were analyzed in two national and several international workshops. In December, 1995, a publication was presented with a preliminary version of the Inventory.

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<sup>1</sup> The project GF/4102-92-01 (PP/3011), was formalized November 7 1994 and the study concluded in September of 1995.

The results of the Mexican Inventory were also analyzed and approved by the UNEP **Atmosphere Unit**, with the participation of experts in the area from ICF Incorporated of the United States and from the OECD.

Later, with funding from the U.S. Country Studies Program, the preliminary inventory was updated, calculating the emissions produced by the **energy sector**; the methodology was improved for obtaining data in the area of greenhouse gas emissions in agriculture, specifically of methane, in livestock. All greenhouse gas emissions due to change in land use were also specified in greater detail.

This updated inventory, with base data from 1990, is in its final revision and is shortly to be published.

The Federal Government was in charge of coordinating the preparation of the inventory and of the scenario and vulnerability studies, through the National Ecology Institute, the Department of the Environment, Natural Resources and Fisheries, with the full collaboration of various research centers of the National Autonomous University of Mexico (UNAM). In particular, the noteworthy participation of the Center for Atmospheric Sciences, the Institute of Geography, the University Energy Program, and the Institutes of Ecology and Engineering, as well as the Coordination of Scientific Research, should also be pointed out.

Assistance from other organisms of the Federal Public Administration includes the valuable participation of the Institute for Electrical Research, the Mexican Petroleum Institute, the National Institute of Forest and Agricultural Research and the Mexican Institute of Water Technology.

The results obtained were reviewed by the Secretary of Energy and the Secretary of Commerce and Industrial Development.

This first national communication includes detailed results of the climatic scenario and vulnerability studies.

Taking into consideration that in its preliminary version, the National Emissions Inventory was already thoroughly researched and published, and that its updated version is concluded and to be published shortly, only the basic results of the updated inventory are included in this communication.

With this first national communication, Mexico fulfils its commitment and ratifies its support of the United Nations Framework Convention on Climate Change, under the principle of common but differentiated responsibility, and in accordance with its national situation.

It should be mentioned that the studies for inventory updating, scenarios and research into vulnerability received technical consulting and sponsorship from the U.S. Country Studies Program. These also received consulting and financial support from the Canadian

government for the first stage of the inventory. The initial studies on emissions mitigation received support from the World Bank, through the GEF.

## I. MEXICO AND CLIMATE CHANGE

### AN OVERALL VIEW

The lowest layer of the atmosphere, known as the troposphere, contains those gases that are largely responsible for the temperature of the planet and thus for creating conditions suitable for life.

The gases referred to are mainly water vapor, carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and chlorofluorocarbons (CFC), also known as greenhouse gases. Except for CFCs, all these gases exist naturally, representing less than 1% of the atmosphere, and trap part of the heat (infrared or long-wave radiation) emitted by the earth's surface as it absorbs the solar energy that heats it (Figure 1). This retention is what is known as the "greenhouse effect", an essential process in the climatic system. Without these gases, the average temperature of the planet would be -18°C instead of 15°C, as it is normally.

Figure 1

#### SUN

Solar radiation passes through the atmosphere  $343 \text{ Wm}^{-2}$   
 $103 \text{ Wm}^{-2}$

$240 \text{ Wm}^{-2}$

One part of the infrared radiation passes through the atmosphere while another part is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. This produces the warming of the Earth's surface and of the lower part of the atmosphere (troposphere).

#### ATMOSPHERE

$240 \text{ Wm}^{-2}$

#### EARTH

Most of the radiation is absorbed by the Earth's surface, thus heating it.  
The surface of the earth emits infrared radiation.

Source: Simplified version of the diagram published in "Climate Change 1994", Intergovernmental Panel on Climate Change.

Due to the increase in the atmospheric concentrations of various greenhouse gases, the earth's temperature has risen by approximately half a degree in the last 100 years, and if this trend were to continue, the phenomenon of global climatic change could worsen.

The concentrations of CO<sub>2</sub> and N<sub>2</sub>O have increased due to the burning of fossil fuels and deforestation. CH<sub>4</sub> has increased, among other reasons due to the increase in livestock

herds, enteric fermentation of organic matter, and the exploitation of natural gas. CFCs are produced by man and used in manufacturing refrigerants, solvents and propellants.

Table 1. Principal greenhouse gases

Gas

Carbon dioxide CO<sub>2</sub>\*

Methane CH<sub>4</sub>\*

Nitrous Oxide N<sub>2</sub>O\*\*

Main sources

Burning of fossil fuels, cement production, changes in tropical land use

Rice growing, sanitary landfill, livestock farming, combustion of biomass, and consumption of fossil fuels

Agriculture (pasture in tropical regions), burning of biomass, industrial processes (production of adipic acid and nitric acid), burning of fossil fuels.

Pre-industrial concentrations

Present concentrations

Potentials for global warming

20 - 100 - 500  
years

Growth (yearly rate) %

Atmospheric life (years)

\*Parts per million

\*\*Parts per billion (thousand million)

Source: Chart based on various international publications, especially Climate Change 1994, Intergovernmental Panel on Climate Change.

The most plentiful of these gases is CO<sub>2</sub>, found in concentrations of 350 parts per million (ppm). Sulfur dioxide, present in a maximum proportion of 0.05 ppm, contributes to acid deposition from the rain, the corrosion of some materials and reduced visibility. Nitrogen oxides are precursors of acid rain, photochemical smog and the reduction of ozone in the stratosphere. CFCs, in 0.003 ppm, contribute to the thinning of the stratospheric ozone shield and, together with methane, nitrous oxide and carbon dioxide, are responsible for the increase in the planet's temperature and for possibly producing serious climate changes through an increase in the greenhouse effect.

Although the atmospheric composition has undergone natural variations over a period of millions of years, anthropogenic emissions are producing changes in the planet's climate in a few decades. For example, it has been observed that the average temperature of the

earth's surface has increased by 0.3 to 0.6°C since 1886. Regional changes have also been evident: recent warming has been greater over the middle latitudes of the continents in winter and summer, with only a few areas of cooling, such as the northern Atlantic Ocean, whereas rains have increased over continents at high latitudes in the northern hemisphere, especially during the cold season. Another symptom of global warming has been the rise in sea level of 10 to 25 cm.

In spite of the fact that there are insufficient statistics to determine whether or not global changes, consisting of climatic variability or extreme climatic events, have taken place during the 20<sup>th</sup> century, there exists clear evidence on the regional scale of changes in some indicators. For example, the continuous warm phase of "El Niño" from 1990 through early 1995, causing drought and flooding in many areas, has not been a common phenomenon during the last 120 years. Less frost has been observed over large areas and a greater amount of rain during extreme climatic events.

Recently it has been detected that CO<sub>2</sub> concentrations have been increasing year to year by approximately 1.6%. It is estimated that this increase is mostly due to emissions produced by the burning of fossil fuels, which are not offset by CO<sub>2</sub> sinks (photosynthesis in terrestrial, continental and marine aquatic vegetation, among others). That is, industrial activity is emitting close to 6 billion (thousand million) tonnes of carbon per year, of which some 3 billion remain and accumulate in the atmosphere. An increase has also been observed in the atmospheric concentrations of methane and nitrous oxide, which increased by 112% and 7% respectively, from the pre-industrial age to 1992.

The main global predictions concerning the consequences of climate change may be summarized in the following points:

If CO<sub>2</sub> emissions to the atmosphere were to be maintained at the same levels as those reached in 1994, this would involve a sustained increase in atmospheric concentrations for at least 200 years, reaching close to 500 ppmv (nearly double the level of the pre-industrial era of 280 ppmv) by the end of the 21<sup>st</sup> century.

A variety of carbon cycle models indicate that the stabilization of the concentrations of this gas in the atmosphere in 450, 650 or 1000 ppmv could be reached only if the global anthropogenic emissions of CO<sub>2</sub> were to fall to the 1990 levels over the next 40, 140 or 240 years respectively, and were then maintained substantially below that level.

- If the increase in atmospheric greenhouse gas concentrations were to continue, the average temperature of the Earth could increase by between 1 and 3.5°C by the year 2100, which would mean an increase greater than any observed in the last 10 thousand years.
- The average sea level could increase by between 15 and 95 centimeters (the most generally accepted figure is 50 cm) by the year 2100, and coastal zones and small island states would be most affected.
- Even if greenhouse gas concentrations were to be stabilized by the year 2100, temperatures would continue to rise for several decades, and sea level would continue

to rise for centuries, because of the long life of many greenhouse gases in the atmosphere and the thermal inertia of the oceans.

- Possible extreme climatic events (floods, hurricanes, etc), associated with climate change, could cause widespread devastation.
- Some of the changes predicted include effects potentially harmful both to the economy and the quality of life of present and future generations, manifested in the form of health problems, water and food shortages, as well as the loss of homes and the degradation of ecosystems, among others.

#### MEXICO: EFFECT ON CLIMATE CHANGE AND VULNERABILITY

Total carbon dioxide emissions in Mexico are associated mainly with change in land use, the generation of energy, and transport. Although Mexico is among the 20 countries with the greatest greenhouse gas emissions per capita, these are much lower than those of the developed countries.

Processing and energy industries 24.40%  
Change in land use and forestry 30.56%  
Others 1.19%  
Industrial processes 2.61%  
Residential and commercial 5.30%  
Transport 21.31%  
Industries (ISIC) 14.62%

Processing and energy industries 108,473.18  
Industry (\*) 64,971.20  
Transport 94,705.60  
Residential and commercial 23,558.68  
Others 5,301.98  
Industrial processes 11,621.00  
Change in land use and forestry 135,857.333

\*According to the International Classification of the Industrial Sector, which includes the cement production and metallurgy, among other industries.

## COUNTRIES WITH THE GREATEST EMISSIONS OF CARBON (C) PER CAPITA 1994

Country                      Annual emissions per capita (Tonnes)

1. United States
2. Kazakhstan
3. Australia
4. Canada
5. Russia
6. North Korea
7. Germany
8. United Kingdom
9. Ukraine
10. Japan
11. Poland
12. South Africa
13. South Korea
14. Italy
15. France
16. Iran
17. Mexico
18. China
19. Brazil
20. India

Source: G. Marland, R.J. Andres T. A. Boden, "Global, Regional and National CO<sub>2</sub> Emission Estimates from Fossil Fuel Burning, Cement Production and Gas Flaring: 1950-1992" (Electronic database) (Oak Ridge, Tenn. Carbon Dioxide Information Analysis Center. Oak Ridge National Laboratory, 1995). World watch estimates based on ibid., and on British Petroleum, BP Statistical Review of World Energy (London: Group Media & Publications, 1995). Population Reference Bureau, 1994 World Population Data Sheet (Washington, D. C.: 1994); World Bank, The World Bank Atlas 1995 (Washington, D. C.: 1995).

As countries develop, they tend to increase their per capita emissions at the same time as they increase their energy intensity and therefore the proportion of greenhouse gas emissions with respect to gross national product.

Mexico shows less energy efficiency than the average for Organization for Economic Cooperation and Development (OECD) countries, which means that it generates more greenhouse gas emissions per GNP unit than they do. However, the more developed countries are the ones that emit greater quantities of greenhouse gases into the atmosphere per capita; which supports the principle of a common, but differentiated, responsibility in the face of the phenomenon of climate change.

GENERATION OF CO<sub>2</sub> EMISSIONS PER GNP UNIT FOR MEXICO AND OTHER  
OECD COUNTRIES Gg = 10<sup>9</sup> grams.

Gg/GNP

United States  
Canada  
Germany  
England  
Italy  
France  
Spain  
Mexico

Average

Source: United Nations, Climate Change Bulletin, 2<sup>nd</sup> trimester, 1996, p. 5

MEXICO: VULNERABILITY TO CLIMATE CHANGE

This report presents the detailed results of a study that identifies zones, resources, and economic activities that would register greater vulnerability to the potential effects of climate change.

Agriculture:

Regions identified as most vulnerable would be the northern and central areas of the country.

Human settlements

Areas of greatest vulnerability:

Center (Federal District, Mexico State, Guanajuato, Jalisco)

Desertification:

48.21% of the country's surface area would have high levels of vulnerability.

Most vulnerable states:

Aguascalientes, Baja California, Coahuila, Jalisco, Colima, Nayarit, Querétaro, Guanajuato, Michoacán, Sonora, and Hidalgo.

Meteorological drought:

Most vulnerable states:

Northern Sinaloa, Jalisco, Michoacán, Guerrero, Oaxaca, Quintana Roo, Campeche, and Chiapas.

Forest ecosystems:

Temperate forest would be very vulnerable, nearly 50% of the vegetation cover would change.

Water resources:

The most vulnerable watersheds would be: the Panuco and Lerma-Chapala-Santiago; and the Baja California peninsula.

Industry and energy:

Sectors with high vulnerability:

Oil industry

Electric industry

Petrochemical industry

Coastal regions

Regions with greatest vulnerability:

Tamaulipas (delta lagoon of the Rio Grande)

Veracruz (Alvarado Lagoon, Papaloapan River)

Tabasco (Delta complex of the Grijalva-Mexcapala-Usumacinta)

Yucatan (Los Petenes)

Quintana Roo (Sian Ka'an Bay and Chetumal)

#### FRAMEWORK CONVENTION: COMMITMENTS

As was mentioned already, the increase in greenhouse gas concentrations is linked to key activities in the economy, so that policies aimed at controlling the emissions of these gases will directly affect the present means of production.

Measures of adaptation to climate change include adjustments in practices, processes or structures, and aim at reducing adverse impacts and taking advantage of the potentially beneficial effects of climate change.

The success of the adaptation will depend on technological advances, institutional arrangements, availability of funding, technology transfer and the exchange of information. The options for adaptation for many developing countries are very limited, due to the lack of economic and technological resources.

The General Assembly of the United Nations, in its 1990 session, decided to create the **Intergovernmental Committee for Negotiation** of a Framework Convention on Climate Change (**ICN**). The **ICN** drew up the text of the Convention and approved it on May 9, 1992, at the United Nations Headquarters. This convention was opened for signing at the Earth Summit in Rio de Janeiro in June, 1992, on which occasion 154 countries (and the European Community) signed it. The Convention went into effect on March 21, 1994.

THE PARTIES WHICH ARE DEVELOPED COUNTRIES AND THE OTHER PARTIES INCLUDED IN ANNEX I ARE SPECIFICALLY BOUND TO THE TERMS STIPULATED BELOW:

- a) Each of the Parties shall adopt national policies<sup>1</sup> and shall take corresponding measures toward climate change mitigation, limiting their anthropogenic greenhouse gas emissions and protecting and improving their sinks and deposits of greenhouse gases. These policies and measures shall demonstrate that the developed countries are taking the initiative in modifying longer term trends in anthropogenic emissions in keeping with the objective of this Convention, recognizing that returning to previous levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol by the end of the present decade would contribute to said modification; and bearing in mind the differences in starting points and approaches, economic structures and resource bases of said Parties, the need to maintain strong, sustainable economic growth, available technologies and other individual circumstances, as well as the need for each of said Parties to contribute equitably and appropriately to worldwide action toward achieving this objective. These Parties shall be able to apply these policies and measures jointly with other Parties in contributing to the objective of the Convention and, in particular, to the objective of this paragraph;
- b) In order to promote progress toward this goal, each of said Parties shall, in accordance with article 12, within six months following the Convention's coming into effect for that Party and thenceforth periodically, present detailed information concerning the policies and measures referred to in paragraph a) as well as concerning the resulting projections with respect to anthropogenic emissions by sources and absorption by sinks of greenhouse gases not controlled by the Montreal Protocol for the period referred to in paragraph a), in order to restore individually or jointly to 1990 levels the anthropogenic greenhouse gas emissions not controlled by the Montreal Protocol. The Conference of Parties shall examine this information in its first session period and thenceforward, periodically, in accordance with article 7.
  1. This includes policies and measures adopted by regional organizations for economic integration.

Source: Secretary of Climate Change, United Nation Framework Convention on Climate Change, Article 4, Commitments, paragraph 2.

According to the text of the Convention, its ultimate objective, and that of every linked legal instrument adopted by the supreme body of the Convention, called the Conference of Parties, is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous, anthropogenic interference in the climate system. This level should be reached in a short enough interval to permit ecosystems to adapt naturally to climate change, insure that food production would not be threatened and to permit economic development to continue in a sustainable way.

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<sup>1</sup> This includes policies and measures adopted by regional organizations for economic integration.

All Parties of the Convention, bearing in mind their common but differentiated responsibilities and the specific character of their national and regional development priorities, objectives and circumstances, assume the following commitments, among others:

- To prepare, update periodically and publish national inventories of anthropogenic emissions –by sources and sinks– of greenhouse gases not controlled by the Montreal Protocol;
- To formulate, apply, publish and regularly update national programs and, whenever appropriate, regional programs that would include measures both to mitigate climate change, through control of the greenhouse gas emissions mentioned above, and to provide adequate adaptation to climate change.

Developing countries such as Mexico do not appear in the annexes mentioned below.

#### Annex 1

Australia  
Austria  
Belarus Tr  
Belgium  
Bulgaria Tr  
Canada  
Czechoslovakia Tr  
Denmark  
Estonia Tr  
European Economic Community  
Finland  
France  
Germany  
Greece  
Hungary Tr  
Iceland  
Ireland  
Italy  
Japan  
Latvia Tr  
Lithuania Tr  
Luxembourg  
Netherlands  
New Zealand  
Norway  
Poland Tr  
Portugal  
Rumania Tr  
Russian Federation Tr  
Spain  
Sweden  
Switzerland

Turkey  
Ukraine Tr  
United Kingdom of Great Britain and Northern Ireland  
United States of America

Tr Countries in the process of transition to a market economy

## Annex II

Australia  
Austria  
Belgium  
Canada  
Denmark  
European Economic Community  
Finland  
France  
Germany  
Greece  
Iceland  
Ireland  
Italy  
Japan  
Luxembourg  
Netherlands  
New Zealand  
Norway  
Portugal  
Spain  
Sweden  
Switzerland  
Turkey  
United Kingdom of Great Britain and Northern Ireland  
United States of America

## II. BASIC RESULTS

In Mexico, in order to honor its commitments assumed under the United Nations Framework Convention on Climate Change and with the Montreal Protocol, activities are carried out through the INE/SEMARNAP that enable the different work and actions being performed in the areas of climate change, the ozone shield, and climatic variability, to be dealt with in an orderly fashion. Regarding the Framework Convention, research was conducted for the *Country Study on Climate Change*, including the inventory of antropogenic emissions of greenhouse gases by sources and sinks; scenarios of future emissions; climatic scenarios; and studies on Mexico's potential vulnerability in seven different areas.

In order to carry out the studies in climatic vulnerability, models of climate simulation and of climatic forecasting have been used to study the "El Niño" phenomenon and seasonal drought. Impacts of climatic change on agriculture, forests, water resources, coastal zones, desertification, human settlements, as well as the energy sector, were studied.

These studies are prepared with the technical and, in some cases, financial support of various institutions such as the Environmental Protection Agency of the United States, the Inter-American Institute for Global Change Research (IAI), the National Meteorological Service, the UNAM's Center of Atmospheric Sciences, the International Research Institute (on "El Niño") (IRI) and the supercomputing system of the UNAM, among others.

The Ozone Protection Unit of the National Ecology Institute is in charge of seeing that the program to eliminate substances that exhaust the ozone shield is carried out punctually with the collaboration of the United Nations Development Program (UNDP), and resources of the Montreal Protocol Fund.

In the area of inventories of greenhouse gas emissions, it is important to bring them up to date biannually, depending on the resources that can be obtained for doing this. For the time being, studies are carried out to determine factors of greenhouse gas emissions in live systems and flows between different media: air, soil, etc..

The National Ecology Institute coordinates studies to evaluate technologies for mitigating greenhouse gas emissions conducted by the Engineering Institute of the UNAM: 11 technologies in the area of energy and two in forestry. These studies receive funding from the Agency for International Development (AID) of the United States and from the World Bank.

At the present time the possibility is also being studied of setting up a government agency for mitigating greenhouse gases, since joint implementation action may require, in the near future, methodologies for determining and monitoring the saving and capture of carbon dioxide emissions. This agency would also be in charge of following up the studies already concluded so that industries would voluntarily register for a government program for registering actions to prevent or capture greenhouse gas emissions.

Since 1993 to date, the Mexican government has organized workshops, publications, conferences, courses (more than 15 altogether), both national and international, notably the Twelfth Plenary Session of the Intergovernmental Panel on Climate Change, held in Mexico City in September, 1997. These sessions dealt with topics of inventories of greenhouse gas emissions, vulnerability, mitigation and adaptation to climate change, of which the respective records exist.

Since this first communication is to emphasize the information of the inventories and studies carried out, a synthesis of the results of the Updated National Inventory of Greenhouse Gas Emissions for 1990 is presented (as mentioned above, the results of the preliminary inventory have already been discussed thoroughly and published) and of the vulnerability studies. Respective sections of this report may be consulted for more detailed information.

In addition, this same report documents the national context, the development of institutions and mitigation measures being adopted by the Mexican government.

#### NATIONAL INVENTORY OF ANTHROPOGENIC GREENHOUSE GAS EMISSIONS BY SOURCES AND SINKS

The first step toward taking effective measures toward mitigating climate change is to prepare a national inventory of greenhouse gas emissions, since it allows emissions to be evaluated consistently and systematically at both national and international levels. This is a prerequisite for evaluating the feasibility and cost-effectiveness of implementing strategies and adopting technologies for reducing emissions.

The inventory also provides consistent information that allows all signatory countries of the Framework Convention to compare the relative contributions to climate change of the different sources.

The results of the updated inventory are summarized below and, as noted above, detailed information is presented in chapter V.

The updating for 1990 of the Mexican National Inventory of Anthropogenic Greenhouse Gas Emissions (prepared in 1996, and now in press) includes direct greenhouse gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), as well as indirect (which contribute to the atmospheric formation of ozone): carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) and non-methane volatile organic compounds (NMVOC).

Results show that the emissions come mainly from the use of fuels for generating energy, change in land use, agriculture and emissions due to leaks associated with the production of oil and gas.

- Energy sector emissions are the most important anthropogenic source in Mexico.
- In particular, the energy sector constituted the most important source of carbon dioxide.

- The transportation sector represents 32% of emissions from fossil fuel consumption, followed by the electrical (23%) and industrial (22%) sectors. The transportation sector is also the main contributor to emissions of NO<sub>x</sub>, CH<sub>4</sub>, N<sub>2</sub>O and CO.
- In 1990, nearly 84% of final use energy and 62% of generated electricity were produced by fossil fuels.
- It is estimated that between 1987 and 1993, per capita emissions of CO<sub>2</sub> fell by 7.1%, from 3.75 to 3.48 tonnes.
- Over the same period, the intensity of CO<sub>2</sub> emissions, measured as emissions per Gross Domestic Product (GDP), declined by 6.1%.

TABLE SUMMARIZING THE MEXICAN INVENTORY OF GREENHOUSE GAS EMISSIONS FOR 1990

Category of sources and sinks of greenhouse gases

National total of emissions and capture

1. Energy total (fuel + leaks)
2. Industrial processes
3. Agriculture
4. Change in land use and forestry
5. Waste

CO<sub>2</sub> top/down

CO<sub>2</sub> bottom/up

CH<sub>4</sub>

N<sub>2</sub>O

CO

NMVOC

FIGURE 1. GREENHOUSE GAS EMISSIONS IN MEXICO

Carbon dioxide 96.42%

Methane 0.79%

Others 2.79%

Carbon dioxide: 444,488.97

Methane: 3,641.66

Others 12,857.95

FIGURE 2. CARBON DIOXIDE EMISSIONS IN MEXICO 1990 ( Gg)

Processing and energy industries 24.40%

Industry (ISIC) 14.62%

Transportation 21.31%

Residential and commercial 5.30%

Others 1.19%

Industrial processes 2.61%  
Change in land use and forestry 30.56%

Processing and energy industry 108,473.18  
Industry (ISIC) 64,971.20  
Transportation 94,705.60  
Residential and commercial 23,558.68  
Others 5,301.98  
Industrial processes 11,621.00  
Change in land use and forestry 135,857.333

\*ISIC: "Industrial Sector International Classification": International Classification of the industrial sector that includes the production of cement and metallurgy, among other industries.

## VULNERABILITY STUDIES

Adaptation measures arise as an answer to the effects foreseen on human beings and their activities, as well as on the environment, as a result of global climate change. For this reason it is important to have an analysis of the geographical areas and zones in Mexico that would show greater vulnerability to the potential effects of climate change.

In the *Country Study: Mexico*, vulnerability studies were carried out in the areas of agriculture, human settlements, coastal zones, desertification and meteorological drought, forest ecosystems, water resources and the energy and industrial sectors. To carry out this analysis, it was necessary to prepare both present and changed, regional climatic scenarios. The basic results by geographical zones of the country are described below, and in chapter VI the complete information is given according to each research area.

### Northern Zone

The northern zone of Mexico includes eleven states: Baja California, Baja California Sur, Sonora and Sinaloa to the northwest; Chihuahua, Durango, Coahuila and Zacatecas in the north central area and Nuevo León, Tamaulipas and San Luis Potosí to the northeast. At the present time the conditions in this zone are difficult, since dry, arid climates predominate, except for the mountainous parts in which the climate is temperate wet, temperate, sub-wet and semi-cold.

Based on the variations in temperature and precipitation given by the General Circulation Models (GCM), under conditions of a doubling in CO<sub>2</sub> concentrations, the arid and semi-arid climates would increase in surface area, extending southward, while the semi-cold would disappear. One could say that this zone would not undergo drastic changes in climate, although there might be greater climatic pressure and, therefore, an increase in the demand for water and energy.

In this zone the most serious indices of drought were found, ranging from strong to very severe. In the Canadian Climate Center Model (CCCM), this surface would increase by 36% and in the GFDL model (Geophysical Fluids Dynamics Laboratory), by 30%.

Concerning water resources in the region, there are watersheds that, for the basic scenario, go beyond the indices of vulnerability specifically established for the study. This situation occurs in Baja California and that part of Tamaulipas that corresponds to the watershed of the Pánuco. Three indices are exceeded in the rest of the zone, except for the center of Tamaulipas, where only one is. When applying the GCMs, the only changes, according on the model used, would be found in Tamaulipas, where the number of indices exceeded would increase, indicating an increase in vulnerability.

The results of a possible rise in sea level of 0 to 2 m reveal that the coast of Gulf of Mexico would be affected at the Pánuco delta, and particularly in the area of the Rio Grande delta, given its geomorphological characteristics.

In the face of these conditions, sectors such as the industrial, energy, and agricultural, and human settlement in the northern zone would be affected. The degree to which they would be affected would vary in accordance to the GCM used, as a function of the extent to which temperature and precipitation increased, since it diminishes in the CCCM and increases in the GFDL-R30.

In the energy and industrial sectors, there is a great difference between the results of the two models: in the CCCM model, the shortage of water would make hydroelectric power plants and thermal power stations using steam, as well as industries requiring large volumes of water in their processes, more vulnerable, with high to very high degrees of vulnerability, whereas, in the GFDL-R30 model, the zones with these values would decrease considerably.

Nearly 10% of all types of vegetation in forest ecosystems would be affected by the warm, dry conditions. This percentage would include the xerophytic scrub in southern Chihuahua, central-eastern Coahuila, and the northern areas of Zacatecas and San Luis Potosí. Extensive grazing areas and temperate forests in the north of Mexico would face hotter climates, which leads one to believe that the areas with dry and very dry tropical forests, as well as the areas of desert scrub, would increase.

As for the cultivation of non-irrigated maize, according to the agroclimatic ranges used in this work, most of the area is unsuitable for this crop, except for Tamaulipas and southern Sinaloa, which are considered moderately suitable in the basic scenario. Although it is true that at the moment large areas in this zone are used for growing it, the yields obtained are very low (less than one tonne per hectare) with high levels of crop loss. The changes recorded with the CCCM model indicate that the southern part of Sinaloa would become unsuitable and the northern part of Nuevo León, moderately suitable.

Each of the states that comprise this area has between one and three million inhabitants, except for Baja California Sur which, with less than a million inhabitants, has a population density of less than 50 hab/km<sup>2</sup>. In general, the population of the northern states is

concentrated in urban areas (70% of the population is considered urban), for which reason they are vulnerable to climate change. According to the results of the study, vulnerability is low in Sonora, Chihuahua, Durango, Zacatecas, San Luis Potosí and the Baja California peninsula, and moderate in Coahuila, Nuevo León, Tamaulipas and Sinaloa.

### Central Zone

The central zone of the country includes the following fourteen states (and district): Nayarit, Jalisco, Colima and Michoacán on the Pacific coast; Aguascalientes, Guanajuato, Querétaro, Hidalgo, state of Mexico, the Federal District, Morelos, Tlaxcala and Puebla in the center; and Veracruz on the Gulf of Mexico. The greatest population and industrial densities are concentrated here (mainly in the state of Mexico and the Federal District), for which reason its water, energy and food requirements are very high. 60% of the population in this area is urban. There is also great competition for land use, mainly for urban and industrial use, to the detriment of agricultural and forest use. Because this is the zone where modification of the environment for human activities is evident, and due to the density of the population, the consequences of a possible climate change would be extremely negative.

The climates in this area are: the warm, sub-wet ones of the coasts, both the Pacific and the Gulf; the semi-warm and temperate ones of the high, mountainous areas; and the dry ones of the center. According to the general circulation models, the wet and sub-wet, temperate climates would tend to disappear from this zone, with the dry, warm ones increasing and arid ones appearing in small areas (CCCM). Drought, although it would be present in low degrees, would increase in severity, affecting mainly the states of Tlaxcala, Puebla, Veracruz and Michoacán. This last state would also have a high degree of vulnerability to desertification over more than 50% of its surface, together with Jalisco, Colima, Nayarit, Querétaro, Hidalgo and Guanajuato.

In addition, the region has problems of water supply, since the watersheds here already have a deficit of water in the basic scenario, mainly in the Lerma-Chapala-Santiago watershed and the area corresponding to the watershed of the river Pánuco. This situation would worsen in the face of a climatic change. The industrial corridors of Rapuato-Celaya-Salamanca-León (in the state of Guanajuato) and of Tula-Vito-Apasco (in the state of Hidalgo) would be severely affected.

The lands for growing non-irrigated maize in Jalisco, Nayarit, Guanajuato, Aguascalientes, Mexico, Colima and northern Michoacán would change from moderately suitable and suitable to unsuitable, reducing the agricultural potential of these states.

In addition to these scenarios, as mentioned above, this zone has most of the country's population, and with rapid growth rates. It is calculated that by the year 2050, several of these states will have more than eight million inhabitants, which would imply heavy demands for water and services that the area would not be in conditions to provide, so that its degrees of vulnerability are among the highest.

The forest ecosystems most affected in this central region of the country would be the temperate forests in eastern Michoacán, the northern part of the state of Morelos and the wet, temperate forests of the Zongolica sierra in Veracruz.

The coasts of Veracruz, especially in the Alvarado lagoon, are considered vulnerable to the rise in sea level, taken as being two meters in height above the average level of high tide.

#### Southern zone

Mexico's southern zone includes the following seven states: Guerrero, Oaxaca, Chiapas, Tabasco, Campeche, Yucatan and Quintana Roo. The last four constitute the Mexican southeast.

The climates that prevail in this region are warm ones. The main changes would take place in Oaxaca and Chiapas.

The degree of drought, which in the basic scenario is practically zero in Tabasco, part of Veracruz, Campeche, Oaxaca and Chiapas, would increase in the CCCM model but would be unchanged in the GFDL-R30. Most of the surface of Chiapas would display increasing levels of drought. This situation would also be found in Quintana Roo and in the eastern part of the Yucatán peninsula, where it would increase from slight to strong.

Concerning water resources, the southern zone would not undergo modifications in the scenarios of the CCCM and GFDL-R30 models with respect to the basic scenario. In the southeast, Tabasco and Chiapas, the modifications would be slight. For the states of Campeche, Yucatan and Quintana Roo, where draining does not take place on the surface but underground, the current scenario would not be exceeded according to the results of the study.

On the coasts of the Gulf of Mexico and Caribbean Sea, there are regions that are sensitive to the rise in sea level, specifically in the delta of the Grijalva-Usumacinta Rivers in Tabasco, on the coasts of northeastern Campeche, and in the Sian Ka'an region, which is considered a biosphere reserve.

The industrial activities of the southeast (heavy, light or processing industries) are affected to different degrees by climatic change. According to the CCCM model, industries show greater vulnerability (medium to high) than in the pattern GFDL-R30 (low to high), due to differences in precipitation and, therefore, in the availability of water. As for the energy sector, the oil-producing zones, such as the extraction platforms in Campeche Sound, would be the most vulnerable if there were a rise in sea level.

In agricultural activity, most of the surface is considered moderately suitable for growing non-irrigated maize, except for the coasts of Guerrero and Oaxaca, which are considered unsuitable. Tabasco, Chiapas and part of Campeche are considered suitable. However, a large part of the country's forests are located in this zone.

If a climate change were to take place, according to the CCCM model, the suitable surface would disappear from the southern and southeastern zones of the country; the coastal strip, considered unsuitable, would extend toward the interior. Most of the Yucatan Peninsula would become unsuitable. According to the GFDL-R30 model, the suitable area would increase and the moderately suitable would change to unsuitable.

The temperate and cold, wet forests located in the mountainous areas of Oaxaca and Chiapas would be the most affected forest ecosystems in the area and, according to the CCCM model, could even disappear.

### III. NATIONAL CONTEXT

#### BASIC DATA

- Mexico is in the northern portion of the American continent; it is bounded by the following extreme coordinates:
  - To the north: 32° 43' 06" (Monument 206 of the international Mexico-United States border)
  - To the west: 118° 27' 24" (Isla Guadalupe)
  - To the east: 86° 42' 36" (Isla Mujeres)
  - To the south: 14° 32' 27" (mouth of the Suchiate River)
- Mexico adjoins the United States of America to the north, along a border 3,152.2 km long, and Guatemala and Belize to the southeast, with a combined border 1,149.2 km in length; its continental coasts are 11,122.5 km long, the third longest in America, after the United States and Canada.
- Mexican territory covers 1,964,381.7 km<sup>2</sup>, of which 1,959,248.3 km<sup>2</sup> are on the continent and 5,133.4 km<sup>2</sup>, made up of islands, which places it in fourteenth position in area among the countries of the world.
- The political division of Mexico is made up of 31 states and a Federal District. The capital of the country is Mexico City, located at an altitude of 2,240 m above sea level.
- Due to its latitude and topography, Mexico has a great diversity of climates, ranging from warm, with yearly temperatures that average over 26°C, to cold, with temperatures below 10°C; however, 93% of national territory oscillates between temperatures of 10°C and 26°C; this percentage includes warm-subwet climates, occupying 23% of national territory; dry, 28%; very dry, 21%; and temperate-subwet, 21%.
- 36% of the country's surface corresponds to areas with slopes of less than 10%; the rest includes mountain regions.
- Territorial waters consist of a strip 12 nautical miles wide, measured from the base line (coast line). The exclusive economic zone covers a surface of 3,146,145 km<sup>2</sup>.
- According to figures of the Population and Housing Count, 1995, by the end of that year the Mexican population had reached a total of 91.2 million inhabitants, which places it in 11th position worldwide.
- In 1996, Mexico's Gross Domestic Product amounted to 334,790.1 million dollars. In addition, its production of crude oil came to 2,858,000 thousands of barrels per day.

#### BIODIVERSITY

The biological patrimony of Mexico is one of the most important in the world, for which reason it is included in the list of the 12 megadiverse countries, which together are home to between 60% and 70% of all the species on our planet.

Mexico's megadiversity is mainly due to the fact that its latitudinal position straddles two of the biogeographical regions, the Neo-Arctic and the Neo-tropical. If we add to that its complex topography and variety of climates, we can explain the existence here of practically all the ecosystems of the planet.

Thus in Mexico between 10 and 15% of the earth's species converge, foremost of which are: 717 species of reptiles (first place worldwide), 295 of amphibians (fourth place), 500 of mammals (second place), 1,150 of birds (11th place) and possibly fourth place in angiosperms (flowering plants), with an estimated 25,000 species.

Precise information is not available on invertebrates, but it is known that Mexico has 52 of the 1,012 recognized species of butterflies of the family Papilionidae.

The wide range of coastal resources and ecosystems of the country means that, in terms of sea coasts and ocean surface, Mexico occupies 12th place in extension in the world. Thus, in inland waters and national seas, there is great diversity in fish species (2,122 species are calculated, including both fresh water and marine), turtles, crustaceans, mollusks, echinoderms, sponges, corals and mammals. Of these last, in the Sea of Cortés alone can be found 35% of the planet's cetacean species and 82% of all species of marine mammals in the northeastern Pacific.

At the level of flora, variations range from the xerophytic and desert vegetation, to luxuriant forest vegetation over 40 meters high in areas with annual precipitation of over four thousand millimeters. Between these extremes there is a great variety of brush communities, forming extensive scrubland; grazing land; coniferous and oak forests in almost all the mountain systems; palm trees and forests with different deciduous proportions; coasts with mangrove swamps, from very developed to barely a meter high; pioneer communities of vegetation in coastal dunes, among others.

## PHYSICAL-GEOGRAPHICAL CHARACTERISTICS

In Mexico there are four groups of climates: warm wet, temperate wet, cold and dry.

The natural regions with a warm climate are the tropical or rain forest and the savannah. These regions are located mainly in southern Mexico and cover a large part of states such as Veracruz, Tabasco, Chiapas, Campeche, Yucatan and Quintana Roo. The group of wet, temperate climates is located mainly in the center of the country, in important areas of states such as Puebla, state of Mexico, Guanajuato, Querétaro and Michoacán.

The group of cold climates is located only in the highest regions of the large volcanoes of Mexico such as the Orizaba Peak, Malinche, Popocatepetl, Iztaccíhuatl, Nevado de Toluca and Colima Volcano. The group of dry climate is the group that occupies the greatest area of the country. Natural regions with this type of climate, steppe and desert, have the extreme temperatures in common, but they differ amongst themselves in having scarce or very scarce rains.

Very dry climates are found in the northern part of the Mexican altiplano, at altitudes of under 1,500 masl, as well as in the portion of the coastal plain of the Pacific and in the coastal areas of the Baja California Peninsula except for the northwestern end.

However, some states, especially those with very varied relief, have almost all types of climates. In general, the percent distribution of these climate types is: warm wet, 4.7%; warm subwet, 23.0%; dry, 28.3%; very dry, 20.8%; temperate subwet, 20.5%; and temperate wet, 2.7% of the territory.

Mexico is one of the countries with the most diversified relief, which affects both its natural conditions (climate, soil, vegetation) and its economic activities.

Based on their geological and morphological characteristics, Mexican territory is divided into 15 physiographic provinces. Some of these provinces are shared with neighboring countries; such is the case of the Great Plains of North America, in the northern part of the country, where a small part of an area that extends as far as Canada penetrates Mexico, or of the province called the Central American Cordillera, which occupies a larger surface in countries located to the south of the Mexican border.

Southeastern Mexico, for its part, particularly the states of Oaxaca and Chiapas, is the area with most biodiversity, and constitutes one of the 15 critical regions for biodiversity in the world, which altogether represent only 1% of the planet's surface and contain between the 30 and 40% of all known species.

## POPULATION DYNAMIC

In 1995 the population of Mexico consisted of 91,158,290 inhabitants, according to definitive results of the National Population and Housing Count of 1995, carried out by the INEGI (National Institute of Statistics, Geography and Computing), which means nearly 10 million more than at the beginning of 1990.

The current demographic situation in Mexico is the result of the rapid growth in population that occurred until the seventies. Although the growth rate began to diminish from then on, the population has continued to increase significantly in absolute numbers. The rate of growth has decreased in the last 25 years, from a yearly average of 3.2% from 1950 – 1970, to 2.06% for the five year period 1990 – 1995, so that the population increased from 48.2 million in 1970 to 91.1 million inhabitants in 1995.

One of the most important advances in the economic and social development of contemporary Mexico has been the significant reduction in the sick rate and mortality rate. Since 1930 there has been an important drop in mortality, which has been reflected in a significant increase in life expectancy at birth.

The decline in fertility is the main factor in demographic change in Mexico during the last decades. Compared with the gradual decrease in mortality, the decline in fertility is more recent and has a steeper slope. In 1960, the overall fertility rate was greater than 7 children per woman, while in 1995, according to the estimates of the National Council on Population, it reached an average of 2.65 children.

In the last few decades, interstate migration has involved millions of Mexicans: in 1960 slightly more than 5.5 million people lived in a state different from that of their birth; in

1970 the number increased to 7.5 million and in 1990 to almost 14 million people, which is to say, 17.4% of the country's inhabitants. By 1995 that segment had increased by 3.3 million people compared to 1990, so that 19% of the population reported having been born in a state different from that of their residence.

#### DISTRIBUTION OF THE DOMINANT SOILS IN MEXICO<sup>1</sup>

Soil unit	Surface (Km3)	%
Leptosols		
Regosols		
Calcisols		
Feozems		
Vertisols		
Arenosols		
Cambisols		
Luvisols		
Gleysols		
Alisols		
Andosols		
Kastanozems		
Solonchaks		
Planosols		
Acrisols		
Nitisols		
Fluvisols		

#### Urbanization process

Mexico is a predominantly urban country. The most outstanding features in its urbanization process consist in the fact that, in a first phase, it experienced an intensive growth in urban population – reaching a rate of growth of 7.2% annually between 1950 and 1960 – as well as an increase in the size and number of its cities, with the pre-eminence of Mexico City and the appearance of the metropolitan zones of Guadalajara and Monterrey, each representing more than a million inhabitants.

A later phase is characterized by urbanization involving physical expansion and an informal structure, besides a decline in the consolidated central areas and a horizontal expansion that invaded large extensions of agricultural land.

The urban population, with an annual growth rate of 4.6%, increased from 23.8 millions to 37.6 million inhabitants. Thus, between 1970 and 1980, 56.2% of the total population lived in 229 cities of over 15 thousand inhabitants. During this period Puebla appeared among the cities with over a million inhabitants, so that, together with the Metropolitan Area of

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<sup>1</sup> According to the FAO/UNESCO/ISRIC, 1988, soil classification.  
Source: Semarnap, 1996.

Mexico City, Guadalajara and Monterrey, it is the most dynamic city in terms of population. Altogether, these four metropolitan areas contribute 47.8% of the population of the group of cities having more than a million inhabitants.

In 1990 the urban population reached a little over 49 million inhabitants, equivalent to 60.8% of the total population, with an annual growth rate of 2.8% during the period 1980 – 1990, noticeably lower than the 4.7% of the previous decade. Its distribution by city size shows significant changes. The cities having more than a million inhabitants reduce their weight within the urban population to 45%, though continuing to figure in the main rank of urban hierarchy.

Another of the intervals that decreased its contribution is the category from 100,000 to 500,000 inhabitants, dropping from 27.2% in 1980 to 23.2% in 1990. Urban centers with populations of 500,000 to a million, for their part, gained 8.4 percentage points, moving from fourth into third place in the hierarchy with 15.2%, equivalent to 7.5 million people. Similar behavior is observed in the intervals of smaller cities (15 thousand to 20 thousand inhabitants, 20 to 50 thousand, and from 50 thousand to a hundred thousand), whose contributions rose from 2.7 to 2.8% in the first case, from 7.7 to 8.0% in the second and, finally, from 4.3% to 5.7 in the third.

Part of the reason for these changes is the reorientation of the migratory flows toward the cities on the northern border, mainly because of the **economic opening** and the expansion of the assembly industry.

On the threshold of the 21st century, Mexico continues to undergo a process of urbanization of such magnitude that in 1995 more than 60% of the total population inhabited areas with more than 15 thousand inhabitants, and had a much more diversified and less concentrated system of cities than the one during the period of rapid urbanization.

The pattern of territorial distribution of the country can be observed through urban and rural characteristics. In 1995, 59.9% of the population lived in little more than 300 cities, while the other 40% resided in more than 200 thousand towns of less than 15 thousand inhabitants, which meant an increase of 44,536 towns from those registered in 1990. The largest increase takes place in towns of one to 2,500 inhabitants, at a rate of 8,859 new towns annually, which explains the great dynamism shown by the dispersed rural settlements in the extensive national territory.

The dynamism in the appearance of small rural settlements is accompanied by a progressive decrease in its rate of population growth, which during the last 25 years has been less than 1% yearly on the average, whereas the urban population has grown at a rate three times greater.

## ECONOMY

In 1996, Mexico's Gross Domestic Product amounted to 334,790.1 million dollars. The contribution of the main economic sectors in the GDP was the following: agricultural with 5.9%; industrial with 28.8%, where manufactured goods constitute 74.7% of their value;

and the service sector with 65.3%, with trade, restaurants and hotels foremost with 21.1%. The production of crude oil was 2,580,000 thousand barrels per day.

## BASIC MACROECONOMIC AND SECTORIAL ASPECTS

As of December, 1982, the economic policy of the country changed its priorities in order to face restrictions from outside, as well as to begin a drastic change in the productive specialization and international **insertion** of the Mexican economy. The definitive exhaustion of the model of substitute industrialization of imports, effective for more than three decades, the fall of the international price of oil and the increase in international interest rates, gave rise to a serious crisis accentuated by recurrent devaluations of the Mexican peso and very severe inflationary processes.

Due to the weak international competitiveness of the production capacity of the country and to its high financial risk, it began a process of repairing public finances and an important modification of the content of its exports. Including non-traditional goods in the export offer (automobiles, auto parts, glass, beer, cement, various manufactured products from assembly plants, etc.) meant changing the driving force of the country's economic growth: it changed from investment and public expenditure to the dynamism of exporting and private investment.

The amount and composition of Mexican sales abroad changed substantially. These rose from 15,512 million dollars in 1980, representing 11% of the gross domestic product (GDP) for that year, to 95,999.7 million dollars in 1996, representing 28.6% of the GDP for that year. The breakdown of Mexican exports for 1980 was the following: 67% crude oil, 20% miscellaneous manufactured goods, 10% agricultural and livestock products and 3% extractive products. For 1996, it was: 83.65% miscellaneous manufactured goods, 12.13% crude oil, 3.74% agricultural products and 0.48% extractive products.

After the most difficult period in the financial crisis and structural adjustment (1982-1987), the national economy was reactivated by accelerating the process of economic deregulation and privatization, and increased opening up of trade. This was a process that, after the important precedent of Mexico's formal entry into the General Agreement on Tariffs and Trade (GATT), was extended when the North American Free Trade Agreement (NAFTA) started up and when Mexico entered the Organization for Economic Cooperation and Development (OECD) in 1994. The process of economic recovery was interrupted in 1995, the year in which the GDP registered a sharp decline of -6.2%, with a serious inflationary upturn of 52%. With the exception of agricultural and livestock activities, all economic activities registered negative rates of growth.

The development of basic macroeconomic variables during 1996 and 1997 has been much better. The average yearly rate of growth of the GDP for 1996 was 5.1% and for the present year (1997), it is estimated at 6.5%. The consumer price index is again registering a downward tendency: 28% in 1996 and 16% in 1997, with a one-digit inflation level projected for the year 2000.

The current expanding cycle with a continuing decline in inflation is headed by those economic sectors whose average yearly rate of growth is higher than that of the total GDP, such as construction (10.2%), manufactured goods (8.7%), transportation, storage and communications (7.9%), and services, such as stores, restaurants and hotels (6.8%). The macroeconomic scenarios estimated for the period 1997-2000 are the following:

GDP (ayrg %)

Inflation (Dec-Dec %)

Type of nominal change (yearly average)

International price of oil (dpc)

Public balance (% of GDP)

aarg = average yearly rate of growth.

Source: SHCP, General Criteria in Economic Politics for 1998; and SHCP, PRONAFIDE.

For the two-year period of 1999-2000, a growth in the GDP is expected of over 5% per year, with a one-digit inflation rate.

## WATER RESOURCES

Water resources in Mexico are made up of rivers, lakes, lagoons and underground waters. Taking into account the continental surface of the country, bodies of water occupy 1.4%, of which salt water constitutes 55.6%, dams 17%, swamps in the southeast 15.6%, lagoon areas in the Gulf 4.1% and lakes and lagoons 7.6%.

The central problem of water resources is not their lack but rather their distribution: their availability is mainly concentrated in southeastern Mexico where the population density and water demand are low. In contrast, in the center, north and northwest, where population density is greater and the demands are high, water is scarce.

Water is utilized in different ways, which differ in being consumptive or non-consumptive. The former ones impact on the availability because they make use of water and return only part of it; the non-consumptive ones, such as the use in hydroelectric generation, return the entire quantity of water used.

It is estimated that in 1995, the total extraction for the main uses was 186.7 km<sup>3</sup>, of which 73.5 km<sup>3</sup> were intended for consumptive uses, according to the following distribution: agricultural 61.2, domestic 8.5, industrial 2.5, intensive aquaculture 1.3; and the remaining 113.2 km<sup>3</sup> were intended for the generation of hydroelectric energy, classified as non-consumptive.

In 1996, thermoelectric power stations (including coal-fired, geothermal and nuclear) generated 79.3% of the energy produced in the country, and hydroelectric, 20.7%. Thermoelectric and hydroelectric plants used 113.2 km<sup>3</sup> of water.

Among the most important hydroelectric plants are the following: La Angostura, Chicoasén, Malpaso and Peñitas, on the Grijalva River; El Infiernillo, La Villita and

Caracol, on the Balsas River; and Temascal, on the Papaloapan. Recently Agua Prieta, Aguamilpa, Zimapán and Huites were incorporated.

The main problems, in the case of the hydroelectric plants, are those that originate in the incompatibility in the time of generation (peak hours) with the requirements of other uses such as irrigation.

WATER EXTRACTION FOR THE GENERATION OF ELECTRICAL POWER IN 1994 (KM<sup>3</sup>)

Region	Plants	Plants	Total
Northwest			
North			
Northeast			
Lerma-Balsas			
Valley of Mexico			
Southeast			
Total			

Source: Federal Electric Commission, 1994

It is estimated that for the year 2000 the demand for water will be 142 km<sup>3</sup> per year for hydroelectricity, and 2.89 km<sup>3</sup> per year for cooling in thermoelectric plants. Most of the needs for thermoelectric plants are due to the starting up of the Petacalco plant.

DEMAND FOR WATER IN GENERATION OF ELECTRICAL POWER FOR THE YEAR 2000 (KM<sup>3</sup>)

Region
Northwest
North
Northeast
Lerma-Balsas
Valley of Mexico
Southeast
Total

Average generation expected (GWh/y)
Hydroelectric
Thermoelectric
Total

Consumption of fresh water<sup>1</sup>  
**Subt.**

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<sup>1</sup> Refers exclusively to thermoelectric plants, since there is no consumption in hydroelectric ones.

Sup.

Total

Extraction of fresh water<sup>2</sup>

Res.

Hydroelectric

Thermoelectric

Total

Source: Federal Electric Commission, 1994.

## ENERGY RESOURCES

At the present, the evaluation made of the country's available fuel resources, and consideration of the adverse environmental impacts which their excessive use implies, has allowed new sectorial policies and goals to be defined.

Proven hydrocarbon reserves amounted in 1997 to 50,812 million barrels, 80% of which corresponded to crude oil and condensates, and 20% to natural gas. The richest and most profitable deposits are located in the ocean area in the southeast. Exploitation of natural gas reserves, according to the production rates for 1996, is expected to last approximately until the year 2030, according to estimates.

In the main watersheds of the country, there are 204 projects at different stages (operation, development and study) corresponding to the generation of 82,319 gigawatt hours (GWh). Of this technically feasible potential, 34% is exploited.

There are 662.9 million tonnes of coal distributed throughout four main watersheds: Villa de Fuentes-Río Escondido, Coahuila; Colombia, Nuevo León; the Mixteca, Oaxaca; and Barranca, Sonora. It is similarly estimated that the uranium reserves amount to 14.5 thousand tonnes. Nevertheless, the uranium potential could be greater in as much as exploration activities have not been carried out for almost 15 years.

Distributed throughout various points of national territory there are more than 500 thermal foci (mud volcanoes, fumaroles, wells, solfataras and hot water). At the moment there are proven reserves for 700 megawatts (MW) of equivalent capacity in Cerro Prieto, Baja California; as well as 380 MW in Los Azufres, Michoacán, and in Los Humeros, Puebla. In these fields there are plants operating with a capacity of 753 MW and others with a 250 MW capacity programmed to begin operations by the year 2000. In addition, according to current exploration studies, it is estimated that other foci with a capacity equivalent to 1,000 MW could begin operations in the first decade of the next century.

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<sup>2</sup> Extraction recorded in the extraction column in thermoelectric plants is in addition to that given under consumption; these volumes are completely returned to their original source. Most thermoelectric requirements are due to the starting up of the Petacalco plant.

Mexico is located in one of the regions of greatest insolation, so that activities oriented toward thermal and photovoltaic uses of solar energy have already been carried out. The main uses at present of this energy source are related to water heating, rural electricity, communications, signals and pumping water.

Recent studies indicate that in La Venta, Oaxaca, the use of wind power potential could be extended to 600 MW, at present being 1.6 MW. Besides, as regards biomass, it is estimated that the use of firewood and bagasse represents around 7% of the national energy consumption. Firewood is used mainly in cooking food, especially in rural communities. Bagasse from sugarcane is the main fuel used in sugar refineries and supplies 1.6% of the national consumption of energy.

In summary, Mexico possesses an appreciable potential in alternative energy sources, such as geothermal, nuclear, solar, wind and tidal power, among others.

The evolution of the national production of hydrocarbons, of internal sales of oil and natural gas, as well as exported crude oil, oil and natural gas during the period 1980-1994, are given in the following tables.

#### MEXICO: PRODUCTION OF HYDROCARBONS 1980-1996

Product:

Crude oil

Natural gas

Gas liquids\*

Unit

TBD

MCFD

TBD

\*Includes stabilized condensates

TBD = thousands of barrels per day. MCFD = millions of cubic feet per day

Source: Petróleos Mexicanos

#### MEXICO: DOMESTIC SALES OF OIL AND NATURAL GAS 1980-1996 (THOUSANDS OF BARRELS PER DAY)

Products:

Fuel oil

Gasolines

Diesel

Liquefied natural gas

Others

Total

Natural gas

Source: Petróleos Mexicanos

MEXICO: EXPORTS OF CRUDE OIL 1980-1996 (THOUSANDS OF BARRELS PER DAY)

Type of crude oil

Maya

Istmo

Olmecca

Total

Source: Petróleos Mexicanos

MEXICO: EXPORTS OF OIL AND NATURAL GAS 1980-1996 (THOUSANDS OF BARRELS PER DAY)

Product

Liquefied natural gas

Gasolines

Turbosine

Diesel

Fuel oil

Others

Total

Natural gas\*

\* Expressed in TBD of equivalent fuel oil.

Source: Petróleos Mexicanos

The national capacity for generating electric power by type of power station is given in the following table:

EFFECTIVE CAPACITY FOR GENERATION OF ELECTRICAL POWER  
ACCORDING TO TYPE OF POWER STATION 1980-1996  
(MEGAWATTS)

Hydroelectric

Steam

Combined cycle

Turbogas

Internal combustion

Dual

Coal-fired

Geothermoelectric

Nucleoelectric

Wind

Source: Operations Report, several years, Federal Electric Commission

## FOREST RESOURCES AND LAND USE

The forests, rain forests and other areas with natural vegetation occupy 141.7 million hectares, that is to say, approximately 72% of Mexican territory. The distribution of forestry resources is as follows:

### FOREST AREA BY ECOSYSTEM (HECTARES AND PERCENTAGE OF CONTRIBUTION)

Ecosystem

Forests

Rain forests

Vegetation of arid zones

Hydrophyte and halophyte vegetation

Total

Source: SARH. 1994. Periodic National Inventory of Forests.

Mexico possesses 56 million hectares of forests and rain forests, of which 32.5 million are closed formations and 22.9 million are open formations.

Coniferous forests in Mexico occupy 21 million ha, latifoliate 9.5 and mesophytes 1.4.

The rain forests are made up of wet tropic and dry tropic vegetation; wet tropic vegetation includes the types of high and medium rain forest and occupies 14.1 million hectares approximately.

The forest ecosystems of Mexico are of utmost importance due to both their biological and socioeconomic characteristics, of which the following stand out:

1. Biological; being a megadiverse country, Mexico's forest ecosystems contain 10% of the world's biodiversity, including a high number of endemic species;
2. Environmental; because they are elements of soil stabilization and play an important part in the conservation of water cycles, in carbon sequestering, and for climate regulation.
3. Social; because more than eleven million Mexicans live inside forest ecosystems, and these in turn represent a source of subsistence products; and
4. Economic; because they are a source of both timber-yielding and non-timber-yielding products.

### Deforestation

The change in forest land use to other uses has been the main cause of deforestation (mainly because of the expansion of agricultural and livestock boundaries). During the years from 1970 to 1990, agricultural lands increased by 39%, those used for livestock raising 15%, and forest areas decreased by 13%. Also among the main causes of the deforestation process are the change to livestock raising, itinerant monoculture, secret cutting and fires.

The average deforestation figure in Mexico during the years from 1990 to 1995 is of the order of 500 thousand hectares per year.

#### DEFORESTATION IN MEXICO: TENDENCIES 1990-1995 ANNUAL DEFORESTATION BY REGIONS

Region  
Northeast  
Northwest  
West  
Center  
Southeast  
Total

Deforestation (thousands of hectares)

Percentage

Source: FAO estimates with figures from the Periodic National Inventory of Forests for 1994.

#### DEFORESTATION IN MEXICO: MAIN CAUSES

Cause  
Forests  
Fires  
Livestock raising  
Agriculture  
Others  
Rain forests  
Livestock raising  
Fires  
Agriculture

Source: Programa Forestal y de Suelos 1995-2000, Department of the Environment, Natural Resources and Fisheries.

Agriculture

Agriculture in Mexico has faced major problems, which limits its contribution to national objectives. Among other problems we could mention:

- A low production growth over the last 30 years.
- Increase in imports to satisfy domestic demand.
- Major problems of profitability, capitalization and productivity.
- Disparity between the levels of productive and technological development in different regions and activities.
- More than three-quarters of the population living in the Mexican countryside are living in conditions of poverty.<sup>1</sup>

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<sup>1</sup> Programa Agropecuario y de Desarrollo Rural 1995-2000, SAGAR

The agricultural and livestock sector experienced rapid growth from the forties to the sixties, which promoted the incursion of the agricultural boundaries.

Agricultural activity grew at a rate of over 4% annually, surpassing the rate of population growth (2.8% between 1940 and 1960). This growth could not be sustained, because the best lands for agriculture had been taken and a significant increase in productivity was not achieved.

Between 1965 and 1980 the growth of the agricultural sector grew at rates of less than 2.5% (less than the rate of population growth), and thus Mexico became an importer of agricultural products.

Nearly 9.7 million people, of the 23 million that live in the countryside, are engaged in agriculture and livestock activities (as producers and workers).<sup>2</sup>

Between 1970 and 1995, the surface harvested per inhabitant dropped from 0.36 to 0.21 hectares. At the present time nearly 18 million hectares are harvested annually on the average, of which 12.5 million are non-irrigated maize, and 5.5 million irrigated.

As for agricultural production, it should be pointed out that grains (palay rice, bean, maize and wheat, principally) occupy 77.4% of cultivated land in Mexico and represent less than half the total production, whereas vegetable and fruit production uses 6.7% of the surface and represents one-third of the total.

#### AGRICULTURAL PRODUCTION: STRUCTURE IN 1994

Crops

Grains

Oily plants

Garden produce

Fruits

Plantations

Forage

Total

Surface area cultivated

Total production

Relative value as percentage

Source: SAGAR and INEGI.

Livestock raising

The livestock sector grew quickly, mainly from the sixties to the mid-eighties, when the number of head of livestock increased by 15%. This was achieved by extending the area

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<sup>2</sup> Encuesta Nacional de Empleo 1995, INEGI. Rural population is considered to include anyone who lives in towns of less than 2,500 inhabitants.

used for grazing. As in agricultural areas, a large part of the new grazing lands were created at the cost of eliminating forests and rain forests by means of official clearance programs, mainly in the southeast. In 1955 the surface used for livestock raising comprised about 50 million hectares. At the present time (1997), it covers approximately 114 million hectares.

In Mexico, the livestock population is made up mainly of cattle. Cattle raising has repeatedly demonstrated this tendency to expand, occupying increasing extensions of lands with brush, forests or natural grasses. To the surface occupied for livestock raising we should add that used indirectly for this activity, namely for the production of fodder.

#### LIVESTOCK POPULATION: EVOLUTION 1980-1994 (THOUSAND HEAD)

Year  
Cattle  
Pigs  
Goats  
Sheep  
Poultry\*  
Total

\* Million head. It includes poultry producing eggs and meat, and turkeys.

Source: Anuario Estadístico de los Estados Unidos Mexicanos, 1995, INEGI.

#### IV. INSTITUTIONAL DEVELOPMENT AND MITIGATION MEASURES

##### INSTITUTIONAL DEVELOPMENT

Over the past few years, Mexico has accelerated the development of its legal, institutional and programmatic platform for the unfolding of a wide range of environmental policies, supported in a growing co-responsibility between the government and society. This development favors a synergy between attention to local and national environmental problems with the fulfilling of our international commitments concerning global problems, such as that of climate change.

A brief synthesis of institutional development is presented below, emphasizing those elements that, directly or indirectly, represent an asset in favor of actions relating to climate change. Also, the actions that are presently under way in Mexico are mentioned, in energy, industrial, urban, forestry and land use matters that are consistent with the mitigation measures promoted on an international scale concerning greenhouse gas emissions.

Since the eighties, Mexican environmental policy began to acquire a comprehensive focus:

- In 1982 the Department of Urban Development and Ecology (SEDUE, initials in Spanish) was created, to determine and to boost ecological policies; that same year the Federal Law of Protection of the Atmosphere (LFPA, initials in Spanish) was passed, as a new legal instrument.
- In 1987 the Constitution was modified to grant the State the powers to impose on private property, regulations tending to preserve and restore the ecological balance; and to empower Congress to pass laws to establish agreement between the Federal Government's measures and those of the state and municipal governments throughout the country.
- In 1988 the General Law of Ecological Balance and Protection of the Atmosphere (LGEEPA, initials in Spanish) was gazetted, as well as the respective laws in the states; this law contemplates the dispositions regarding ecological classification, evaluation of impact and environmental risk, protection of flora and fauna, the rational use of natural resources, prevention and ecological restoration of natural resources, social participation and ecological education, as well as control, safety and sanction measures.
- In 1989 the National Water Commission was created as sole authority in the federal area regarding water administration, granting it technical and operative autonomy; in the respective Law of National Waters, with the reform of 1992, the regulation of the use or exploitation of national waters was improved, and the preservation of their quality.
- In 1992 the SEDUE became the Department of Social Development (SEDESOL, initials in Spanish), with powers to formulate, direct and evaluate ecological policy, and with the support of two specialized organisms: the National Ecology Institute (INE,

initials in Spanish) and the Federal Agency for the Protection of the Atmosphere (PROFEPA, initials in Spanish).

With the present federal administration, qualitative advances are being promoted in the institutional development of environmental management: the Department of the Environment, Natural Resources and Fisheries was created in December of 1994 (see box); between 1995 and 1996 sector programs were prepared for the Environment, Forestry and Lands, Fisheries and Aquaculture and Water Resources; in 1996 the General Law on Ecological Balance and Protection of the Atmosphere (LGEEPA, initials in Spanish) was reformed; and as regards environmental planning, in these last three years an enormous effort has been made to define strategies and program preparation, with the focus on sustainable development.

The National Development Plan 1995-2000 defines strategic guidelines for reactivating economic growth, with a clear commitment in favor of policies and instruments contributing to the transition from national development toward sustainability; and with a recognition of the risks for the country's very future, economically, if the tendencies toward the deterioration of resources and the environment were not halted. Within the framework of this plan, the four sector programs mentioned above were drawn up. The programs were prepared with the support of a full process involving dialogue and consulting with the Advisory Councils for Sustainable Development and Technical Advisory Councils; with legislators, academic and scientific institutions, and local governments.

#### DEPARTMENT OF THE ENVIRONMENT, NATURAL RESOURCES AND FISHERIES (SEMARNAP, initials in Spanish)

In December, 1994, the Congress of the Union approved the creation of the Department of the Environment, Natural Resources and Fisheries (SEMARNAP), whose mission consists in establishing the bases for a transition to sustainable development. In the present stage the strategy concentrates on slowing the processes of deterioration of the environment and natural resources.

The SEMARNAP combines, in a single institution, the following powers:

- Fostering the protection, restoration and conservation of the ecosystems, natural resources, environmental goods and services to favor their sustainable development and exploitation.
- The environmental regulation of productive activities related to the use and exploitation of natural resources.
- The coordinated and co-responsible establishment and supervision of Mexican official norms for the protection, restoration and conservation of ecosystems and of the atmosphere.

- Promoting the ecological classification of national territory, in coordination with federal, state and municipal authorities, and with the participation of the society.

To this end, the policies, programs, and fiscal resources for the promotion of forestry and fisheries, soil conservation and restoration, the ecological care of the federal maritime land zone of the country, and the planning of environmental policy, are organized under a single federal office and the policies and programs of the National Water Commission, the National Ecology Institute, the Federal Agency for the Protection of the Environment, the National Institute of Fisheries and the Mexican Institute of Water Technology are all coordinated.

Although the programs correspond to a sector topic, they share the following main components:

- Protection, conservation and restoration of the environment and natural resources. This is mainly oriented toward the conservation of the ecological balance, the regulation of activities related to the use of natural resources and the preparation of national inventories that would allow the ecological classification to be carried out with certainty.
- Management and sustainable exploitation of natural resources and fisheries. The objective is to diversify the exploitation of natural resources and improve productive activity ecologically, in order to achieve a better control of environmental effects and reduce risk and deterioration.
- Updating the environmental regulation of industry. It implies a new normative focus that prioritizes the multimedia regulation of the processes of pollution with emphasis on prevention rather than on solutions after the fact. Updating the environmental regulation of industry promotes, through administrative and economic incentives, volunteer programs in environmental management that go beyond the obligatory fulfilling of regulations.
- Inspection, surveillance and control. This aspect of environmental management is oriented toward establishing a new form of relationship between federal inspectors and local communities, in order to involve them in the process of protecting resources and meeting environmental regulations more effectively. The objective is to insure the environmental regulations are carried out by strengthening the instruments for promotion, control and prevention as opposed to correction.
- Education, training and dissemination. The actions programmed in this area are intended to consolidate a profound change of attitude in the society which means incorporating the concept of sustainable development into daily life, productive processes and public administration.
- Research and technological development. The fundamental purposes in this area are: the conservation and rehabilitation of habitats and species; the transfer of technologies

that guarantee environmental sustainability; and the improvement of economic processes.

This effort in sector programming simplifies the preparation of a comprehensive framework: the Program to Deal With the Agenda of Sustainable Development (PAADS, initials in Spanish) or Agenda 21 for Mexico, which forms part of the commitments undertaken by the international community at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992. In this respect, it is necessary to mention the beginning of the project of cooperation with the United Nations Development Program (UNDP), to formulate the national strategy to deal with Agenda 21 and to test the procedure for evaluating policies on a specific topic and establishing collective recommendations for incorporating the environmental dimension into relevant public policies. Also, it is necessary to highlight the integration of Mexico's Report 1997 before the **Commission on Sustainable Development (CSD)** of the United Nations, which monitors the Agenda.

## MITIGATION

In any case, a series of special programs have been prepared, foremost among which are those that coincide with the purposes and actions related to climate change:

- Specific Programs 1997-2000 to Improve Air Quality in the Metropolitan Areas of the Valley of Mexico, Guadalajara, Monterrey and the Valley of Toluca
- Program of Protected Natural Areas 1995-2000
- Programs for Minimization and Comprehensive Management of Industrial Waste 1997-2000
- Program for Industrial Environmental Regulations 1997-2000
- Integrated System of Industrial Regulation and Management (SIRG, initials in Spanish)
- Registration of Emissions and Pollutant Transfer (RETC, initials in Spanish)
- Program of Wildlife Conservation and Productive Diversification in the Rural Sector 1997-2000
- Programs of Forestry Development
- Programs for the Development of Commercial Forest Plantations
- Program Frontier XXI

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Regarding the development of the legal environmental framework, the Ordinance reforming the General Law of Ecological Balance and Protection of the Atmosphere (LGEEPA) was published Dec. 13, 1996. The integration of the project of reforms to this law was the result of the joint effort carried out over more than 18 months by the federal Legislative and Executive powers, through the commissions of Ecology and the Environment by the House of Representatives and the Senate. The reform of the LGEEPA is prompted by the following purposes:

- To increase the efficiency of the environmental regulation system extending the reach and minimizing social costs.

- To broaden the perspectives of government administration and social participation.
- To orient the production and consumption decisions toward collective objectives of environmental protection.
- To promote technological change with a preventive focus.
- To present clear rules that would give security to investment and disseminate long-term decisions in favor of environmental protection.
- To generate opportunities promoting technological adaptation and the development of new production alternatives.
- To create an atmosphere of trust between the environmental authorities and the private sector.

Later, in May, 1997, the reform of the Forestry Law was formalized in answer to the concerns of diverse social and business organizations. The Semarnap, in coordination with the commissions of Forests and Rain Forests of the House of Representatives and of Forestry and Water Resources of the Senate of the Republic, and with the participation of the National Technical Advisory Council on Forestry, began the consulting process for the revision of this Law in July of 1996. The reformation was oriented toward:

- Reinforcing the link between environmental and forest legislation;
- Regulating afforestations (commercial forest plantations) in order to minimize their environmental impact, facilitating the participation of the social sector and granting legal security to those who carry out this type of activity;
- Fortifying the mechanisms for authorizing the exploitation of timber-yielding and non-timber-yielding forest resources, taking into account the traditional uses of the indigenous communities;
- Improving the control systems for transporting forest products, in order to eradicate illegal cutting;
- Fortifying the chapter on sanctions for offenders of forest legislation and regulations;
- Favoring the improvement in quality of technical forest services; and
- Regulating and controlling the soundness of imported forest products, in order to prevent the entry of plagues and forest illnesses.

In addition, official Mexican norms were issued to prevent the extraction of firewood from becoming a factor in the degradation of forested areas and to regulate the use of the fire in agricultural and livestock-raising activities in order to reduce the risk of forest fires. Also, other norms intended to prevent the destruction of the coastal wetlands and to promote the recovery of lands used for livestock are in process.

In the area of international agreements and commitments, substantial advances have also been made in the area of regulations, institutions and programs. Among these, the following are noteworthy:

a) The definition and starting up of a series of high-priority actions related to the derived international commitments deriving from:

- The United Nations Framework Convention on Climatic Change.

- The Basle Agreement on Cross-border Movement of Dangerous Wastes.
- The Montreal Protocol on Substances that Deplete the Ozone Shield.
- The Convention on International Trade of Endangered Species of Wild Animals and Plants.

b) The formation of and participation in regional institutions associated with the Free Trade Agreement with the United States and Canada (promoted in the framework of the North American Environmental Cooperation Agreement, as a linking document parallel to the Treaty itself):

- The **North American Commission on Environmental Cooperation (NAECC)**.
- The North American Development Bank (NADB).
- The North **American Environmental Fund**.
- Also, the prevention and control of environmental pollution on the northern border, through the Commission of Ecological Border Cooperation (COCEF, initials in Spanish) and the Environmental Program Frontier XXI.

c) Active cooperation with the Central American Atmosphere and Development Commission (CCAD, initials in Spanish).

## ENERGY POLICY

The energy sector has played a decisive role in the economic and social development of Mexico. Over a long period of time, this policy prioritized self-sufficiency in energy supply as a goal; at present, other equally important goals have been added to this: the promotion of energy saving, technical and economic efficiency in its use and supply, the reference of domestic prices to international prices and the consideration of new guidelines established by the environmental policy of the country for the energy sector.

The care of natural resources and protection of the environment are inherent parts of the set of policies promoted by the energy sector, which has developed an environmental awareness that boosts actions for compensating for or reversing the negative impact of some energy uses; because of this, they set certain criteria in the selection of technologies and in the evaluation of projects, so that environmental considerations will be incorporated into decisions on production and services.

Saving and using conventional energy efficiently, improving the quality of automobile fuels (gasolines and diesel), as well as replacing high-sulfur fuel oil with natural gas for generating electrical power in environmentally critical areas and in industry, as well as promoting the use of economically profitable alternative energies, are aspects that are included in Mexico's energy policy.

The future dynamics of energy consumption in Mexico will depend on various critical factors, especially international economic dynamism, technological advances and their effects on energy efficiency and production costs, as well as environmental regulations related to processes of production, services, transportation and urbanization.

Fuel quality is a particularly relevant topic, since environmental legislation in all countries tends to establish stricter specifications for transport fuels (gasoline and diesel, mainly) and fuels for industrial use (low-sulfur fuel oil and greater use of natural gas).

Undoubtedly, the necessity to respond to the intensifying of the global phenomenon of climatic change will bring about changes in the use of fossil fuels, in the systems of generation of electrical power and, apart from the energy sector, in the conservation, extension and sustainable use of our planet's forest resources.

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#### FUEL IMPROVEMENT POLICY

Mexico has advanced significantly in this sense. Aware of its role in the fight against pollution and with the support of analyses carried out by Fuel Policy Group (GPC, initials in Spanish, high-level interdepartmental group), Petróleos Mexicanos (PEMEX) has developed investment projects that have allowed them to continue supplying larger quantities of better-quality fuel. Most of these investments have been grouped into what is known as the "Ecological Package", which contemplates strategic projects for producing gasolines, diesel and fuel oil of international ecological quality and for developing technologies for refining better-quality fuels, primarily.

This package was considered in PEMEX's ecological program, as part of the Comprehensive Program against Atmospheric Contamination in the Metropolitan Area of Mexico City (PICCA, initials in Spanish), issued by the Department of the Federal District (DDF, initials in Spanish) in September, 1989, and since that date, new projects have been added. In fact, the current Program to Improve Air Quality in the Valley of Mexico 1995-2000 (PROAIRE, from the Spanish) has, as one of their central strategies, the improvement of the quality of the gasolines for vehicle consumption and of fuels for industrial use.

In the domestic market the consumption of unleaded gasolines has increased for this reason; while in 1991 the consumption of these gasolines represented only 10% of national consumption, in August, 1997 it reached 93.5%. Specifically, gasoline containing lead is no longer marketed on the northern border, in the Metropolitan Area of the Valley of Mexico or in Monterrey.

Regarding diesel, it has improved spectacularly through a drastic reduction in its sulfur content. The diesel with 1% sulfur, which in 1991 represented 79% of the market, is not marketed at present and has been replaced with desulfured diesel, with 0.5% sulfur, and by Diesel Sin with only 0.05% sulfur (now PEMEX-diesel). As of May, 1997, PEMEX-diesel had already reached 100% penetration in the automobile market, which demonstrates the magnitude of the effort made by the national oil industry to produce better-quality fuel.

In addition, the hydro-desulphuring plant for waste in the Tula refinery has been completed, which allows low-sulfur fuel oil to be produced.

#### FUEL SUBSTITUTION POLICY

Since 1993, the Department of Energy (SE, initials in Spanish) has coordinated the work of the GPC (Fuel Policy Group, initials in Spanish), which has allowed a comprehensive fuel policy to be outlined for Mexico. One of the main conclusions of the group is the reorientation of the national fuel policy during the period from 1994 to 2005, which consists in reducing the consumption of high-sulfur fuel oil and significantly increasing the use of natural gas.

In addition, around 70% of the thermoelectric plants located in environmentally critical areas will be converted from fuel oil to natural gas. In the process of energy sector planning, environmental regulations have been considered and incorporated with the aim of harmonizing the changes that are taking place, in order to make fuel substitution compatible with ecological protection.

In May, 1995, the Regulations of Article 27 of the Mexican Constitution was modified in the area of oil, to allow for the participation of social and private sectors in the transportation, storage and distribution of natural gas; as well as allowing them to become owners of pipelines, facilities and equipment, which they can build and operate, with the purpose of encouraging the use of this fuel primarily for generating electricity and for industrial use. In addition, this modification promotes the use of natural gas in the residential and commercial sectors.

#### POLICY OF ENERGY SAVING AND USING ENERGY EFFICIENTLY

One of the elements of the National Energy Policy is that of saving and using energy efficiently, which has been incorporated into the development programs of the energy sector. This brought about the creation of the National Energy-Saving Commission (CONAE, initials in Spanish) in 1989 and of the Support Fund for the Energy-Saving Program of the Electrical Sector (FIDE, initials in Spanish) in 1990.

It should be pointed out that through the rational use of fossil fuels, reductions can be achieved in greenhouse gas emissions. The FIDE promotes energy audits and financing of adaptations and demonstration projects in industries, businesses, educational institutions and public services, supplemented by dissemination and training activities. Also, since 1996, the FIDE Fund has coordinated the implementation of daylight saving, which saved approximately 1.7 million barrels of petroleum from being burned, thereby preventing a great quantity of greenhouse gas emissions.

For its part, the CONAE includes among its functions the establishment of energy-saving programs on a national scale, promotes the dissemination of co-generation in industry, and prepares the Mexican Official Regulations (NOM, initials in Spanish) that regulate the energy consumption of building facilities and electrical apparatuses.

At the beginning of the present decade, the Public Service Law on Electrical Energy was modified. At the present time the priorities of public investment are oriented toward strengthening the areas of transmission and distribution, inasmuch as private participation has been allowed in generating energy, through diverse modalities foreseen in the stipulations in this Law and its Regulations: independent production, self-sufficiency, co-

generation and small production, as well as importing for one's own consumption and exporting.

## ADDITIONAL OPTIONS FOR THE MITIGATION OF GREENHOUSE GASES

In the study "Evaluation of Greenhouse Gas Emissions and Mitigation Strategies in Mexico", carried out by the University Energy Program of the National Autonomous University of Mexico (PUE-UNAM, initials in Spanish), three scenarios contemplating the analysis of fuel-efficient technologies have been established:

- Co-generation for five branches of industry (including changes in current technology and in the new plants).
- Compact fluorescent lamps in the residential sector.
- Efficient illumination in the commercial sector.

In order to determine Mexico's energy requirements of Mexico for the year 2005, the STAIR model was used and, for cost estimates, the ETO (Energy Technology Optimization) model, which calculates minimum costs for the different scenarios.

Generally, the results obtained show that:

- **Combined-cycle** technology is preferable economically to other technologies for generating electricity;
- Additional needs for natural gas should be covered by imports;
- The model is extremely dependent on the transportation and supply of natural gas;
- Co-generation is highly profitable, by avoiding the construction of new generating plants;
- The results in total CO<sub>2</sub> emissions make it clear that the greatest mitigation is in generating electricity.

## NEW ENVIRONMENTAL POLICY TOWARD INDUSTRY

The regulation system regarding the environment in Mexico was developed quickly, beginning in the eighties and reaching very significant achievements. Since approximately four years ago, a stage of revision has begun, consistent with the new environmental conditions and demands in Mexico and globalized markets. Instead of emphasizing command and control in solving environmental problems, at the end of the processes that caused them, and the traditional work of inspection and supervision, another approach has been adopted, without losing the advantages and progress of the previous one.

This new focus on regulations in the environmental area promotes the establishment of maximum permissible levels of pollutant emissions, more according to the characteristics of the receiving medium (water, soil, atmosphere) than the emission source (specific industries). It also encourages multimedia environmental regulations, being concerned with the aggregate and accumulative character of the polluting processes, and with the transfer of pollution among different media. While tightening control, it prioritizes the prevention of

pollution, promoting technological innovation, the substitution and improvement of inputs, processes and energy, which makes regulations more effective environmentally and more efficient economically.

By means of the design of administrative inducements and the promotion of economic incentives, this focus attempts to go beyond the goals and obligations of industrial establishments in the environmental area. In this framework, voluntary agreements in the environmental management of industrial processes are very relevant, with an increasing number of promising cases of self-regulation.

The following indications can be pointed out as the present guidelines in developing environmental regulations for industry in Mexico:

- They should be generally observed by a relatively large number of actors, processes or activities;
- If possible, they should be applicable to all agents contributing to the problem and differentiated by the type of ecosystem, if convenient;
- Their application should be gradual in order to allow for less expensive adjustment;
- The potential effects on other media need to be considered, to avoid or reduce transfer among them;
- Derived effects that might influence other sectors should be analyzed (for example, considering the effect on demand and availability of fuels);
- Application time should be as long as possible in order to give assurance to agents being regulated.

The updating of environmental regulations for industry is supported by the new focus on regulations, which prioritizes the multimedia regulation of pollution processes, with more emphasis on prevention than on after-the-fact solutions. Also, through administrative inducements and economic incentives, it promotes volunteer programs in environmental management that go beyond the obligatory compliance with regulations.

Consequently, the implementation began in 1997 of a coherent and effective system that avoids institutional divergences, over-regulation and administrative inefficiencies, named the Integrated System of Regulation and Environmental Management in Industry (SIRG). SIRG is made up of three closely related, basic elements: the Sole Environmental License (LAU, initials in Spanish), the Annual **Operation Permit** (COA, initials in Spanish) and the Voluntary Program in Environmental Management (PVG, initials in Spanish).

To complement this, the project under way in the Registration of Emissions and Pollutant Transfer (RETC) corresponds to one of the main ideas, arising out of the Earth Summit on the Environment in Rio de Janeiro in 1992, that refers to extending the experience of several countries that have modified or adapted their instruments of environmental regulation to include a multimedia inventory of their emissions and pollutant transfer. Mexico joined that initiative, with the development of a Pilot Project in the state of Querétaro and the formation of the National Coordinating Group, which prepared the **RETC** Executive Proposal.

By means of the **RETC**, with a multimedia focus and the development of capacities for administering relational databases, systems of geographical information and models for indirect estimates of non-point sources and establishments not subject to reporting, it will be possible to know the emissions and transfers of high-priority pollutants pertaining to all sectors of the economy and throughout all municipalities and states in the country.

Also, the RETC is a basic tool of environmental management so that, at different levels (companies, associations, municipal, state and federal governments), actions can be undertaken in relation to:

- Plans of action for reducing greenhouse gases in compliance with the Convention on Climate Change;
- Complying with environmental regulations;
- Evaluation and communication of environmental risks;
- Prevention of pollution and reduction of waste at the source and throughout the process;
- Control of air pollution;
- Administration of watersheds;
- Prevention of chemical risks;
- Programs of public dissemination on levels of compliance with regulations and environmental performance of establishments, and public access to environmental information;
- Environmental administration and certification.

#### Sole environmental license (LAU)

The LAU is the backbone of the SIRG. It coordinates the COA and the PVG. The license is an instrument of direct regulation, of an obligatory nature for industrial establishments under federal jurisdiction that will permit the coordination, in a single process, of the evaluation, verdict and monitoring of the corresponding obligations and processes, according to the case, regarding environmental impact and risk, emissions to the atmosphere, exploitation of national waters, discharge of wastewater into bodies of water and federal lands, as well as in relation to the generation and treatment of dangerous waste. It introduces, as a new focus, the comprehensive consideration of environmental pollution that each industrial establishment generates when relating the polluting effects on different media (water, soil, atmosphere).

#### Annual Operating Permit (COA)

The COA is the instrument for monitoring, updating and giving informing on each industrial establishment regarding emissions and pollutant transfer. It aims at favoring the progressive control of pollution and updating the grounds for licensing. An important part of the Permit is the annual information that it provides on the performance of the industrial establishment, enabling an Inventory of Emissions and Pollutant Transfer to be prepared annually and enabling specialized databases, able to give greater solidity to decision-making on the part of the environmental authorities, to be fed; these databases are

integrated into the National System of Environmental Information (SINIA, initials in Spanish ).

#### Volunteer Program of Environmental Management (PVG)

It aims at developing the capacity for environmental management in each industrial establishment and at environmental protection forming part of its system of total management. Its purpose is to achieve a comprehensive, continuous and growing protection, privileging the prevention and decrease of pollution and the sustainable exploitation of natural resources at all stages of the productive and commercial chains, as well as the use of process technologies before control equipment.

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The operation of the RETC will represent a fundamental instrument for defining priorities for environmental policy; also, it will guarantee pertinent information on the environmental effects of industry.

#### ENERGY CONSUMPTION STRATEGIES

The efficient use of energy is the most cost-effective strategy for mitigating greenhouse gas emissions originating in the energy system. Although present in the official energy plans since 1976, until recently an investment effort structured at the national level had not been carried out with this purpose on the part of the public sector. By constitutional mandate, this sector is responsible for the supply and administration of energy. Historically, the energy sector had focused more on covering the growing demand for a developing country, than on managing the demand efficiently.

In 1979, the **Federal Electrical Commission** (CFE, initials in Spanish) carried out an effort to handle the demand, offering information to consumers on energy-saving. This program was supported, as pointed out above, by the creation of the Support Fund for the Energy-Saving Program of the Electrical Sector (FIDE) and of the National Energy-Saving Commission (CONAE).

#### ENERGY SUPPLY STRATEGIES

Reorientation of the national fuel policy during the period 1994-2005, which consists in reducing the consumption of fuel oil and increasing the participation of natural gas, mainly in the generation of electric power (in plants located in environmentally critical areas) and for the industrial sector, will be particularly helpful in preventing the emission of a major quantity of CO<sub>2</sub>, since the emission factor for this gas is 38% less than that of fuel oil.

With modifications to the Regulations of Article 27 of the Mexican Constitution in the area of oil, social and private sectors are permitted to transport, store and distribute natural gas, as well as to become owners of pipelines, facilities and equipment, which they can build and operate, with the purpose of encouraging the use of this fuel, mainly for generating electricity and for industrial use, as well as their employment in the commercial and residential sectors, so that a wider perspective has opened up for its use.

Another interesting aspect arises from the different modalities foreseen in the stipulations contained in the Public Service Law on Electrical Energy and its Regulation: independent production, self-sufficiency, co-generation and small production, as well as importing for one's own consumption and exporting. Co-generation increases efficiency in fuel use and contributes to moderating the growth of greenhouse gas emissions.

## URBAN REORGANIZATION, TRANSPORTION AND IMPROVEMENT OF AIR QUALITY

Among the actions and policies that are being carried out in the country to mitigate emissions of pollutants is the construction of an inventory of emissions by source type and pollutant. In 1989 an inventory of emissions was elaborated for the Metropolitan Area of the Valley of Mexico (ZMVM, initials in Spanish), according to which industrial and service sources contributed 8.4% of the total emissions to the atmosphere and vehicles, 77%. 24% of the NO<sub>x</sub> emissions came from industrial and service sources, with 75% corresponding to vehicle sources. On the other hand, the source of 13% of HC emissions were industries and services, and 53% were vehicle transportation.

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In 1995 a new inventory of emissions was prepared with information available up to 1994, which is not comparable with the results of the 1989 inventory, because they were prepared with different methodologies for estimation and construction. The more recent one indicates that the total emissions of gases and particulates into the atmosphere are 4,009,629 tonnes per year, 13% of which corresponds to industry and services, and 75% to the transportation sector. The contribution of industrial sources comes to 50.3% of SO<sub>2</sub> and 25% of NO<sub>x</sub>, while automobiles emit 71% of all NO<sub>x</sub>, 99% of CO, 54% of HC and 27% of SO<sub>2</sub>.

The vehicle contribution in the area of particulates is less than 5% of the total; however, it should be stressed that their degree of toxicity and the exposure of people associated with this sector is much more significant. It should be pointed out that the contribution of services represents 39% of the total HC, a sector in which marketing and distribution of LP gas contributes significantly. Preliminary estimates of these emissions indicate that they could be of the order of 250 thousand tonnes annually, that is to say, 24% of the total hydrocarbons emitted.

According to the inventory of existing economic units in the ZMVM, in 1994 there were 4,623 industrial establishments and 13,269 service establishments which, together with 20% of the national population that inhabits this area and a corresponding vehicle pool that is considered to have between 2.5 and 3 million automobiles (which has grown continuously during the last few years to rates of nearly 10% annually), makes pressure on the atmospheric basin excessive.

In the four most densely populated and industrialized metropolitan areas in the country (the Valley of Mexico, Guadalajara, Monterrey and the Valley of Toluca) in the two-year period

of 1996-1997, specific programs for improving air quality were put into effect and, with some particularities, concentrate their strategies on achieving four major goals:

#### Goals

- i) Clean industry
- ii) Clean vehicles
- iii) Efficient transportation and new urban order
- iv) Ecological recovery

#### Strategies

- Reduction of the concentrations of emissions of Pb, HC, NO<sub>x</sub>, SO<sub>2</sub>, and total suspended particulate matter, produced by industrial and service sources
- Reduction of emissions per unit of added value in industry and services
- Improvement and incorporation of new technologies, improvement and replacement of industrial fuels
- Economic incentives
- Industrial inspection and supervision
- Environmental information and education, and social participation
  
- Reduction in vehicle emissions per kilometer traveled
- Improvement and replacement of automobile fuels
- Economic incentives
- Vehicle inspection and supervision
- Environmental information and education, and social participation
  
- Regulation of total kilometers traveled by automobiles, ample offer of safe and efficient public transportation
- Integration of metropolitan policies (urban development, transportation and ecology)
- Economic incentives
- Transit inspection and supervision
- Environmental information and education, and social participation
  
- Stamping out erosion due to the invasion of urban sprawl onto forest and agricultural land
- Ecological recovery of urban and urban/rural ecosystems
- Integration of metropolitan policies (urban development, transportation and ecology)
- Economic incentives, environmental information and education and social participation

#### 1994 Emissions Inventory

Tonnes/year

Type of source:

TSP (total suspended particulates)

SO<sub>2</sub>

CO

NO<sub>x</sub>  
HC  
Total

Industry:

Generation of electrical power  
Petroleum/petrochemical refining  
Chemicals industry  
Metallic minerals  
Non-metallic minerals  
Vegetable and animal products  
Wood and derivatives  
Food products  
Clothing industry  
Products of consumption (various)  
Printing products  
Metallic products  
Medium-life products of consumption  
Long-life products of consumption  
Graphic arts  
Others

Services:

Washing and grease removal  
Solvent consumption  
Gasoline storing and distribution  
Marketing and distribution of LP gas  
Dry-cleaning operation  
Architectural grounds  
Bakeries  
Automobile painting  
Transit painting  
Hospital sterilization  
Hospital incineration  
Use of asphalt  
Wastewater treatment plants  
Hospital combustion  
Residential combustion  
Commercial/institutional combustion

Transportation

Private automobile  
Pick-up truck  
Microbus  
Van  
Taxi  
Public transport bus (R-100)

Coach, suburban bus  
Transport truck  
Transport truck (more than 2 axles)  
Municipal bus  
Locomotives  
Shunting locomotives  
Airport  
Vegetation  
Vegetation  
Soils  
Soils  
Total

Source: DDF, state of Mexico, Department of Health, 1996. Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000, pp. 76-77.

1994 Emissions Inventory  
Percentage by weight according to pollutant

Type of source:

TSP  
SO<sub>2</sub>  
CO  
NO<sub>x</sub>  
HC

Industry:

Generation of electrical power  
Petroleum/petrochemical refining  
Chemicals industry  
Metallic minerals  
Non-metallic minerals  
Vegetable and animal products  
Wood and derivatives  
Food products  
Clothing industry  
Products of consumption (various)  
Printing products  
Metallic products  
Medium-life products of consumption  
Long-life products of consumption  
Graphic arts  
Others

Services:

Washing and grease removal  
Solvent consumption

Gasoline storing and distribution  
Marketing and distribution of LP gas  
Dry-cleaning operation  
Architectural grounds  
Bakeries  
Automobile painting  
Transit painting  
Hospital sterilization  
Hospital incineration  
Use of asphalt  
Wastewater treatment plants  
Hospital combustion  
Residential combustion  
Commercial/institutional combustion

Transportation  
Private automobile  
Pick-up truck  
Microbus  
Van  
Taxi  
Public transport bus (R-100)  
Coach, suburban bus  
Transport truck  
Transport truck (more than 2 axles)  
Municipal bus  
Locomotives  
Shunting locomotives  
Airport

Vegetation  
Vegetation

Soils  
Soils

Total

Source: DDF, state of Mexico, Department of Health, 1996. Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000, pp. 78-79.

Due to the environmental impact of urban transport and industry, as well as the size of the population that lives in and uses an automobile in urban areas, the National Ecology Institute (INE) recommends that in cities with populations near, or above, 500 thousand inhabitants should install at least four monitoring stations. At the present time, 50 cities in Mexico have at least one (manual or automatic) air-monitoring station. Of these,

Guadalajara, Toluca, Monterrey and Tijuana, as well as Mexico City, frequently experience high levels of ozone and suspended particulate matter above acceptable limits.

Of all the cities with environmental monitoring systems, 47 have manual stations to measure total suspended particulates and sulfur oxides, and 29 cities have automatic monitoring stations. The city with the most extensive network is Mexico City, which has 32 automatic stations and 19 manual ones; Toluca, for its part, has 7 automatic and 5 manual stations, and San Luis Potosí, 5 automatic and 8 manual stations.

Besides the systematic monitoring of the pollutants mentioned and with the coordination of the government offices corresponding to state representations of the Department of the Environment, Natural Resources and Fisheries, Department of Health, state (including federal district) governments and respective municipal ones have been implementing different actions and policies promoting the improvement of fuels, their replacement, energy-saving and efficient energy-use, and the creation of synergies favorable to a reduction in concentrations of the pollutants mentioned. These programs are:

- Programs to improve air quality in the Valley of Mexico 1995-2000.
- Program of air quality management in the metropolitan area of Monterrey.
- ¡Claro! Aire Limpio (Of course! Clean Air). Programs for the Valley of Toluca 1997-2000.
- Programs for improving air quality in the Metropolitan Area of Guadalajara 1997-2001.

## ENVIRONMENTAL ADMINISTRATION OF FOREST RESOURCES AND LAND USE

A central strategy in Mexico's environmental and natural resources policy, is to check tendencies toward exhausting natural resources and to give a new impulse to productive processes that take advantage of all of the country's natural wealth according to criteria of sustainability. In particular, two major headings can be identified in actions and policies under way that, direct or indirectly, help in reducing greenhouse gas emissions and in conserving sinks and natural deposits for CO<sub>2</sub> in Mexico.

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- In order to curb the depletion of natural resources, revitalized policies and programs for protecting the environment are being deployed that emphasize the protection of biodiversity and of the functions of the ecosystems, which in turn gradually promotes sustainable production practices in the rural sector.
- The aim to conserve and make the most of the forest potential of our lands and ecosystems has given rise to new instruments, both of a technical or institutional nature and of an economic nature, for the betterment and environmental management of our forest resources.

## PROTECTED NATURAL AREAS

Mexico is recognized worldwide for its great natural wealth. It is one of the twelve countries considered biologically megadiverse, since its territory is home to a large number

of the ecosystems and live species of our planet. For that reason, the conservation and protection of this biodiversity constitute a high priority in Mexico's environmental policy.

In 1996, the Program of Protected Natural Areas of Mexico 1995-2000 was made public. According to this, these areas constitute the primary instrument in conserving both biodiversity and ecological goods and services, by representing the possibility of reconciling the safeguarding of the ecosystems with management mechanisms and institutions solidly founded in our legislation.

The aims of the strategy regarding natural areas include the extension of the surface under protection and, at the same time, the improvement in the efficiency of the conservation of biodiversity. Recently, 27 protected natural areas were selected for pilot projects, as objects of combined efforts in institutional integration, financing, handling and administration. By attending to these areas, that section of the designated area having greatest natural wealth is covered, and the most representative ecosystems in the country are thus protected.

Also, the National System of Protected Natural Areas and the National Council of Protected Natural Areas were created.

Instruments used for these purposes include: declarations, pacts and participation agreements; fiscal funding and international financial sources; mechanisms of voluntary economic exchange; management programs and the annual operative programs; administration systems; concurrence with sector programs and regulations. All of this is intended to create a strong system, with financial and administrative capacity, that would contribute effectively to the goals of ecological conservation and sustainable exploitation of the country's natural wealth.

At the present time, Mexico has 99 protected natural areas occupying 11,687,563 hectares, that is to say, almost 6% of national territory.

It should be mentioned that for the first time in Mexico, a considerable amount of funding from different sources has been allocated to the appropriate development of the protected natural areas: in 1997, 28,840,000 pesos of fiscal resources were programmed to deal with 11 pilot areas; 14 others have the support of funds from the Global Environmental Facility (GEF) and the Northern Border Environmental Program (partially funded by the World Bank).

Given the need to attend to the many different requirements for conservation of the protected areas, government funds, even with external financing, are not enough. It is for that reason that an unprecedented effort has been made to obtain additional funds from various sources. Important agreements have been signed with companies of the private sector with the object of supporting the management and administration of protected areas and of endangered species, with a contribution estimated at 10 million pesos annually for seven protected natural areas. On the other hand, Petróleos Mexicanos contributes the sum of 4,700,000 pesos for the Conservation and Management of the "Laguna de Términos" Wildlife Protection Area.

## DEFENSE OF THE FOREST BOUNDARY

It is estimated that 80% of the land in Mexico suffers from some degree of degradation. Contributing significantly to it is the loss of forest mass. Particularly severe is the case of the rain forests in the south, which lose between 1 and 2% of their surface per year. If these tendencies are not reversed, there will be very serious consequences for Mexico.

The recovery of the forest boundary implies reclaiming lands already degraded - either because they have lost their original vegetation cover or because the soils are degraded or in the process of degradation -, and carrying out preventive work through appropriate management, both of the forests and of the soil itself.

To this end, a strategy is being deployed that proposes integrating an appropriate framework of regulations, applying direct incentives, drawing benefits from technical assistance services and distributing information to allow producers to use the best technologies for their land management.

In this same vein, a national effort is being carried out through the National Reforestation Program (PRONARE, from the Spanish). This program is reoriented toward restoring strategic areas, enriching forest masses, introducing appropriate species and effectively developing agroforestry programs. Among its goals is the production of 340 million trees. Since 1993, substantial changes have been brought about in the PRONARE, giving it a fundamentally rural character, in comparison with the approximately 40, mostly ornamental, species produced up until 1992. At the moment, 347 species are reproduced, mainly regional and utilitarian.

With the object of promoting the co-responsibility of the social agents involved and coordination of actions in the area, the National Technical Advisory Council for Soil Restoration and Conservation was created, and work with the Soil and anti-Desertification Information Network (RISDE, initials in Spanish) was consolidated.

In addition, the National Network of Germ Plasma Banks has begun operations, with an estimated 25 affiliated banks for the near future and expected approval of Official Mexican Regulations on germ plasma. By the year 2000, this will permit rural reforestation with certified seeds, and technical assistance and training.

To support better management of lands, the framework of regulations is being modified. Regulations related to summer pastures, wetlands, mines and candelilla are under consideration. Also, work has begun on drawing up and discussing the preliminary plan for a new Soil Law.

## PROGRAMS FOR FOREST DEVELOPMENT (PRODEFOR, from the Spanish)

Mexico has an important forest potential that has not however been developed completely. Of the 21.6 million hectares of forest with commercial potential, only 7.1 (33% of the total) are being exploited. The rational use of forest resources is a necessary condition for improving the living conditions of the twelve million Mexicans living in the forests, rain

forests and arid areas of the country. The recent Program of Forest Development, which constitutes the Mexican government's first great effort at dealing with the problem of the forest sector, places emphasis on the conservation and use of forest resources; it directly encourages producers to commission the preparation or updating of forest management programs, to carry out conservation work and train them in management techniques aimed at regional and community development.

The strategies of this Program are: to increase the surface being exploited, through aid for Programs of Technical Studies and Management; to increase yields, through aid for technical assistance and training; to generate a greater added value by means of aid for productive organization; and to diversify products and uses, by granting aid for diversification, exploiting non-timber-yielding resources and promoting alternative uses for forests.

The Program involving a plan to permit the coordination of growing federal fiscal funds, external credit and contributions from state governments and the forest producers themselves, was initiated in 1997.

## COMMERCIAL FOREST PLANTATIONS

Mexico has great agro-ecological and market advantages for developing commercial forest plantations on an international scale. In fact, 12 million acres of lands with great productive potential for this activity have been identified.

The Program for the Development of Commercial Forest Plantations (PRODEPLAN) is based on this productive potential. It aims at forming a sustainable model of commercial forest plantations and contributing toward overcoming the high rates of degradation.

As a result of this program, 875,000 hectares of plantations are expected to be established over the next 25 years. The base plan of the PRODEPLAN will permit the reimbursement of up to 65% of the costs incurred by stakeholders in establishing and maintaining the plantations during the first few years.

The responsibility for administering the resources corresponds to a Fund created for this purpose. It should be pointed out that the PRODEPLAN subsidies are to be allocated by public bid, by means of a procedure of successive auction.

For 1997, the operation of 250 million pesos has been authorized: 190 million for plantations for obtaining raw cellulose materials; and 60 million for plantations for other raw materials.

The projects selected should insure that the plantations will not substitute the existent vegetation and that their development will not alter regional ecosystems. The plantations should favor the creation of a new natural wealth, since they will reclaim, for forest use, areas that are degraded at present.

- Forest mitigation strategies

The forest sector deserves special attention, because at the present time it constitutes the second most important source of carbon emissions at the world level, and the first in Latin America (IPCC, 1992).

In spite of being a net source of emissions nowadays, the forests have the potential of becoming major carbon sinks (Dixon et al, 1994). In recent years numerous mitigation analyses have been carried out in the forest sector, especially at the worldwide level (Trexler and Haugen, 1993). These analyses have demonstrated that a great potential exists for sequestering carbon inside this sector. Besides, many forest options seem competitive with savings in the energy sector (Dixon et al., 1993, Sedjo et al., 1995).

In any case, standard procedures are not yet available for estimating the implications, in economic terms and in terms of carbon, of a reduction in emissions of this gas and of increasing its absorption in the forest ecosystems (EAP, 1995). There is also a need in Mexico for detailed mitigation analyses that would enable more realistic estimates to be made of technically and socio-politically available land for the different mitigation options, the quantity of carbon sequestered per unit area, and the costs and benefits associated with each option.

The analysis of mitigation options in the forest is particularly difficult, since there are large gaps in information regarding carbon densities in the vegetation and soils, particularly in tropical ecosystems. As opposed to the burning of fossil fuels, in which carbon is emitted once and for all, forests are simultaneously carbon sources and sinks. Besides, carbon emissions and sequestering have a complex time dynamic concerning carbon pools with very different residence times. Finally, the socioeconomic aspects of forest options in general are closely related to other land uses.

There are many challenges in deriving future scenarios for carbon sequestering and emission in the forest sector. In the first place, there are great discrepancies regarding the forest cover and current deforestation rates in Mexico.

A mitigation option can be defined as any action that results in a net increase in carbon density in a given area and/or replacement of fossil fuels. At the biophysical level, the two basic options for carbon mitigation are:

- a) Preventing (avoiding) carbon emissions, and
- b) Increasing the fixation and storage of carbon.

The first can be achieved by avoiding the degradation and cutting of forest areas. This is normally achieved through caring for protected areas and through the sustainable management of natural forests. Carbon emissions can also be avoided by burning biomass harvested sustainably, instead of fossil fuels, for energy production (for example, using energy plantations to supply energy to plants generating electrical power), and by replacing wooden products with industrial products that are manufactured with intensively used fossil fuels or replacing logs with cement.

The second focus includes increasing the carbon density in a certain area and/or the reservoir of stored carbon. In this case, the basic option is to reforest the land, for example, restoring or establishing industrial plantations and/or biofuels in degraded areas. Alternately, actions can be considered for increasing the carbon density in existing forests (increasing rotation period, changing to selective low-intensity cutting, etc.).

Once the mitigation options have been identified, it is necessary to estimate the net and unit carbon sequestering for each of them. These parameters will serve as a basis for estimating the implications of carbon sequestering in alternative future scenarios for the forest sector.

- Unit of carbon sequestering

A correct analysis of the implications of undertaking a carbon mitigation option should include the different carbon reservoirs that can be created or saved with the project (Swisher, 1991; EAP, 1995). These reservoirs include that carbon which is stored in the vegetation (above and below ground level), in decomposing matter, soil, and wooden products, and that saved by burning wood for energy production instead of fossil fuels. Most carbon stored in forest ecosystems and in wooden products is necessary, because the different carbon reservoirs increase or diminish with the rotation period (for example, in the plantation project, the carbon stored in the vegetation constantly increases during the rotation period, decreases abruptly with the harvesting and increases when trees are replanted again). Thus, if a point estimate is used – for example, the carbon content at the end of the rotation period – it would overestimate or underestimate the real quantity of carbon sequestered by the project.

Ideally, the planning horizon should be long enough to ensure that all reservoirs have reached a state of stability or nearly so. The terms to be included will vary according to the type of project. For example, in most restoration plantations there will not be timber-yielding products, while in the bioenergy projects, everything that is harvested will usually be used as fuel. Additional carbon storing can be achieved in the reservoir in wooden products by taking into consideration their possible replacement with products of intensively used fossil fuels such as cement, steel and other construction materials.

- Unit of net carbon sequestering

In order to incorporate any forest option into a carbon mitigation analysis, it is necessary to estimate the net carbon sequestering associated with the option proposed. This means defining a "reference case", and the time horizon of the mitigation option. The reference case indicates the quantity of carbon that could be sequestered if the option were not implemented. Thus the carbon benefit of a given option (the "net carbon sequestering") is the difference between the total carbon sequestered with and without the project.

Following this procedure, we will avoid, for example, declaring the carbon benefits for a plantation established by cutting natural forests. As for the time horizon, we should distinguish conceptually between two carbon sequestering alternatives: the carbon saved by replacing fossil fuels and that sequestered by vegetation, soil and wooden products. In the

first case, the net carbon sequestering is simply the quantity saved during the period the project lasts (usually, the amount of carbon saved per year by replacing fossil fuels).

In the second case, the net carbon sequestering will depend in large part on the selected time horizon. If (stable) long-term averages of the different carbon reservoirs are used to estimate the total carbon stored, it is assumed that the project will have infinite duration. If this is not the case, the total carbon stored should be adjusted by a factor that would take into consideration the value of keeping a tonne of carbon away from the atmosphere for a limited length of time. For example, having a plantation project operating during one or two rotations and then adapting the land for agriculture. The adjusted value of the total stored carbon will be considerably smaller than that obtained in a stable state, and the smaller the period of time considered, the smaller it will be.

- Mitigation options in the forest sector

In table 1, seven options are described for conserving existing forests and increasing the present forest area. These options include, within the conservation of existing forests, the protected natural areas, the management of natural forests and the distribution of improved, wooden-combustion, kitchen stoves. Under the heading of reforestation, restoration plantations, pulp plantations for paper, plantations for energy production and systems of agroforestry.

#### JOINT PROJECT IMPLEMENTATION

The incremental costs of reducing greenhouse gas emissions in developed and developing countries are very different. The former face greater incremental costs, so that the same quantity of money invested in a developing country will produce much greater reductions of these gases (mitigation) than if it were invested in a developed one. The proposal for joint implementation implies sharing the saving of emissions taking into consideration such concepts as that of common but differentiated responsibility and that of equitable distribution of environmental and economic benefits.

TABLE 1. PROCEDURE FOLLOWED IN CALCULATING NET CARBON SEQUESTERING ACCORDING TO MITIGATION OPTION

#### Option

##### Conservation

Natural Protected Areas\*

Natural forest management\*

Kitchen stoves fueled with improved firewood

##### Reforestation

Restorative plantations

Industrial plantations\*

Plantations for generating electricity\*

Agroforestry\*

## Net carbon sequestering

Emissions from deforestation prevented (both immediately and subsequently). Emissions estimated by some models assume 10% of biomass burned is converted into charcoal and a loss in the soil of 30% (high estimate) or with no loss in the soil (low estimate).

Same as above. Assumes harvesting based on selective, low-intensity cutting, so that total biomass of managed forests is similar to that of original, natural forest. Carbon stored in the wood products is added to net sequestering.

Emissions prevented by sustainable use of firewood. Carbon sequestering incorporates firewood saved in final use corrected by a factor that takes into account total cutting of wood in the place that is harvested.

Assumes plantations established on degraded lands with carbon densities of 5 tonnes C/ha (temperate) and 10 tonnes C/ha (tropical). Plantations reach carbon density of 70% (vegetation plus soil) of natural forests. There is a 50% carbon gain from soil of degraded forest land. High and low estimates differ in supposed carbon content of soil.

Assumes plantations established on agricultural/grazing lands with carbon densities of 5 tonnes C/ha (temperate) and 10 tonnes C/ha. Also assumes plantations reach 70% carbon density of natural forests. There is a 50% carbon gain from soil with alternative land use. High and low estimates differ in supposed carbon content of soil.

Incremental carbon content of degraded forest lands (with same carbon content indicated above), plus additional yearly sequestering from amount saved (for example, non-combustion) of fossil fuels (bunker).

Incremental carbon content of present agricultural systems. Agroforestry systems give 50% gain in carbon contents in soil.

Note:\* It is assumed that the alternative land use is yearly agriculture or degraded rangeland with a carbon density of 5 tonnes C/ha in the vegetation and decomposing matter (in temperate regions) or 10 tonnes C/ha (in tropical regions).

The objective is to explore the possibility of crediting -selectively for each type of gas - these reductions to the inventories of developed countries, while developing countries could receive financial and technological cooperation for achieving such reductions. In other words, this means the possibility of subtracting them from the greenhouse gas emissions inventory of a country that would grant financial resources to enable sinks to be conserved in countries of lesser development. The goal is to make developed countries and those in transition toward market economies return, either individually or jointly, by the year 2000, to 1990 levels of greenhouse gas emissions.

Formally and on an international scale, this alternative is in the pilot stage, which means that no country can request a credit for emissions in these projects. Later on, with

experience and the development of methodologies and criteria, full joint implementation will begin, as of the year 2000.

Although the meaning of joint implementation, in the context of the Article 4.2 of the Convention, refers to countries belonging to Annex I, after the First Conference of Parties in Berlin, in 1995, this concept was extended to include countries not belonging to this Annex.

#### SUMMARY OF JOINT IMPLEMENTACION OF PROJECTS (PILOT PHASE)

1. ILUMEX project. ...This is the first project developed with the Joint Implementation plan by our country. It is being carried out through the Federal Commission of Electricity and has the international collaboration of the government of Norway and the Global Environment Facility (GEF). Its duration will be from 1995 to 2006.

ILUMEX is a project for managing energy demand that promotes the initial replacement of 200,000 incandescent light bulbs with compact fluorescent lamps in the cities of Monterrey and Guadalajara. These lamps consume 25% less energy than conventional light bulbs, which produces a reduction in the greenhouse gas emissions associated with the generation of electrical power. By the year 2006, 1.7 million light bulbs will have been replaced.

2. Carbon sequestering: forest communities in the Sierra Norte of Oaxaca (in the initial stage, reference terms complete).

In the framework of the Semarnap initiative to reduce deforestation rates and to promote the correct management of forest resources, two high-priority actions are found that can contribute to reducing greenhouse gas emissions, especially CO<sub>2</sub>. Based on the work of the Consejo Civil para la Silvicultura sustentable, A. C. [Civil Council for Sustainable Forestry], in support of the design of strategies for the conservation and use of forest resources on public lands in the Sierra Norte of Oaxaca for the communities of Ixeto, Uzachi and Ucefo, four communities will implement a pilot phase of the program that will cover 45,150 hectares.

3. Carbon sequestering and sustainable administration of forests in the state of Chiapas (in progress).

This carbon sequestering project assists in the development of small companies of forest products in two regions of Chiapas located within regions with indigenous populations. Initially, the farmers will participate by planting trees inside their plantations. Later on, plans are expected to be implemented for the management of communal areas of forests or degraded lands. Although the time scale for the entry of inputs is three years, consulting and financing will be maintained for at least 25 years, in order to increase the prospects for sustainability.

The project receives technical assistance from the University of Edinburgh, and will be carried out by the Pajal Credit Union and monitored by the School of the Southern Border (Ecosur). Besides the service of direct carbon sequestering, major social and ecological benefits are expected.

4. Sustainable commercial development of tropical rain forests in the state of Campeche (in the initial stage, reference terms under revision).

Local participation in the project is the responsibility of a company called Forestry of the Ejido of Champotón, formed with capital contributed in equal proportions by the Ejidatarios and Maderas Ese, S. A. de C. V., a company of forest products. The project aims at creating a sustainable forest economy, by developing methods to obtain commercial wood from tropical rain forests and other resources, in order to increase the socioeconomic level of the inhabitants, increase the biodiversity and confront the problem of global heating. Hopefully an end will also be put to the practice of slash-and-burn agriculture. The products of the tropical rain forests would include biological, ecological products, oxygen generation (through photosynthesis and carbon sinks) and ecotourism.

5. An agrological forest diagnosis of productivity in forest soils and vegetation, and an assessment of the carbon sequestering capacity in the Special Reserve of the Monarch Butterfly Biosphere (in the initial stage, reference terms under revision).

The evaluation of carbon sequestering in this project will be made by means of a study of the capacity for biomass production. This estimate will be based on a detailed study of forest agrology defining the characteristics, composition and structures of forest soils and vegetation as well as their natural productivity and distribution. Training will be a decisive factor in managing resources of the communities and it will permit precise zoning of the sanctuaries and management programs corresponding to each area, thus optimizing carbon sequestering. The project will last 12 months as soon as the budget and work means are cleared.

6. Wind as a resource (in the initial stage, reference terms completed).

Electricidad del Sureste, S.A. de C.V., intends to install and operate a wind-powered electric plant in the area of La Ventosa, Oaxaca, with a capacity of 27 MW, with possibilities for expansion. The distribution will be made in the ejidos of Aguascalientes, La Mata, La Ventosa and La Venta.

7. Implications of carbon sequestering for the cultivation of halophytes in the state of Sonora (in process).

Genética y Sistemas de Ingeniería Solar (Genesis), S.A. de C.V. [Genetics and Systems of Solar Engineering], and Salt River Project, of Arizona, have created this project of the commercial cultivation of saltwort in Bahía de Kino, Sonora, in order to obtain carbon sequesterings and to produce at the same time a variety of products ranging from the commercialization of the tips of this plant as food, to obtaining construction materials from their fiber to manufacture conglomerates. One of the main attractions of this crop, besides its multiple products, lies in its resistance to salt water, so that it can be irrigated with sea water.

## V. INVENTORY OF GREENHOUSE GAS EMISSIONS IN MEXICO

The development of an inventory of emissions identifying and quantifying the main greenhouse gas sources and sinks in a country is basic to any study on climate change. The inventory process is important for two reasons:

- 1) It provides a basis for developing a comprehensive, detailed methodology for estimating greenhouse gas sources and drains.
- 2) It provides a common and consistent mechanism that allows all signatory countries of the United Nations Framework Convention on Climate Change to estimate their emissions and compare their relative contributions to climatic change of the different sources of greenhouse gas emissions.

To estimate emissions systematically and consistently at the national and international levels is prerequisite to evaluating the feasibility and cost-effectiveness of implementing possible mitigation strategies and adopting technologies for the reduction of emissions.

The 1990 updating of the National Inventory of Greenhouse Gas Emissions in Mexico (carried out in 1996, and now in press) includes direct greenhouse gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O), indirect (which contribute to the atmospheric formation of ozone): carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) and non-methane volatile organic compounds (NMVOC). Table 1 and Figure 1 (on the following pages) show a summary of greenhouse gas emissions. As can be observed, the emissions come mainly from the use of fuels for generating energy, change in land use, agriculture and emissions due to leaks associated with oil and gas production.

### CARBON DIOXIDE

In 1990, total carbon dioxide emissions were 444,489 Gg (10<sup>9</sup> grams). The energy sector constituted the most important source of this gas, with 297,011 Gg.

Taken together, all energy sources related to combustion represent the greatest contribution (67%). However, emissions from the forest sector and those produced by change in land use represent, alone, 30.57% of national CO<sub>2</sub> emissions.

Tabla 1. Summary of national inventory of greenhouse gas emissions, 1990 (Gg = 10<sup>9</sup> gms)

Category of greenhouse gas sources and sinks

National total of emissions and sequestering

1. Total energy (fuels and leaks)

A. Fuel consumption

1 Processing and energy industries

2 Industry (\*\*ISIC)

3 Transportation

4 Small combustions

5 Agriculture and aquaculture

- B. Fuel leak emissions
  - 1 Solid fuels
  - 2 Oil and natural gas
- 2. Industrial processes
- 3. Agriculture
  - A Enteric fermentation
  - B Fertilizer management
  - C Rice growing
  - D Agricultural land
  - E In situ burning of agricultural waste
- 5. Change in land use and forestry
  - A Sequestering/emission in managed forests
  - B Forest cutting
  - C Sequestering in abandoned lands
- 6. Waste
  - A Solid waste disposal areas
  - B Wastewater treatment (urban)

CO<sub>2</sub> top/down\*

CO<sub>2</sub> bottom/up\*\*

CH<sub>4</sub>

N<sub>2</sub>O

NO<sub>x</sub>

CO

NMVOC

\*Top-down: Breakdown from total energy demand to final uses

\*\*Bottom-up: Integration from final energy uses to total demand

Figure 1. Greenhouse gas emissions in Mexico 1990 (Gg = 10<sup>9</sup> gms)

Processing and energy industries: 108,473.18

Carbon dioxide: 444,488.97

Methane: 3,641.66

Others: 12, 857.95

Carbon dioxide: 96.42%

Methane: 0.79%

Others: 2.79%

Figura 2: Carbon dioxide emissions in Mexico 1990 (Gg)

Processing and energy industries: 24.40%

Industry (ISIC): 14.62%

Transportation: 21.31%

Residential and commercial: 5.30%

Others: 1.19%

Industrial processes: 2.61%  
Change in land use and forestry: 30.56%

Industry (ISIC): 64,971.20  
Transportation: 94,705.60  
Residential and commercial: 23,558.68  
Others: 5,301.98  
Industrial processes: 11,621.000  
Change in land use and forestry: 135,857.333

\*ISIC: Industrial Sector International Classification. International classification of industrial sector including production of cement and metallurgy, among other industries.

### Methane

Methane is (from the molecular point of view) a greenhouse gas with a heating potential 21 times greater than that of CO<sub>2</sub>. 1990 emissions amount to 3,641 Gg. Agriculture and livestock raising are their main sources, with a participation of 49.34% (1,793.3 Gg), followed by the emissions from oil industry leaks and a small contribution from coal exploitation that contribute 28.55% (1,039.58 Gg). Waste accounts for 14.44% (526 Gg). Fuel burning makes up 1.15% and, last of all, changes in land use contribute 6.62%. If the heating potential of methane is taken into account (21), these emissions are equal to a quantity of CO<sub>2</sub> constituting 17.20% of the total.

### ENERGY AND INDUSTRY

Energy sector emissions (Figure 3) are the most important antropogenic source in Mexico. In 1990, nearly 84% of final use energy and 62% of generated electricity were produced by fossil fuels.<sup>1</sup> The remainder is produced by hydroelectric, geothermal generation and by firewood and bagasse combustion. Mexico emitted 297 x 10<sup>12</sup> grams (Tg = 10<sup>12</sup> grams) of CO<sub>2</sub>, due to the consumption of fossil fuels and 40.5 Tg, from the use of fuels based on biomass (not included in totals). The CO<sub>2</sub> emissions associated with energy use increased by 14.06% between 1987 and 1993, a growth rate similar to that of the consumption of final use energy, including production of electrical power and the energy sector. Emissions of NO<sub>x</sub>, CO and CH<sub>4</sub> increased by 19.8%, 35.6% and 30.7%, respectively, while N<sub>2</sub>O emissions increased by 6% due to the decreasing fuel oil consumption in the industrial and transportation sectors.

From 1987 to 1993, the per capita CO<sub>2</sub> emissions fell by 7.1% from 3.75 to 3.48 tonnes. The intensity of CO<sub>2</sub> emissions, measured as emissions **per** Gross Domestic Product (GDP) decreased by 6.1%, from 798.0 to 749.3 tons of CO<sub>2</sub> per million of dollars constant in 1993.

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<sup>1</sup> Data of the Department of Energy indicate that by 1995, 85% of final fuel use and 61% of the electricity generated are produced by fossil fuels (not including coal). For this year the nuclear option is included among the remaining forms of generation.

Figure 3. Greenhouse gas emissions by sector 1990 (Tg = 10<sup>12</sup> grams)

Transportation  
Production of electrical energy  
Industrial  
Energy  
Residential  
Agriculture and fisheries  
Commercial  
1E+02  
1E+01  
1E+00  
1E-01  
1E-02  
1E-03  
1E-04  
1E-05  
CO<sub>2</sub>  
NO<sub>x</sub>  
CO  
CH<sub>4</sub>  
N<sub>2</sub>O

\*\*\*ISIC: Industrial Sector International Classification. International classification of the industrial sector that includes, among others, cement production and metallurgy.

If energy sources of each emission are analyzed, it becomes clear that fuel oil, gasoline and natural gas were the main contributors to CO<sub>2</sub> emissions. Gasoline was the main source of CO emissions. NO<sub>x</sub> emissions were mainly due to the use of gasoline, fuel oil and diesel, whereas CH<sub>4</sub> emissions had fuel oil and gasoline as their main precursors. The same thing happened in the case of N<sub>2</sub>O emissions, although in this case the use of the diesel was also included.

In the case of the emissions by sector, transportation represents 32% of the emissions in Mexico for its consumption of fossil fuels, followed by generation of electricity (23%) and industry (22%). The transportation sector is also the main contributor to emissions of NO<sub>x</sub>, CH<sub>4</sub>, N<sub>2</sub>O and CO. The indicators reviewed here, in spite of reporting greenhouse gas emissions, are not analytic enough to allow additional conclusions to be formed. To complete this research, energy consumption should be studied according to final use sector.

Carbon dioxide as an intermediate product of industrial processes not generating electricity, was only calculated in the case of cement production, coming to 11,621 Gg in 1990.

#### AGRICULTURE AND CHANGE IN LAND USE

Greenhouse gas emissions produced by agriculture (Figures 4) (not including energy use) originate mainly from fertilizer and enteric fermentation of livestock manure (1,749 Gg methane), specific crops (i.e., 35 Gg of methane produced by rice fields), fertilizer use

(5.55 Gg N<sub>2</sub>O) and a family of greenhouse gases from prescribed burning of crop waste in situ. Greenhouse gas emissions other than CO<sub>2</sub> caused by the prescribed burning of crop waste are already included in the inventory.

FIGURE 4. METHANE EMISSIONS IN AGRICULTURE 1990 (Gg)

Enteric fermentation 95%  
 Fertilizer management 3%  
 Rice growing 2%  
 In situ burning of agricultural waste 1%

Enteric fermentation: 1700.9  
 Fertilizer management: 48.10  
 Rice growing: 35.00  
 In situ burning of agricultural waste: 9.29

A model to predict the number of head of livestock based on population, annual income and annual GDP growth allowed methane emissions to be estimated for future years (Fig. 5). Experts were very cautious about the impact that the recent changes in the Constitution, related to land ownership and NAFTA, could have. However, the model has the capacity to show the sensitivity of real salary increases, as in the seventies, and the decreases in demand caused by the recent financial crisis. This model also shows that once economic growth recovers, the rises in demand will bring with them a return to historical tendencies dominated by population growth.

Concerning changes in land use, this report includes estimates of greenhouse gas emissions from this source in Mexico for the year 1990. Previous studies have demonstrated that deforestation constitutes the second greatest source of greenhouse gas emissions in our country, after the burning of fossil fuels. Therefore, updating emissions due to changes in land use is of vital importance for the national inventory. The report is based on a thorough revision of existing information on deforestation indices, reforested areas or growth and biological characteristics of forests related to carbon. The analysis covers evergreen tropical forests, temperate **deciduous** forests of conifers, closed forests of wide leaves and open forests.

FIGURE 5. SIZE OF FLOCK AND METHANE EMISSIONS

$h = a + bP + cP/G + d$   
 $h = a + bP$   
 censuses

Head  
 6E+07  
 5E+07  
 4E+07  
 3E+07  
 2E+07

1E+07

Year

1950

1960

1970

1980

1990

2000

2010

Emissions (gms)

1E+02

8E+01

6E+01

4E+01

2E+01

0E+00

In this part, as much local information as possible was used -both from official sources and from case studies -, using IPCC values only when this was not available. The study covers all types of closed forests in the country: evergreen tropical, deciduous tropical, temperate coniferous, temperate wide-leaved and open forests.

A model was created that imitates the counting procedure proposed by the IPCC (for example, the MINERG model). This allowed consistent results to be maintained with the methodology proposed by the IPCC and at the same time allowed much more flexibility in the changing parameters, using multiple estimates and sensitivity analyses.

The updated carbon dioxide emissions produced by the change in land use and forestry for 1990 are of 135,857.33 Gg, which represents an increase of 21.5% with respect to the Preliminary Inventory, because of the greater knowledge of deforestation rates and carbon sequestering on both managed and abandoned lands. These represent 31.4% of total CO<sub>2</sub> emissions. If a potential heating of methane of 21 is considered, the participation of change in land use in total greenhouse gas emissions is 26.8% and that of the agriculture, 7.1%. Together, both sources contribute 33.9%.

## SOLID WASTE DISPOSAL

In Mexico, sanitary landfill contributes 0.468 Tg, representing 12.85% of the country's methane emissions. Of this, 41.6% converges in Mexico City and 58.4% is distributed throughout the country, produced mainly in other large cities.

## MEXICAN GREENHOUSE GAS EMISSIONS IN THE GLOBAL CONTEXT

Mexico is classified among the top 15 countries in greenhouse gas emissions (Table 2).

In 1990, Mexico contributed approximately 2% of overall emissions, while the United States produced 19%, and the ex-Soviet Union 13%. With respect to carbon dioxide, the Mexican energy sector emitted 296,756.87 Gg. From the point of view of per capita CO<sub>2</sub> emissions, 4.1 tonnes were produced per person.

In terms of energy efficiency, Mexico has lower levels than those reached by the industrialized countries, due to insufficient technological updating and to the fact that, being a developing country, it produces capital assets of lower added value, like cement or vegetables, while the industrialized nations produce computer chips or electronic apparatus.

#### INVENTORY TASKS PENDING

Some inventory categories, such as solvents and some industrial processes, were not processed, but will be included in future inventory updating. Another task pending is that of completing the establishment of procedures for the annual updating of all parts of the inventory.

TABLE 2. COUNTRIES WITH MOST CARBON (C) EMISSION FROM BURNING OF FOSSIL FUELS, 1994.

Country
1. United States
2. China
3. Russia
4. Japan
5. Germany
6. India
7. United Kingdom
8. Ukraine
9. Canada
10. Italy
11. France
12. Poland
13. South Korea
14. Mexico
15. South Africa
16. Kazakhstan
17. Australia
18. North Korea
19. Iran
20. Brasil

Total emissions (millions of tonnes)

Source: G. Marland, R.J. Andres and T. A. Boden, "Global, Regional and National CO<sub>2</sub> Emission Estimates from Fossil Fuel Burning, Cement Production and Gas Flaring: 1950-1992" (Electronic database) (Oak Ridge, Tenn. Carbon Dioxide Information Analysis

Center. Oak Ridge National Laboratory, 1995). World watch estimates based on *ibid.*, and on British Petroleum, BP Statistical Review of World Energy (London: Group Media & Publications, 1995). Population Reference Bureau, 1994 World Population Data Sheet (Washington, D. C.: 1994); World Bank, The World Bank Atlas 1995 (Washington, D. C.: 1995).

Note: Countries in italics belong to Annex I of the United Nations Framework Convention on Climate Change.

## VI. VULNERABILITY TO CLIMATIC CHANGE

Mitigation and adaptation measures emerge as an answer to the effects that it is predicted global climatic change will produce, on human beings and their activities, as well as on the environment. For that reason it is important to have an analysis of the areas and geographical zones of the country that exhibit greater vulnerability to potential effects of climatic change.

In the *Country Study: Mexico*, vulnerability studies were carried out in the areas of agriculture, human settlements, coastal areas, desertification and meteorological drought, forest ecosystems, water resources and the energy and industrial sectors. To carry out this analysis, it was necessary to prepare regional climatic scenarios for the present time and after climate change.

### REGIONAL CLIMATIC SCENARIOS AT PRESENT AND AFTER CHANGE

#### Present scenario

There are many criteria that should be used to determine the regional climatic scenarios for the present time, depending on the requirements of each of the vulnerability studies carried out (Table 1).

Among other factors that influence in this, one could mention type, availability and integrity of the series, and the spatial scale of the required data. Thus, in some points of vulnerability it was necessary to have daily temperature data (maxima and minima), precipitation and radiation in isolated places (agriculture). In others, monthly, seasonal and/or yearly averages of basic climatic variables were used. Some of them required time series of over 30 years, or data such as wind velocity (desertification). Also, depending on the requirements of each study, daily and/or monthly data, obtained from the National Meteorological Service (NMS) database, were used.

The method used to regionalize is crucial in any vulnerability study. It is evident that, for the spatial resolution of the General Circulation Models (GCM's), the units exhibited (forests, agricultural regions or watersheds, etc.) may not have been accurately defined.

A regional scenario was built based on Arthur Douglas's database, from the University of Creighton, Nebraska, which contains temperature (92 points) and precipitation (279 points) averages over more than 30 years, including the period from 1950 to 1980.

Douglas groups these figures into 18 regions, taking into consideration the density of location of the meteorology stations, altitude and analogous precipitation in the database, which are illustrated in Map 1. Maps 2 and 3 show the isolines generated from temperature and precipitation statistics. This scenario was employed in the studies on agriculture, desertification and drought. A direct interpolation was made to build the isolines or areas that characterized the country's temperature and precipitation. Also, Maps 2 and 3 show the results for summer and winter. When the needs of the studies demanded it (Table 2), the

Douglas database was completed with other climatology station data obtained from the NMS.

#### MAP 1. THE 18 REGIONS PROPOSED BY DOUGLAS

The symbols represent the climatology stations with temperature data for each region.

#### MAP 2. BASE TEMPERATURE SCENARIOS (1950-1980) DOUGLAS DATABASE (°C)

Winter (December-February)

Latitude

Longitude

Summer (June-August)

Latitude

Longitude

#### MAP 3. BASE PRECIPITATION SCENARIO (1950-1980)

Winter (December-February)

Latitude

Longitude

Summer (June-August)

Latitude

Longitude

Scenarios of regional climatic change I (interpolation)

For the vulnerability studies of the Country Study: Mexico (except for coastal areas), two methods were suggested for generating climatic change scenarios, in order to study the possible impacts of this phenomenon:

#### Sensitivity Method

The first consists in establishing arbitrary increments in temperature (+2 and +4 °C) and precipitation ( $\pm 10\%$  and 20%) and combinations of these (for example, +2°C and +20%).

Certain vulnerability lines (forest ecosystems and agriculture) applied the incremental scenarios proposed in this way, in order to study the sensitivity of the system studied, to arbitrary climatic changes (Table 2).

#### Method with general circulation models

The second is based on the use of increments in temperature and proportions of change in precipitation and radiation, calculated from the simulations of two General Circulation

Models (GCMs): the GFDL-R30 (Geophysical Fluids Dynamics Laboratory) and the CCCM (Canadian Climate Center Model) (Table 1).

Regionalization of the climatic change scenarios based on GCMs initially involves certain considerations. The data of these models correspond to points in a horizontal grid with a minimum resolution of between 100 and 200 kilometers. This introduces approximation errors in variations of the required parameters, when interpolating or using the point nearest the one studied. Also, it was decided that all vulnerability areas should apply the interpolation of the 2 x CO<sub>2</sub> variations of the GFDL-R30 and CCCM models.

To carry out regionalization, first the direct interpolation method was applied to each point of Douglas's 18 regions, **generating** the possible scenarios of corresponding climatic change, according to the models GFDL-R30 and CCCM. The maps were prepared with these figures, for variations in temperature and precipitation for winter and summer (Maps 4 and 5 for the CCCM model. Maps 6 and 7 show the results corresponding to the GFDL-R30 model).

MAP 4. INCREMENTS IN TEMPERATURE AND PROPORTIONS OF CHANGE FOR PRECIPITATION. CCCM MODEL (°C)

Summer  
Latitude  
Longitude

Precipitation (proportion of change)  
Latitude  
Longitude

MAP 5. INCREMENTS IN TEMPERATURE AND PROPORTIONS OF CHANGE FOR PRECIPITATION. CCCM MODEL (°C)

Winter  
Latitude  
Longitude

Precipitation (proportion of change)  
Latitude  
Longitude

MAP 6. INCREMENTS IN TEMPERATURE AND PROPORTIONS OF CHANGE FOR PRECIPITATION. GFDL MODEL

Winter  
Latitude  
Longitude

Precipitation (proportion of change)

Latitude  
Longitude

#### MAP 7. INCREMENTS IN TEMPERATURE AND PROPORTIONS OF CHANGE FOR PRECIPITATION. GFDL MODEL

Summer  
Latitude  
Longitude

Precipitation (proportion of change)  
Latitude  
Longitude

In the two cases above, results are obtained from the two models that differ both in magnitude and in sign. The GFDL-R30 model shows high increases in temperature - between 2.5°C and 4.5°C - and precipitation - between 10% and 20% - (as well as in radiation). Using the CCCM model, more moderate increases in temperature were obtained - between 1.5°C and 3.5°C - and decreases in precipitation - between -10% and -20% - (and in radiation).

These behaviors are reflected in the vulnerability studies, where the results inferred from the increasing scenarios with decreases in precipitation resemble the results of the CCCM model; while in the other case, they are similar to those of the GFDL-R30. It is understood therefore that for a country with extensive arid or semi-arid regions and with severe problems from droughts, in some vulnerability areas the GFDL-R30 scenario is called "positive" or "optimistic", and does not necessarily coincide with other results of this same Country Study.

#### Regional climatic change scenarios II (statistics)

The climate scenarios generated from the use of models associate present, large-scale circulation, and climatic change, patterns with regional or local climates. These scenarios were developed as part of the Country Study: Mexico, and although it was not possible to use them in the different vulnerability areas, it would be interesting to apply them to subsequent studies.

Control and CO<sub>2</sub>-doubling runs, obtained through the INTERNET for NCAR (National Center for Atmospheric Research) and GFDL (Geophysical Fluids Dynamics Laboratory) models were used to improve regional analysis. In this way the scenarios for present and for climatic change situations were generated, turning first to the statistical analysis of the behavior of local variables of interest (temperature and precipitation), as opposed to observed variables on a large scale, such as sea level pressure (SLP), sea surface temperature (SST), the temperature in 500 and 700 mb (t500 and t700) and the geopotential altitude in 500 and 700 mb (z500 and z700).

For the new scenarios the coupled GCM models were used (GFDL and NCAR), in order to generate the anomalies that the scenarios give us for a doubling of carbon dioxide.

The regional temperature and precipitation scenarios were prepared by establishing regression equations for the time series of temperature (or precipitation) in each of the 18 Douglas regions, taken as a dependent variable, and those of SLP and SST for two different points with an extreme correlation (in all, four independent variables), for a period extending from 1947 to 1987. With this methodology, increases in temperature turned out to be more moderate than those obtained with the first methodology; also, there is no difference in the sign of the precipitation anomalies between the NCAR and GFDL. The isoline structure is similar for both models in winter, but varies substantially for summer, especially in the northwest.

#### TABLE 1. DESCRIPTION OF CLIMATE CHANGE SCENARIOS, ACCORDING TO GENERAL CIRCULATION MODELS

Sector or line

Climatic scenarios

Methods

- i) Interpolation
- ii) Statistical

Basic scenario

1950-1980: 18 regions  
97 – 279 stations  
(Douglas)

Climate change scenario GCM

CCCM (1989):  
 $3.75^0 \times 3.75^0$   
10 levels

GFDL-R30 (1994):  
 $2.22^0 \times 3.75$   
14 levels

TRANSIENT (GFDL-R30)  
Fourth, seventh and tenth decades

NCAR (1994)

Climatic variables

T (°C) ave hi, lo

Pcp\* (mm)

S (hrs sun)

Daily

Monthly

Seasonal

Yearly

Ranges of variation

$\Delta T$  (°C) (yearly average)

$\Delta Pcp$  (%) (yearly average)

Method I:

CCCM:

$1.5^\circ < \Delta T < 3.5^\circ C$

$\Delta Pcp < 0$

$-20\% < \Delta Pcp < -10\%$

GFDL-R30:

$2.5^\circ C < \Delta T < 4.5^\circ C$

$\Delta Pcp > 0$

$10\% < \Delta Pcp < 20\%$

Method II:

GFDL-R30:

$1.5^\circ C < \Delta T < 2.5^\circ C$

$\Delta Pcp > 0$

NCAR

$1.5^\circ C < \Delta T < 2.5^\circ C$

$\Delta Pcp > 0$

TABLE 2. SCENARIOS AND CLIMATE MODELS USED IN EACH VULNERABILITY AREA

Sector or area

Agriculture (non-irrigated maize)

Forest

Water resources

Desertification

Methods

Ceres-maize  
Suitability maps

Holdridge  
Rzedowski – García

Model of thermal-hydrological balance  
Turk's formula (Evaporation)

Water erosion model  
Wind erosion model

Basic scenario  
30 year suitability  
Douglas + CLICOM:  
158 and 171 stations.  
CERES  
10 to 20 years  
7 sites (CLICOM)

30 years  
491 hydrometric stations

30 years (1941 – 1970)  
106 stations  
monthly  
SOTER database

Climate change scenario  
Increment

T: +2, +4 °C  
PCP: ±10, ±20%

+2°C, -10%

Climate change scenario  
GCM

CCCM  
GFDL-R30

CCCM

GFDL-R30

CCCM  
GFDL-R30  
MTC

CCCM  
GFDL-R30

Climatic variables

T(°C) ave, hi, lo

Pcp (mm)  
S (hrs sun)  
Daily  
Monthly

T(°C) ave  
Pcp (mm)  
Monthly

T(°C) ave Pcp (mm)  
Monthly

T(°C) ave  
Pcp (mm)  
(winds)

Measurement of vulnerability

Change in suitability

Variation in yields

Change in Holdridge life zones

Effects on present vegetation

5 indices (draining, availability, storage, consumption, extraction)

5 levels of erosion  
Change in areas

Most vulnerable regions

Centre

North

Temperate forests

V (Centre)

VI (Lerma-Chapala-Santiago)

IX (Baja California)

Center

South

North

Table 2. (continued)

Sector or line

Drought

Human settlements

Energy and Industry

Coastal zones

Methods

Severity model

Projections

Projections

0.5 M/Decade up to 2 M

Basic scenario

Douglas

30 years

20 years of data

population (70-90):

growth, density,

death rate, water supply

30 years

365 stations

## García Climate Classification\*

115 topographic charts  
scale 1: 50,000

Climate change scenario  
Increment

Climate change scenario  
GCM

CCCM,GFDL-R30

CCCM,GFDL-R30

CCCM,GFDL-R30

2 m rise in sea level

Climatic variables

Pcp (mm) monthly  
Seasonal

T (°C) ave  
Pcp (mm) monthly

Pcp (mm) monthly  
Seasonal

Measurement of vulnerability

5 severity indices.  
Positive and negative changes

5 degrees of vulnerability  
Increase in Stress

5 degrees of vulnerability

2masl

Most vulnerable regions

North  
Centre  
South

Center  
North

Center  
North

Coasts of Tabasco  
South of Tabasco  
Peninsula of Yucatan

## CONSTRUCTION OF CLIMATIC SCENARIOS

In order to be able to apply the results contributed by the 23 GCM points to Mexico's present climate, with the help of a system of geographical information (SGI) a cartographic study was carried out using a grid of 0.5 x 0.5 degrees of latitude and longitude to better represent the climatic characteristics of the country. 365 meteorological stations were selected, representing each of the 770 squares into which Mexican territory was divided, having average temperature and total precipitation data on a monthly basis, over a 30 year-old period, between 1950 and 1980.

With this database, and based on the climatic classification drawn up for Mexico by García (1988), a map of the present climate was generated for the country. Climatic types were grouped into 16, out of a total of 29 defined by Garcia. Temperature and precipitation modifications were applied, as indicated by models CCCM and GFDL-R30, to obtain the resulting climate maps.

The maps of the two future climatic scenarios were superimposed on those of the present climate. Maps were obtained showing the areas of the country that would undergo modifications in climate type, according to each model, as opposed to those that would remain unchanged.

Because the CCCM and GFDL-R30 models propose a graduation in temperature and precipitation changes, depending on the geographical area of the country (increases in temperature between 2 and 4°C, and increases or decreases in precipitation of -30% to +60%), climatic variations were first evaluated that would be experienced by different geographical regions in Mexico, both in absolute values for the variables of temperature and precipitation and in relation to the present climate.

### TABLE 3. PRESENT CLIMATE

Present climate and % of area it occupies

Warm (27.23%)

Semiwarm (9%)

Temperate (6.4%)

Semicold (2.3%)

Dry (33%)

Arid (22%)

Climatic group

Warm wet

Warm subwet

Semiwarm

Temperate

Semicold

Dry

Arid

Average yearly temperature

22°C

22°C

18°C < T < 22°C

12°C < T < 18°C

5°C < T < 12°C

Same as warm, semiwarm and temperate

Same as warm, semiwarm and temperate

Temperature coldest month

>18°C

>18°C

<18°C

$-3 < T < 18^{\circ}\text{C}$

$-3 < T < 18^{\circ}\text{C}$

Precipitation and/or P/T

Rain all year long

Rain in summer  
 $P/T > 55$  for type 2

Same as warm climates

Difference between type 1 and type 2 for P/T

Limit not established by P/T, but according to formulas  $r_h$  and  $r_s$  indicated in text

95

Results

- Present Climate

To define climatic groups, the general parameters and classification established by García were followed (temperature, rain and Precipitation/Temperature quotient: P/T). The subgroups indicated here were carried out as a function of these same parameters (Table 3). Map 8 shows the main climatic regions of the country.

Warm, wet climates show an average annual temperature of over  $22^{\circ}\text{C}$ ; the coldest month is located above  $18^{\circ}\text{C}$ , with rain all year. The warm, subwet 2 and 1, show the same ranges of temperature as the previous type, generally with rain in summer. The degrees of wetness were established by the quotient P/T. The subindex 2 indicates the wettest, with a P/T of over 55.

In general, all the warm climates along the Pacific slope, south of the 24th parallel North and along that of the Gulf of Mexico, south of the 23rd parallel North. They are also found through most of the Yucatan peninsula and the mountains in northern Chiapas (García, 1988). Approximately 27.23% of the country's surface is covered by this group.

Semi-warm climates are those whose average annual temperature varies between  $18^{\circ}$  and  $22^{\circ}\text{C}$ . The coldest month can be lower than  $18^{\circ}\text{C}$ . The ranges of wetness are the same as those described for the warm climates and have been established in a same way. This subgroup occupies 9% of the country's surface area, mainly the lower regions of the Sierra Madre Occidental and the northern portion of the Sierra Madre Oriental.

Temperate climates show an average annual temperature that ranges from  $12^{\circ}\text{C}$  to  $18^{\circ}\text{C}$ . The average temperature of the coldest month varies between  $-3^{\circ}\text{C}$  and  $18^{\circ}\text{C}$ . As in the

previous cases, the P/T would indicate the separation in degrees of wetness between subindices 1 and 2. These climates take up 6.4% of Mexico's surface area and are found in most mountainous areas of the country.

Semi-cold climate shows an average annual temperature of between 5° and 12°C. The average temperature of the coldest month is within the same ranges as the previous type. This climate is found in the highest regions of the major mountains of Mexico and occupies 2.3% of the surface.

Dry and arid climates are defined by the factor  $r_h$ <sup>1</sup>, which marks the limit between dry and wet or subwet ones. Between the dry climates and the arid ones, the factor  $r_s$  is used.<sup>2</sup> In these cases the temperature gradients were established in a same way as the warm, semi-warm and temperate climates indicated above. These climatic types occupy the greater part of the country's surface area. In the case of the former, the dry ones occupy 33% and in the latter, 22%, for a total of 55 percent.

#### MAP 8. PRESENT CLIMATE

Warm wet  
 Warm subwet 2  
 Warm subwet 1  
 Semiwarm wet  
 Semiwarm subwet 2  
 Semiwarm subwet 1  
 Temperate wet  
 Temperate subwet 2  
 Temperate subwet 1  
 Cold  
 Semiarid warm  
 Semiarid semiwarm  
 Semiarid temperate  
 Arid warm  
 Arid semiwarm  
 Arid temperate

- Application of the models to the present climate

The climatic variations at the national level to which different geographical areas of the country would be subject, as indicated by the CCCM and GFDL-R30 models, are very contrasting. For the CCCM model, increases in temperature in most of the country vary from 1.5C to 2.5°C. The states in the north show increases of from 3°C to 4°C. In particular,

---

<sup>1</sup> Minimum quantity of annual rainfall (expressed in cm) necessary for the climate to be wet or subwet. This value is related to the rain and temperature conditions.  $r_h = 2t+28$  and  $2t+21$  (rain conditions in summer);  $r_h = 2t+14$  (rains the whole year);  $r_h = 2t$  (rains in winter).

<sup>2</sup>  $R_s = r_h / 2$ , according to the formula indicated for different rain conditions.

the northern border strip (states of Chihuahua, Sonora and Baja California) would reach increases of up to 4 and 4.5°C.

In the case of the GFDL-R30 model, increases in temperature for most of the country would be of the order of 2.5 to 3.5 °C, whereas in border states such as Chihuahua, Coahuila and Sonora, it would rise by 3.5 to 4.0 °C.

Regarding variations in precipitation, ranges of variation are very wide. In the case of the CCCM model, the decreases range from -20% to -10% with respect to present precipitation. In the case of the GFDL-R30 model, the precipitation would increase from +10 to +30% for most of the country.

Maps 9 and 10 show the result of superimposing the map of the present climate onto each of the two models. The areas that would show variations in precipitation (wetness) and temperature with respect to the present climate are indicated. This means that there would be geographical areas and sectors (industry, human settlements) that would have to tolerate drier, warmer conditions than at present, if precipitation were to decrease (CCCM model) or on the contrary, be exposed to conditions of greater wetness with the same or higher temperatures, as proposed by the GFDL-R30 model.

#### MAP 9. VARIATIONS IN TEMPERATURE AND WETNESS CCCM MODEL

Type of change  
< Hum > Temp  
< Hum = Temp  
= Hum > Temp  
= Hum = Temp  
>Hum > Temp  
>Hum = Temp

#### MAP 10. VARIATIONS IN TEMPERATURE AND WETNESS GFDL-R30

Type of change  
< Hum > Temp  
< Hum = Temp  
= Hum > Temp  
= Hum = Temp  
>Hum > Temp  
>Hum = Temp

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The surface that would be covered by the different climatic types, according to the CCCM and GFDL-R30 models, is shown in Table 4. According to the climatic scenarios, warm climates would increase their surface area by 1% for the CCCM model, and by 10% for the GFDL-R30, due mainly to the increase in subwet 1. The semi-warm climates would fall by

3% for the CCCM and would remain practically the same for the GFDL-R30 model. Temperate climates would decrease by 3% for the CCCM and 2% for the GFDL-R30 models, due mainly to the drops in subwets 2 and 1. Semi-cold climates would disappear in both models. Dry climates would increase by 20%, according to the CCCM, and 12%, according to the GFDL-R30 models. The increase would be found in all subtypes, from warm to temperate. Arid climates would decrease by 13% in the CCCM model and 17% in the GFDL-R30 model. These decreases are mainly due to the disappearance of the temperate arid climate and a strong decrease in the semi-warm.

In general terms, the total surface of the country that would undergo some change with respect to the present climate is 52%, according to the CCCM model, and 58%, according to the GFDL-R30 model.

TABLE 4. SURFACE (%) OF COUNTRY COVERED BY EACH TYPE OF CLIMATE

Type of climate  
(García classification)

- Warm wet
- Warm subwet 2
- Warm subwet 1
- Semiwarm wet
- Semiwarm subwet 2
- Semiwarm subwet 1
- Temperate wet
- Temperate subwet 2
- Temperate subwet 1
- Semicold
- Dry warm
- Dry semiwarm
- Dry temperate
- Arid warm
- Arid semiwarm
- Arid temperate

Present

CCCM Model

GFDL Model

VULNERABILITY OF AGRICULTURE TO THE CLIMATIC CHANGE

This study was developed applying two methods:  
 In the first place, the CERES-MAIZE model was used to simulate the yields in the production of non-irrigated maize for different forms of crop management and different climate conditions, seeds and soils. After calibrating the model, conditions of climatic change were simulated and the impacts on production analyzed (Graph 1). Whenever

reductions in yields were found, adaptation measures were proposed. Finally, the viability of these measures was evaluated with a very simple cost-benefit analysis. This model was applied to seven sites of the Mexican Republic (Table 5): Atlacomulco (Mexico), Izúcar and Ixcamilpa (Puebla), Tuxpan and Coatepec (Veracruz), and Magdalena and La Huerta (Jalisco). The states in which these sites are located are those that have the biggest production of non-irrigated maize in the country.

The second method used optimal ranges of temperature and precipitation for the production of non-irrigated maize to create theoretic agro-climatic maps (maps of potential aptitude) of the regions suitable for spring-summer production.

In the case of the CERES-MAIZE model, adjustments were made to obtain genetic coefficients (depending mainly on climatic parameters), so that the variations proposed by the model simulate the phenology and observed production averages simultaneously. This was necessary since the calculation of the coefficients depending on temperature yielded values outside of the range proposed by the model.

TABLE 5. LOCATION, ALTITUDE AND TIME SERIES FOR SITES SELECTED

Site
Atlacomulco
Izúcar
Ixcamilpa
Coaxtepec
Tuxpan
La Huerta
Magdalena
State
Mexico
Puebla
Puebla
Veracruz
Veracruz
Jalisco
Jalisco
Latitude north
Longitude west
Altitude (masl)
Years
Basic scenario

Information on monthly precipitation of 171 meteorological stations and data of average monthly temperature from 158 stations were used for maps of suitability at the national level.

To develop this scenario it was necessary to have information on climate and crop management. The information on climate (daily high and low temperatures, rain) for the CERES model was obtained from the National Meteorological Service, as was the information on solar radiation. When there was only average monthly information available, daily information was generated by another program. The information on land management and crops was provided by the Secretary of Agriculture, Livestock Raising and Rural Development (SA-GAR) and the National Institute of Statistics, Geography and Computing (INEGI) or it was obtained at each of the sites studied.

With this method, the basic scenario (Map 11) reveals that most of the country (59.6%) is unsuitable for the production of non-irrigated maize. This percentage corresponds to the arid and semi-arid areas of northern, northwestern and central Mexico and the Pacific coast, from Jalisco to Chiapas. The suitable area (7.6%) is located in some regions of Veracruz, Oaxaca, Tabasco and Chiapas. The rest of the country (32.8%) is only moderately suitable for this crop. Today maize is grown in the whole country, even where soil is not suitable, which explains the heavy losses suffered by producers and the low yields (less than 1 tonne/hectare) in over half the national territory. The areas of greatest production are those that are located within the irrigation areas (Sinaloa, Sonora, Baja California peninsula and irrigation districts of Santiago, Jalisco).

GRAPH 1. SCENARIOS

Yield (Tonnes/ha)

- ATLA
- IXCA
- IZUC
- COAT
- TUXP
- HUER
- MAGD
- Sites

- OBS
- BASE
- GF
- GF2x
- CC
- CC2x

MAP 11. AREAS POTENTIALLY SUITABLE FOR PRODUCTION OF NON-IRRIGATED MAIZE

Not suitable  
Moderately suitable  
Suitable  
500 km.

## 101 Scenarios of climatic change

These models were developed taking into account, firstly, arbitrary increments in temperature (+2°C, +4°C) and precipitation ( $\pm 10\%$  or 20%), and combinations of both. Once these changes had been made, sensitivity analyses were made with the CERES model (which also introduces changes in solar radiation) and with the maps of potential suitability. The CERES model was also used to study the physiological effect of doubling CO<sub>2</sub> concentrations under conditions of climatic change (labels CC2X and GF2X in Graph 1).

Also, variations under conditions of 2 x CO<sub>2</sub> were considered, based on the results of two General Circulation Models (GCMs), the GFDL-R30 (Geophysical Flows Dynamics Laboratory) and the CCCM (Canada Climate Center Model). The CCCM and sensitivity scenarios with reductions in precipitation produced similar results. In addition, the GFDL-R30 and the scenarios with increases in precipitation of 10 to 20% gave comparable results.

- Model GFDL-R30

By using the results of this model in the CERES-MAIZE, reductions in yield were observed (except for Atlacomulco), due to the high precipitation level that it predicts, which causes a washing of nutrients and "pressures" on the nitrogen (Graph 1). The adaptation measures in this case depend on an increase in fertilizers.

According to the suitability maps, 75% of the surface of the country would be unsuitable for growing maize, 8.4% would be moderately suitable and 15.9% would be suitable.

The contrast between the basic scenario and the change scenario obtained with the GFDL-R30 model is shown in Map 12. The increase in unsuitable areas would be largely due to the loss of surface of moderate suitability. On the other hand, the gain in suitable surfaces in the center of the country would be due to the increase in the minimum temperature in higher regions such as Atlacomulco.

- CCCM Model

This model predicts positive and negative variations in yield, depending on the area. For example, for Atlacomulco, Coatepec and Tuxpan, favorable conditions for growing maize are predicted (Graph 1). However, adaptation measures were analyzed for the areas of Jalisco and Puebla.

In this case, the suitability maps show that 75.5% of the country is unsuitable for this crop, 22% is moderately suitable and only 2.5% is suitable.

The negative change in suitable surface areas in the basic scenario and CCCM is due to the loss of regions of moderate aptitude. Nevertheless, some positive changes can again be found in the higher regions in the center of the country (Map 13).

#### MAP 12. AREAS OF NON-IRRIGATED MAIZE PRODUCTION VULNERABLE TO CLIMATE CHANGE. GFDL-R30 MODEL

Type of change  
Negative change  
Positive change  
500 km

#### MAP 13. AREAS OF NON-IRRIGATED MAIZE PRODUCTION VULNERABLE TO CLIMATE CHANGE. CCCM MODEL

Type of change  
Negative change  
Positive change  
500 km

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#### Adaptation measures and cost-benefit analysis

As was mentioned previously, experiments in adaptation were conducted using different volumes of fertilizers and water, changes in planting dates and seed types. The combinations of these positive measures also increased production. However, their cost is prohibitive.

The increase in quantities of fertilizer turned out to be a common adaptation measure for all the sites in the study. Urea was experimented with, because this procedure is considered the most economical.

Graph 2 shows that the adaptation measure has positive impacts on the yields of all seven sites for the basic and climatic change scenarios, also taking into consideration those scenarios that include the physiological effects of a doubled CO<sub>2</sub> concentration.

To obtain a cost-benefit rate (Graph 3) a very simple cost analysis was made that does not consider the fluctuations of costs in time, the prices of seeds, fertilizers and tonnes of maize.

In Graph 3 special contrast is shown between the benefits obtained, considering the scenarios observed and those of climatic change ((-) means without adaptation and (+) with adaptation). For the sites in Puebla, even now production is not economically viable without increasing fertilizers. Without taking into account these two sites, the adaptation measure proposed is beneficial under conditions of climatic change.

#### GRAPH 2. ADAPTATION

Yield Tonnes/ha

ATLA  
IXCA  
IZUC  
COAT  
TUXP  
HUER  
MAGD  
Sites

OBS  
BASE  
GF  
GF2x  
CC  
CC2x

### GRAPH 3. BENEFITS EXPECTED IN PUEBLA AND VERACRUZ SITES WITHOUT ADAPTATION MEASURES

Benefits (pesos)

IXCA (-)  
IXCA (+)  
IZUC (-)  
IZUC (+)  
COAT (-)  
COAT (+)  
TUXP (-)  
TUXP (+)  
Sites with (+) or without (-) adaptation measures

OBS  
BASE  
GF  
GF2x  
CC  
CC2x

### HUMAN SETTLEMENTS

The vulnerability of human settlements in the face of a climatic change would also be a function of non-climatic factors, which, in combination, can intensify or mitigate the effects of this phenomenon.

Among the most important non-climatic factors, we could mention: population growth, urbanization, industrialization and the presence of illnesses. On the other hand, climatic factors, according to the predictions of the models applied, refer to increases in sea level, precipitation and temperature. The main consequences of these would be the flooding of coastal areas, greater frequency of heat islands in certain urban settlements, periods of drought and wetter, warmer intervals. These variations can, in turn, bring about changes in the distribution and behavior of human settlements.

Probably the most vulnerable human settlements are those located in areas with great environmental pressure, whether due to high concentrations of population, urbanization processes that are too rapid, a high incidence of illnesses, or a marked, general deterioration of the environment.

This is the case, for example, of the country's large urban zones or areas populated with a deficient supply of services and with poor sanitary conditions.

In order to evaluate the vulnerability of the scenarios to climate change, four criteria were used: population growth and distribution, urbanization, mortality rate and water consumption.

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Basic scenario

- Population growth and distribution

The country's demographic growth in the last few years has been characterized by its tendency to increase in absolute numbers. This tendency will likely be maintained in the near future, with a population growth that is maintained in absolute numbers but at a lesser rate of growth. The areas of greater or lesser vulnerability can be defined from the point of view of regional distribution according to two main variables: absolute concentration of population, and population density (the number of inhabitants per km<sup>2</sup>).

As for population concentration, the most populated areas are located in a central strip that includes, from west to east, the states of Jalisco, Michoacán, Guanajuato, state of Mexico, the Federal District, Puebla and Veracruz. In addition, the states of Oaxaca and Chiapas to the south can be added, and the state of Nuevo León in the north. Each of these have over 3 million inhabitants. These states mentioned contain, together, 62.2% of the country's total population.

By considering population density, one obtains a very similar, but possibly clearer, view of the situation. A great central grouping stands out in Mexico, where the greatest concentrations of population exist per surface unit (more than 100 inhabitants/km<sup>2</sup>). The Federal District and state of Mexico are foremost with a population density of more than 300 inhabitants/km<sup>2</sup>. Aguascalientes, Guanajuato, Morelos, Tlaxcala and Puebla follow, with densities that fluctuate between 100 and 300 inhabitants/km<sup>2</sup>. Smaller densities (50-100 inhabitants/km<sup>2</sup>) complete a central strip that extends from the states of Colima, Michoacán and Jalisco in the west, to the state of Veracruz, in the Gulf of Mexico.

- Urbanization process

The urban population is characterized by its rapid growth (in 1990 it represented 61% of the national population). This growth is even greater than that of either the rural or total population. In this case, the definition of vulnerable areas is directly related to two variables: the rapid pace of growth (growth rates) and the percentage of urban population with respect to the total.

Taking into account the urban population growth rate, it is important to identify those states that register the greatest urban growth rates. By combining these two variables, the more vulnerable spaces could be identified. The highest urban growth rates (upward of 5.1%) are registered in the central part of the country, where the states of Hidalgo, Zacatecas, Guanajuato, Querétaro and state of Mexico are foremost. To the south, the states of Tabasco, Quintana Roo and Yucatan are prominent, with a rapid rate of urbanization, as well as the states of Oaxaca and Chiapas, which show high population concentrations in absolute numbers. In the north, the state of Baja California Sur stands out.

In relation to the total population, the greatest urban concentrations (more than 60% of the total population) are located in some states in the central region such as Jalisco, Colima, Aguascalientes, Guanajuato, state of Mexico, the Federal District and all the states along the northern border.

- Mortality rate

The effects of a climatic change on public health can be either direct, through heat-waves or floods, for example; or indirect, such as in the case of changes in the frequency of transmission of infectious illnesses, or those transmitted by vectors. The vulnerability of human settlements in this case will also be related to their supply of natural resources, technical development and public services. For a first evaluation of the most vulnerable areas in Mexico, two groups of illnesses were taken into account, according to their form of transmission: infectious illnesses transmitted by vector (dengue, onchocerciasis, malaria, leishmaniasis, trypanosomiasis, etc.), and infectious illnesses that are not transmitted by vector (cholera, paratyphoid fever, salmonellosis, typhoid fever, shigellosis, etc.).

Illnesses in the first group are transmitted through an infectious intermediate agent (generally an insect). The proliferation of these insects is directly related to certain conditions of temperature, humidity or the presence of bodies of water. The second group of illnesses is not transmitted by means of any vector and is directly related to the distribution and the quality of surface water. Conducive conditions exist in areas of flooding or with deficient drainage services. In 1993, the greatest death rate was located primarily in some southern states on the **slopes** of the Gulf of Mexico and Pacific Ocean, coinciding with wet and semidry tropical areas. There was also a high concentration of this mortality in the central area of the country, coinciding with highly urbanized areas.

- Water consumption

The availability of this resource is directly related to the climate, to precipitation in particular. As urban centers grow, their necessities for water increase. Under conditions of climatic change, the states with arid or semi-arid climates probably experience situations of desertification and/or aridity, being more vulnerable in their water consumption. By 1991, the highest water consumption per inhabitant was found in Baja California Sur, Chihuahua and Coahuila, with a supply of more than 350 liters/day per inhabitant.

In the central area of the country, Aguascalientes, Colima, the Federal District and Jalisco are primary. In the south, the state of Quintana Roo.

#### Degrees of general vulnerability

According to the variables indicated above, the degree of general vulnerability was calculated for each state in the country according to the following scale:

1. low vulnerability
2. very low vulnerability
3. moderate vulnerability
4. high vulnerability
5. very high vulnerability

The Federal District and state of Mexico show high vulnerability; Guanajuato and Jalisco, medium-high; the rest of the states register a medium-low and low vulnerability.

#### MAP 14. VULNERABILITY OF HUMAN SETTLEMENTS TO CLIMATIC CHANGE

##### Vulnerability

High

Medium high

Medium low

Low

500 km.

Aguilar et al. 1995

#### COASTAL AREAS

##### Introduction

To carry out this study the coastal area of the Gulf of Mexico was selected, because it is a highly productive, natural oceanographic unit that represents 27% of the coasts of Mexico. Located here are:

- Nearly 70% of the rivers, estuaries, lagoons and coastal tropical swamps.
- Six of the country's 10 main fishing ports.
- Three of Mexico's five industrial ports.
- Over 80% of the crude oil and 90% of the gas production.

- It constitutes a very important habitat for its biodiversity, including coastal swamps, **marine** grasslands, mangrove swamps, coastal lagoons and estuaries, estuary mouths joining protected waters with the sea, and the estuary discharge on the **marine** continental shelf.
- Its swamps are vital for aquatic birds and are used intensively by migratory birds (Epomex, 1994).

In addition, as opposed to what happens on the Pacific coast where - because of their geological origin and behavior related to plate collision - rising coastal lines predominate, passive or descending coasts predominate in the Gulf. The tracts of sinking coasts cause problems for the apparent rise in sea level.

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The Mexican coast surrounding the Gulf of Mexico has a longitudinal extension of 3,117 km. including the coast of the Caribbean Sea. The coastal relief is mostly made up of a wide strip of coastal plain that can measure from 30 to 150 km. in width.

The repercussions of global warming on the coast do not imply a homogeneous rise in the sea. During the last hundred years, in all latitudes, the overall rise in the average sea level has been  $\pm 15$  cm; however, the Environmental Protection Agency of the United States (EPA) has predicted that sea level could rise to a maximum of 4.5 m in a short period of time. There is a lot of controversy on the subject, especially as to variations occurring at the local level.

Diverse attenuating factors exist that are controlling the changes in the average sea level; they range from changes in oceanic masses due to the contribution of ice and glaciers in the polar regions, in response to the climatic warming with all its consequences (variations in the volume of the ocean, changes in the gravitational field due to the redistribution of the ice, water and adjustment in the Earth's crust, etc.), to changes in the pattern of discharges from the rivers or changes in oceanic currents, to mention only a few.

### Methodology

The evaluation of the current state of physiographic conditions of the Gulf of Mexico coast was based on the geomorphological characteristics of the coast according to the interpretation of aerial pictures, satellite images and field verification.

The zoning of the basic scenarios was based on the present distribution of the geomorphological components of the longitudinal profile of the coast, divided into two zones: that covered alternately by the tide, or **tidal zone** (Basic scenario), **directly impacted** by variations in sea level, and the adjacent strip included between the average level of high tides and a height of approximately two meters (Future Scenario), which because of its position constitutes an area of buffering or potential risk (Figure 1).

The zoning of future scenarios was identified using a base of altimetric data, at equidistant 90 m intervals along the coast, using this information to generate digital models with the aim of determining the distribution of critical areas.

Land use was also determined in order to estimate the degree of the coast's vulnerability.

#### FIGURE 1. ZONING OF SCENARIOS

Flood plain

Extraordinary    ordinary

Tidal plain

(marshes, lagoons, estuaries)

Offshore zone

(subtidal)

Future scenario: Zone II

High tide

Low tide

Present scenario: Zone I

In order to facilitate the interpretation of the results, the coast was divided into 5 areas:

Gulf of Mexico

North shore

Central-north shore

Central-south shore

East shore

Caribbean Sea coast

For each of these, there was an evaluation of the tidal and of the buffering or potential risk zones.

- Basic scenario. Zone I or tidal

Swamps with mangrove and swamps with halophytes were evaluated in this area, communities that - among other important aspects - help stabilize the coasts through the system of surface roots that fix and protect the beach; they promote soil formation by capturing detritus, which occurs when the level of the sea is stable or varies slightly, but when it rises, the mangrove areas migrate inland.

The probability of important modifications is considered since, if the coast line advances inland, the mangrove swamp will also; provided the mangroves are not subjected to a major ecological imbalance, such as interference caused by man (deforestation, landfill and changes in drainage) or by natural effects (hurricanes, sedimentation), which can cause modifications in the ecosystems.

The distribution of these types of coastal vegetation predominates toward the south of the Gulf of Mexico, due to a greater distribution of water resources, represented by abundant **fluvio-deltaic** systems in the tropical strip (Figure 2).

#### FIGURE 2. ZONE I OR TIDAL ZONE

Gulf of Mexico  
 North shore  
 Central-north shore  
 Central-south shore  
 East shore  
 Caribbean Sea coast

Mangrove  
 Lagoons  
 Halophytes

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- Future scenario. Zone II, buffering or potential risk zone

In this zone, areas susceptible or vulnerable to saltwater encroachment are located, such as lagoons, swamps and estuaries. When affected by high concentrations of salt, the properties of the substratum, soil and water, are altered and consequently, those of the ecosystem in general. The swamps are distributed south-centrally along the coast of Tabasco and Campeche.

Other important regions in the area of production are grasslands and agricultural lands, which are also contaminated by saltwater intrusion and are replaced by coastal

environments. These units are also distributed through the central and southern part of the coast of the Gulf of Mexico (Table 6 and Figure 3).

TABLE 6. TOTAL AREAS (KM<sup>2</sup>) POTENTIALLY VULNERABLE TO RISE IN SEA LEVEL (BY TYPE OF LAND USE)

North shore  
Central-north shore  
Central-south shore  
East shore  
Caribbean Sea coast  
Total

Swamps  
Grasslands  
Agriculture  
Dune fields  
Urban settlements

FIGURE 3. AREAS VULNERABLE TO SALTWATER INTRUSION

Gulf of Mexico  
North shore  
Central-north shore  
Central-south shore  
East shore  
Caribbean Sea coast

Crops  
Grasslands  
Swamps  
Urban settlements  
Dunes

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Conclusions

The most vulnerable scenarios located along the coast of the Gulf of Mexico and of the Caribbean Sea were evaluated. Five zones were found: the delta lagoon of the Rio Grande, in Tamaulipas; the Alvarado lagoon and the lower Papaloapan River, in Veracruz; the Delta Complex of the Grijalva-Mezcapala-Usumacinta, in Tabasco; Los Petenes, in Yucatan and the bays of Sian Ka'an and Chetumal, in Quintana Roo (Map 15).

Because most of the coasts of the Gulf and of the Caribbean Sea are low and sandy, with extensive adjacent wetlands, they are situated at less than a meter above sea level. This marginal strip will be directly affected by the changes in sea level. Of the five zones identified, that of the Tabasco Delta Complex stands out for its high level of vulnerability.

## MAP 15. REGIONS IMPACTED BY THE RISE IN SEA LEVEL

Regions impacted  
200 km.

## DESERTIFICATION AND METEOROLOGICAL DROUGHT

### Methodology

The evaluation of vulnerability to desertification was carried out using five climatic indices: a) water erosivity b) wind erosivity, c) deterioration from salinization and alkalinization, d) chemical deterioration from leaching of bases, and e) biological deterioration from loss of organic matter.

To each of the indices some type of risk was assigned: 1) zero to slight, 2) moderate, 3) high and 4) very high. Also, they were given a factor value that was used for the later evaluation of water erosion.

Later on water erosion was evaluated, for which a strategy was used that was obtained by the combination of two methods: one published by Shields and Coote (1989) and that of the FAO (1980), with small modifications. This procedure is based on the use of the **Universal Equation for Soil Loss (UESL)**.

The potential risk of water erosion is the product of the factors of water **erosivity** times soil erosivity times the land's length-slope factor. It is the result of a risk estimate (in this work it was considered potential risk) of the average, yearly sheet and gully erosion anticipated, if an area is worked continually up and down the dominant slope, without vegetation. Thus the value of the product represents the soil's inherent potential for sheet and gully erosion (Committee on Conservation, 1986).

The current water erosion risk is obtained by multiplying the values of the factor of vegetation cover by the product of the water erosivity factors times the erosion potential of the soil times the land's **length-slope factor** (potential risk of water erosion), to represent the reduction in inherent erosion resulting from successive crops, farming practices and plant detritus on the surface of the soil, which one can interpret as the current erosion velocity (current risk).

Once the above results have been obtained, maps of potential and current water erosion risk were prepared, applying the same models. The base map for water erosion risk was compared with the GFDL-R30 model to identify the areas with an increase or decrease in erosion risk. Only this model was compared, since the CCCM gives results practically identical to the basic scenario.

Global vulnerability to desertification was determined by interpreting maps of specific vulnerability of the variables analyzed (climate, water and wind erosion, land slope, etc.).

Global vulnerability can be considered the "observed current susceptibility" of our national territory to soil desertification. Five ranges were handled, from very low to very high.

## Results

Table 7 shows the evaluation of climatic indices based on the three scenarios. Here their behavior is given in detail and the zones that showed the highest levels of deterioration are indicated.

- Potential water erosion risk

The results of the potential water erosion risk show a similar behavior on the surface of each of the classes, both for the basic scenario and for the GFDL-R30 and CCCM models. Of the results, the most outstanding is that the extreme class occupies most of the territory: 38% for the basic scenario and the CCCM model, and 41% of the surface of this class for the GFDL-R30 model. The moderate and severe classes are second in importance (Table 8).

Distribution of risk classes in the maps of the basic scenario and the CCCM model is very similar. The low class is found in small areas in the center and in the altiplano as well as to the north of Chihuahua and Sonora and in the Baja California peninsula; the moderate class is located mainly in the center, on the coasts of Sinaloa and Sonora and the southern and central Yucatan peninsula; the severe class, in northern Tamaulipas and Nuevo León, some parts of Veracruz and the northern Yucatan peninsula; the extreme class is distributed mainly along the country's mountain ranges and on the Tabasco coast. The GFDL-R30 model is different, with the severe class extending to almost the entire central altiplano, and the moderate and low class reduced.

TABLE 7. EVALUATION AND BEHAVIOR OF CLIMATIC INDICES

Climatic index

Water erosivity

Salinization and alkalinization

Chemical deterioration from leaching of bases

Biological deterioration from loss of organic matter

Behavior

Increase from north to south and to gulf coasts

Increases to north of country

Increases toward north and center of country

Increases from north to south and towards coasts beginning from middle region of country

Zones most affected

Southern Veracruz, eastern Oaxaca, Tabasco, Chiapas and Campeche

Tijuana, Mexicali and Baja California Sur

Central altiplano, Mexicali, central Mexico, South Pacific coasts, Baja California Sur and northern Sonora

Wet and subwet regions of country  
Dry zones of country

TABLE 8. POTENTIAL RISK OF WATER EROSIÓN

Class  
Zero  
Low  
Moderate  
Severe  
Extreme

Basic scenario  
Area km<sup>2</sup>

GFDL-R30 Model  
Area km<sup>2</sup>

CCCM Model  
Area km<sup>2</sup>

- Current water erosion risk

The results of the calculation of the current risk of water erosion for the basic scenario is estimated as extreme in 25% of the country's surface, low in around 24%; practically 50% of the country is located in these two classes. The calculation of the current risk based on the models shows similar results, with slight variations (Table 9).

The maps of current risk of the basic scenario (Map 16) and the CCCM model (Map 17) and GFDL-R30 (Map 18) present very similar results, with the zero and low classes concentrated on the Baja California peninsula, in western Sonora, in the central altiplano, Tamaulipas and the southern Yucatan peninsula; the moderate and severe classes, to the northwest and in small areas of the center and southeast of the country; the extreme class, for its part, shows the same distribution as the scenarios of potential risk.

TABLE 9. CURRENT RISK OF WATER EROSION

Class  
Zero  
Low  
Moderate  
Severe  
Extreme

Basic scenario  
Area km<sup>2</sup>

GFDL-R30 Model  
Area km<sup>2</sup>

CCCM Model  
Area km<sup>2</sup>

The maps of potential risk of current water erosion show a strong influence of the variables called slope, soil type and vegetation cover. This can be seen because in the first, there is a greater surface area in the moderate, extreme and severe classes, while in the current risk the surface percentages are distributed more homogeneously through the five classes, with the low and extreme classes predominating.

#### MAP 16. CURRENT RISK OF WATER EROSION. BASIC SCENARIO

Zero  
Low  
Moderate  
Severe  
Extreme  
500 km.  
Oropeza, O. et al. 1995

#### MAP 17. CURRENT RISK OF WATER EROSION. CCCM MODEL

Zero  
Low  
Moderate  
Severe  
Extreme  
500 km.  
Oropeza, O. et al. 1995

#### MAP 18. CURRENT RISK OF WATER EROSION. GFDL-R30 MODEL

Zero  
Low  
Moderate  
Severe  
Extreme  
500 km.  
Oropeza, O. et al. 1995

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By comparing the maps of potential and current risk, it is striking that the percentage of the national surface area classified as extreme risk, under potential risk, increases by more than 10%, both in the basic scenario (38%), and in the CCCM (39%) and GFDL-R30 (41%) models, with respect to the current risk, with values of 25%, 27% and 29% respectively for

each scenario, while the zero class increases by less than 1% in the scenarios of potential risk, to 14 and 16% in that of current risk.

The regions classified as extreme would be located on the major elevations in national territory. This behavior is presented in all the maps and it can be explained by the weight of the variables considered, which are slope and soil type and vegetation cover.

- Global vulnerability to desertification

The evaluation of global vulnerability to desertification shows the following results: the low range includes areas equivalent to 2.5% of Mexican territory, located mainly on the coastal plains of Tamaulipas, Veracruz, Tabasco and Campeche.

The areas with a high vulnerability level correspond to the arid, semi-arid and dry subwet areas, just as with areas where population and economic activities are concentrated, as is the case with the central region of the country. In the south, this level is related to the extraction of forest resources and the poor management of lands used for agriculture and livestock raising.

At the state level, Aguascalientes has the largest surface percentage (5.1%) with a very high vulnerability level. On the other hand, the states of Baja California, Coahuila, Jalisco, Colima, Nayarit, Querétaro, Guanajuato, Michoacán, Sonora and Hidalgo have a high vulnerability level over more than 68% of their surface.

- Meteorological drought

Meteorological drought is defined as a function of precipitation deficit, expressed in percentage, with respect to the average yearly or seasonal rainfall over a long period and of its duration in a given region.

According to the results obtained from the maps of the present scenario, CCCM and GFDL (Maps 19, 20 and 21) the following stands out: in the present scenario, the index of very great severity covers the greatest proportion of the country's surface (33.2%) located in the northern, northeastern and central regions of the republic; the indices of great severity and severe each cover 24.4% of the territory in the north, center, southern Pacific coasts and the peninsula of Yucatan. The slight and extremely severe indexes are those with the smallest percentage, with 6.3 and 3.6%, respectively (Table 10).

As for the CCCM model, 36% of the national territory shows an increase in the severity of meteorological drought, 53% shows no changes and in only 10% does it diminish.

The smallest area (0.4%) turns out to be the one indicated with an index of slight severity; on the other hand, the one that includes the greatest surface (41.7% of the country's total) is the one with an index of very great severity, while the severe one covers 30% of national territory.

The results of the comparison of the base and CCCM scenarios are presented in Table 11. Here the changes are indicated by the increase or decrease in severity of meteorological drought suffered by the areas defined in the present scenario in the face of a possible climatic change. In general, one could say that the severity of the meteorological drought increases at the lower levels. At the slight level, 85.4% of its surface moved into the “great” category and 78.7% of this increased to “very great”.

MAP 19. SEVERITY OF METEOROLOGICAL DROUGHT. BASIC SCENARIO

Zero  
Low  
High  
Very high  
Severe  
Very severe  
500 km.  
Hernández, M.E. et al. 1995

MAP 20. SEVERITY OF METEOROLOGICAL DROUGHT. CCCM MODEL

Zero  
Low  
High  
Very high  
Severe  
Very severe  
500 km.  
Hernández, M.E. et al. 1995

MAP 21. SEVERITY OF METEOROLOGICAL DROUGHT. GFDL-R30 MODEL

Zero  
Low  
High  
Very high  
Severe  
Very severe  
500 km.  
Hernández, M.E. et al. 1995

TABLE 10. COMPARISON OF SCENARIOS ACCORDING TO DROUGHT SEVERITY INDICES

Drought severity index  
Slight  
Great  
Very great

Severe  
Very severe  
Extremely severe

Present scenario  
CCCM Model  
GFDL-R30 Model

TABLE 11.COMPARISON OF BASIC AND CCCM SCENARIOS

CCCM Model  
Present scenario  
Slight  
Great  
Very great  
Severe  
Very severe  
Extremely severe

Slight  
Great  
Very great  
Severe  
Very severe  
Extremely severe

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The result of the comparison of the two scenarios shows that the changes at the lower levels are located to the south of the parallel 20°30' latitude north and in the eastern half of the Yucatan peninsula, the most affected states being Tlaxcala (almost entirely), Michoacán, Veracruz, Tabasco and Chiapas (90%), as well as Guerrero, Oaxaca and Puebla (50% of their surface).

Concerning the decrease in drought, the most relevant figure is the very severe index, where 29.2% of the surface area would move to severe. This area of change is located in the north, in the state of Coahuila. The other values fluctuate between 0.01 and 12.87%, mainly in the northern part of the country.

As for the GFDL-R30 model, an increase can be seen in the severity of meteorological drought in 30.5% of national territory; in 61.1%, no changes are shown and in the remaining 7.8% of the territory, there is a decrease.

According to the proportion of the surface that they cover, in this model, the indices very great severity and severe predominate, with 28.2 and 39.4% respectively. The smallest value corresponds to the indices of slight severity and extremely severe, with 4.4 and 4.3%, respectively.

The results of the comparison of the base and GFDL-R30 scenarios are given in Table 12. Here the changes are indicated that result from an increase or decrease in the severity of the meteorological drought that would be suffered by areas defined in the present scenario, in the face of a possible climatic change. The largest change in the modified surface is that indicated as great, 73.3% of which changes to very great; meanwhile, the very great one is in second place, with 44.3% of its surface changing to severe.

Another of the increases that should be emphasized is that found in the slight index, in which 22.8% of its surface would move to very great. This change is very abrupt, because it is from the first degree of severity to the third degree in the scale used. These changes are located in the low and central parts of Jalisco and in the continental part of the Balsas watershed, on the border of Guerrero and Puebla.

At the state level, the most vulnerable areas are the following ones: the northern half of Sinaloa; nearly 90% of the surface of Jalisco, Michoacán, Guerrero and Oaxaca; the whole of the state of Quintana Roo; and Campeche and Chiapas, with 75% of their surface.

TABLE 12. COMPARISON BETWEEN BASIC SCENARIO AND THAT OBTAINED WITH GFDL-R30 MODEL

GFDL-R30 Model

Present scenario

Slight

Great

Very great

Severe

Very severe

Extremely severe

Slight

Great

Very great

Severe

Very severe

Extremely severe

The results of the comparison of the two scenarios show that the changes in the low levels are located to the south of parallel 20°30' latitude north and the eastern half of the Yucatan peninsula. The states most affected are Tlaxcala (almost entirely); Michoacán, Veracruz, Tabasco and Chiapas (90%); Guerrero, Oaxaca and Puebla (50% of their surface).

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FOREST ECOSYSTEMS

Introduction

The vulnerability of the Mexican forest ecosystems to climatic change is practically a virgin topic, since most of the studies that refer to them center on their role as carbon emitters or sinks. The studies on how the forest responds to environmental changes range from very detailed ones, with physiological responses, to large-scale changes, such as the distribution of vegetable species, an aspect developed in the present study.

## Methodology

The starting point for these analyses is relating vegetation patterns with environmental conditions on a scale of time and space.

For the case of the Country Study: Mexico, two models of vegetation classification were selected:

- The Holdridge classification of life zones, in order to make comparisons at the international level. This model is a system of climatic classification that relates the distribution of the greatest ecosystems in the world with climatic variables of biotemperature, average yearly precipitation and the ratio obtained by dividing the potential evapotranspiration by precipitation. Its use is recommended in examining vegetation patterns and their relation to climate at the world level, as it enables us to relate the influence of climatic change, to the aptitude of a region to support different types of forest.
- The Mexican classification - which has an appropriate and representative, climate and vegetation classification of the physico-biotic conditions of the entire country - establishes a relationship between climate and vegetation, uses the climatic classification of García (1988) and the map of potential vegetation of Rzedowski (1992). It also offers the possibility of establishing a correspondence with international classifications.

## Implementation of the models

The Holdridge model requires available precipitation and biotemperatura data for a basic grid of latitude and longitude. For their application, a grid must be created with intersections every 0.5°, so that meteorological stations were studied and evaluated that represented the climatic characteristics of Mexico at that level of detail, and for which data were available on monthly average temperature and total precipitation over a 30-year period, between 1950 and 1980.

In order to implement the model of Mexican classification, an evaluation of classifications of Mexican climate and vegetation was carried out, in order to identify the climatic conditions tolerated by each type of vegetation and to evaluate whether a climatic change would substantially modify the conditions in which the vegetation of a certain area is determined.

## Creation of scenarios

Models of forest evaluation were established in order to obtain the basic scenarios, based on which the climate change models were applied.

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- Application of three climatic models to the Mexican classification and creation of future climate and vegetation scenarios

To develop future scenarios the GFDL-R30 (Geophysical Flows Dynamics Laboratory) and CCCM (Canadian Climate Center Model) models were used, and arbitrary variations of +2°C in the temperature and of -10% in the precipitation.

Modifications of temperature and precipitation suggested by the models were applied to the map of the present climate, thus creating maps of the three climatic scenarios projected. By superimposing these maps on those of the present climate, maps were obtained showing both the areas of the country that display climatic changes and those that do not display variations. In any case, the map of present vegetation was superimposed on each of the change-no change maps, in order to indicate the areas of vegetation affected, according to each of the three climatic models.

With respect to the sensitivity model (+2°C in temperature and -10% in precipitation), the type of vegetation most affected, since it is exposed to drier, warmer conditions, would be the mesophyte, mountain forest (30%), followed by temperate forests (22.5%). The thorny forest and the tropical deciduous forest have around 10% of their surface distribution affected by the same situation.

The most sensitive areas are the following (Map 22):

1. The Sierra Madre Occidental, which includes part of the states of Chihuahua and Durango, and the north of Jalisco.
2. The Mexican Volcanic Belt - The mountain ranges south of Lake Chapala, east of Michoacán; northern Morelos and the Zongolica mountains in Veracruz.
3. The mesophyte forests to the east of Oaxaca and the area of Comitán, Chiapas.

#### MAP 22. SENSITIVITY MODEL

Water

Evergreen tropical forests

Sub-evergreen tropical forests

Deciduous tropical forests

Thorn scrub

Xerophyte scrub

Grasslands

Temperate forest

Mesophyte forest

Aquatic vegetation

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The tropical evergreen and tropical deciduous forests maintain around 80% of their distribution in areas that would continue to have the same climate type.

In the CCCM model, nearly 10% of the area of almost all types of vegetation would be affected by warmer, dryer conditions. The greatest percentage of change is in the xerophyte bush of southern Chihuahua, east-central Coahuila, northern Zacatecas and San Luis Potosí (Map 23). A very extensive area that would face climatic change is found in the warmer climates, especially in grasslands, xerophyte scrub land, and oak and coniferous forests.

#### MAP 23. CCCM MODEL

The GFDL-R30 model gives another perspective. In this case, temperature and moisture would be increased over a large part of the country's surface. Thorn scrub, tropical deciduous and tropical subdeciduous (from 11 to 17% of their present areas) would face increases in precipitation without changes in temperature, especially in Oaxaca and along its border with Guerrero (Map 24). In the same way, the areas covered by oak and coniferous forests and mesophyte forests would experience increases in precipitation of almost 10%, although a great part of these would change to warmer climates. The areas covered by xerophyte scrubland and grasslands would also undergo increases in temperature.

- Application of three climate models to the classification of Holdridge life zones.

The computerized program of Holdridge life zones was applied to the database of the present climate, creating a map of 18 present life zones for Mexico. It was later applied to the three climate scenarios.

According to the Holdridge classification and the present climate, 60% of the country's surface is covered with dry, tropical and subtropical forests and thorn scrub. These receive an annual precipitation ranging from 250 mm to 2000 mm and a potential evapotranspiration of between 8 and 1. The temperature of the subtropical forests oscillates between 17°C and 24°C, and for tropical forests, is over 24°C. Next in order of importance are the subtropical desert scrublands and subtropical deserts, covering 15% of the total area.

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#### MAP 24. GFDL-R30 MODEL

The sensitivity model (+2°C and -10% precipitation) (Map 25) predicts an increase of 9% in the area of dry and very dry tropical forests, and a reduction of 6% in dry subtropical forests. Sixty seven percent of the surface would supposedly be covered by dry, tropical and subtropical forests and thorn scrub that at the moment cover only 60%.

The subwet temperate cold and the dry temperate warm forests would be severely reduced (to less than half), while the wet temperate cold ones would disappear and the warm, temperate, thorny steppes would now be practically non-existent.

#### MAP 25. SENSITIVITY MODEL

Cold forests  
 Steppes  
 Dry, temperate forest  
 Wet, temperate forest  
 Desert scrub land  
 Thorny scrub land  
 Dry, tropical forest  
 Dry, subtropical forest  
 Tropical forest

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The Canadian model (CCCM) (Map 26) predicts that the warm temperate forests would be reduced even more (at temperatures that range from 12°C to 17°C), from the present 4% to only 1%. In this case, the warm temperate desert scrub and the cold wet temperate forests would disappear. The subwet subtropical forests would decrease sharply (Table 13). On the other hand, the very dry and dry tropical forests would increase, as would the surface covered with desert scrub.

MAP 26. CCCM MODEL

Cold forests  
 Steppes  
 Dry, temperate forest  
 Wet, temperate forest  
 Desert scrub land  
 Thorny scrub land  
 Dry, tropical forest  
 Dry, subtropical forest  
 Tropical forest

TABLE 13. SURFACE (%) OF COUNTRY COVERED WITH EACH TYPE OF CLIMATE AND VEGETATION

Climate type (Koppen, modified by García)

Wet, warm  
 Subwet, warm 2  
 Subwet, warm 1  
 Wet, semiwarm  
 Subwet, semiwarm 2  
 Subwet, semiwarm 1  
 Wet, temperate  
 Subwet, temperate 2  
 Subwet, temperate 1  
 Semicold  
 Dry, warm

Dry, semiwarm  
Dry, temperate  
Arid, warm  
Arid, semiwarm  
Arid , temperate

Type of vegetation (Rzedowski)

Evergreen tropical forest  
Sub-evergreen tropical forest  
Deciduous tropical forest **sub-evergreen** tropical forest  
Mesophyte forest  
**Sub-evergreen** tropical forest and mesophyte forest  
Deciduous tropical forest  
Oak and conifer forest  
Oak and conifer forest  
Oak and conifer forest  
Conifer forest  
Thorny scrub and xerophyte scrub land  
Grassland and xerophyte scrub land  
Xerophyte scrub land  
Xerophyte scrub land  
Grassland

Present  
T +2°C pp –10% Model  
CCCM Model  
GFDL-R30 Model

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For the GFDL model (Map 27), the cold temperate, wet and subwet forests, as well as the warm ones, temperate desert scrub and the thorn steppes, would disappear completely. On the other hand, dry and very dry tropical forests and the tropical subwet ones would increase by 12.4%, 4% and 4.4% from their total area to 21%, 10% and 7.5%, respectively. The subtropical rain forests and tropical wet ones, which at the moment do not exist in Mexico, would be found in small percentages (Table 13).

MAP 27. GFDL-R30 MODEL

Cold forests  
Steppes  
Dry, temperate forest  
Wet, temperate forest  
Desert scrub land  
Thorny scrub land  
Dry, tropical forest  
Dry, subtropical forest

## Tropical forest

### Results

- Mexican Classification

According to the results obtained using the Mexican classification, all temperate climates would be reduced, corresponding to the natural distribution of the grasslands, which would disappear completely. The cold climates would be replaced with a greater number of temperate areas, causing the displacement of some conifer forests.

The habitat of the temperate forests - which can be found in the mountains of Mexico - would diminish considerably, which would mean the redistribution of these forests or the establishment of forms adapted to warmer, drier conditions. This is the case of the thorn scrub and the xerophyte scrub. In the case of the GFDL-R30 model, which proposes increases both in temperature and in precipitation, the tropical forests would extend their distribution toward the north.

This means that, if a climatic change occurred, the vegetation communities would have to face pressures such as increased aridity or precipitation ranges, depending on the model applied and on the ability of each species to respond quickly to these challenges.

- Holdridge life zones

The application of the three models to the Holdridge life zones in Mexico shows basically that the greatest effect would be felt by the temperate areas, including most of the wet forests, the dry ones and the thorny steppes. These areas would decrease drastically or would disappear completely in all models.

The sensitivity model promotes drier, warmer conditions, and therefore, the change would tend toward an increase in certain life zones, such as the thorny, tropical forests and very dry forests, as well as subtropical desert scrublands.

In the CCCM model, the tendency is very similar to the one described above. The possibility proposed by the GFDL-R30 model is different, since it presents wetter conditions. The life zones that are favored, according to this model, are those that have tropical affinities -dry, subwet and wet -, which are those that show a greater increase in the area.

In general, the cold and warm temperate forests, which cover 13% of the country, would tend to disappear. The dry and very dry, thorny, tropical forests, with temperatures above 24°C, would tend to increase, especially the very dry tropical ones, in the case of the CCCM, and the dry and subwet, tropical ones would do so in the GFDL-R30.

## WATER RESOURCES

To carry out the impact and vulnerability study in the Mexican water resource areas for the global climatic change due to a doubling in atmospheric CO<sub>2</sub>, the technique of modeling of the thermo-hydrological **balance** was used on the regional level, which allowed some conclusions to be reached concerning the impact and vulnerability of the Mexican water resource areas with respect to a possible climatic change for the year 2050 or 2075, using the General Circulation Models (GCM) GFDL-R30 and CCCM, and the thermal energy model, in the face of a doubling of atmospheric CO<sub>2</sub>.

We find that the possible changes caused by this variation in the CO<sub>2</sub> level (changes in the temperature of surface air and precipitation) can have a great impact on the pattern and magnitude of draining, on the wetness of the soil and evaporation and degree of acidity in some water systems in Mexico. Depending on the zone, the consequences of these phenomena could range from noxious to beneficial.

To know the vulnerability of the different zones, definite indices were estimated, according to criteria previously established for this type of study (Waggoner, 1990). By vulnerability is understood the type of water resource area combined with its human aspect (population density, capacity for water transport and storage, use in generating electric power, in agriculture and livestock raising and in domestic activities), as well as the measure of risk of losing the natural balance in the area.

Vulnerability indices allowed the impact on the thermal-hydrological cycle to be determined for seven variables: precipitation, evaporation, drainage, wetness of soil, acidity index, temperature of the air at surface and soil temperature. It was possible to determine the vulnerability of the 12 water resource areas in Mexico both for 1995 and for the future, using eight hypothetical scenarios of uniform climatic changes in all of Mexico, by +2 and +4°C of temperature, -20, 0 and +20% precipitation and -2 and +2% global radiation, by means of the GFDL-R30, CCCM and **MTC** models, using five vulnerability indices.

From the above comes the following classification of the water resource areas and of the country:

- Wet or semi-wet areas that can become dry.
- Areas in which water is an important factor for irrigation.
- Areas in which water is an important factor in the total consumption (irrigation + supply for towns).
- Areas in which total extraction greatly surpasses the potential availability of surface water.
- Areas that have a lack of water storage to give an appropriate mitigation response by constructing a certain number of dams.

According to this classification, the zones that have more vulnerability limits surpassed for all the scenarios are V (Río Pánuco watershed), VI (Lerma-Chapala-Santiago watershed) and XII (Baja California peninsula). In the first two cases, due to the population density (which means a greater water demand) and, in the third, because this is the driest area and with least drainage of the whole country (Figures 2 and 3). It should be pointed out that

future climate simulations for increases in CO<sub>2</sub> levels with General Circulation and energy balance models present uncertainty in the magnitude and distribution of precipitation.

In Maps 28 and 29 the resulting variations can be observed by comparing the basic scenario with the General Circulation, CCCM and GFDL-R30 models.

Potential effect of climatic change on water balance at the national level

In order to obtain values indicative of the potential effect of climatic change on water balance at the national level, a scenario study was carried out on the effect on water needs for crops.

The procedure consisted basically in calculating the values of the evapotranspiration of the crops under present conditions, and under the conditions proposed by the different scenarios suggested by the IPCC (first report, 1991). As meteorological information, the whole historical series available in all the meteorological observatories of Mexico, usually located in the state capitals and important cities, was used.

The method used in calculating evapotranspiration was the one proposed by Mundo and Martínez (1994), which consists in modifying that of the FAO (1976), which is one most used generally.

It was used in calculating what is called the "reference crop", which means that the results are applicable to any crop, multiplying them by the crop coefficient that is characteristic of each variety.

In the following figures, the results of the average yearly evapotranspiration are illustrated for the scenario zero (Figure 4), and for the scenario that corresponds to a temperature increase of 3° centigrade (Figure 5), called scenario three. It can be observed that most sites register increases in water needs, which affects the water balance negatively if a decrease in precipitation is registered simultaneously.

Seasonal scenarios are even more unfavorable. Figure 6 presents the changes in modifications to the evapotranspiration potential during winter, considering the same scenario three.

MAP 28. WATER REGIONS WITH CHANGE IN NUMBER OF INDICES EXCEEDED.  
CCCM MODEL

With change  
500 km  
Mendoza, V. et al. 1995

MAP 29. WATER REGIONS WITH CHANGE IN NUMBER OF INDICES EXCEEDED.  
GFDL-R30 MODEL

With change

500 km

Mendoza, V. et al. 1995

FIGURE 2. NUMBER OF INDICATOR OR LIMIT VALUES EXCEEDED FOR EACH WATER RESOURCE ZONE AND THE WHOLE COUNTRY IN BASIC SCENARIO FOR YEAR 1995 AND IN BASE, GFDL-R30, CCCM AND GFDL-R30 SCENARIOS FOR YEAR 2050, ACCORDING TO BALANCE MODEL. ROMAN NUMERALS INDICATE ASPECT IN WHICH ZONE IS VULNERABLE AND THE PRECEDING NUMBER, HOW MANY OF THESE FACTORS WERE EXCEEDED IN ZONE.

Water resource zone

I

II

III

IV

V

VI

VII

VIII

IX

X

XI

XII

Country

1995

Base

2050

Base

GFDL-R30

CCCM

MTC

Vulnerability key

I Vulnerability of zone in water reserve

II Vulnerability of zone in water reserve

III Vulnerability of zone in water consumption

IV Vulnerability of zone in total water extraction

V Vulnerability of zone in yearly water storage

WATER RESOURCE REGIONS IN MEXICO

**I CAMPECHE-YUCATAN-QUINTANA ROO PLAIN**

**II SLOPE TO SOUTHERN GULF**

**III SLOPE TO SOUTHERN PACIFIC**

IV BALSAS WATERSHED  
V PANUCO WATERSHED

VI LERMA-CHAPALA-SANTIAGO VALLEY

VII SLOPE TO CENTRAL PACIFIC

VIII SLOPE TO NORTHERN PACIFIC

IX INTERIOR SLOPE OF MAPINI-AGUANAVAL-EL SALADO

X SLOPE TO NORTHERN GULF

XI INTERIOR SLOPE OF RIO GRANDE AND CLOSED RIVER VALLEYS IN NORTH

XII BAJA CALIFORNIA PENINSULA

FIGURE 3. NUMBER OF INDICATIVE VALUES OR LIMITS EXCEEDED BY ZONES IV, V, AND VI EN BASIC SCENARIO FOR 1995 AND BASE, GFDL-R30, CCCM AND MTC SCENARIOS FOR THE YEAR 2050, ACCORDING TO TURK'S SECOND METHOD FOR REAL EVAPORATION. ROMAN NUMERALS INDICATE ASPECT IN WHICH ZONE IS VULNERABLE, THE NUMBER PRECEDING THEM SHOWS TOTAL OF LIMIT VALUES EXCEEDED FOR THAT ZONE

Water resources area

1955

Base

2050

Base

GFDL-R30

CCCM

MTC

Vulnerability key

I Vulnerability of zone in water reserve

II Vulnerability of zone in water reserve

III Vulnerability of zone in water consumption

IV Vulnerability of zone in total water extraction

V Vulnerability of zone in yearly water storage

WATER RESOURCE REGIONS IN MEXICO

I CAMPECHE-YUCATAN-QUINTANA ROO PLAIN

II SLOPE TO SOUTHERN GULF

III SLOPE TO SOUTHERN PACIFIC

IV BALSAS WATERSHED

V PANUCO WATERSHED

VI LERMA-CHAPALA-SANTIAGO VALLEY

VII SLOPE TO CENTRAL PACIFIC

VIII SLOPE TO NORTHERN PACIFIC

IX INTERIOR SLOPE OF MAPINI-AGUANAVAL-EL SALADO  
X SLOPE TO NORTHERN GULF  
XI INTERIOR SLOPE OF RIO GRANDE AND CLOSED RIVER VALLEYS IN NORTH  
XII BAJA CALIFORNIA PENINSULA

FIGURE 4

EVAPOTRANSPIRATION

PRESENT CONDITIONS  
SCENARIO ZERO

Source: Polioptro Martínez Austria, Leonardo Hernández Barrios.

FIGURE 5

ISOLINES OF EVAPOTRANSPIRATION

EVAPOTRANSPIRATION +3°C

Source: Polioptro Martínez Austria, Leonardo Hernández Barrios.

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FIGURE 6

ISOLINES OF EVAPOTRANSPIRATION

EVAPOTRANSPIRATION +3°C

Source: Polioptro Martínez Austria, Leonardo Hernández Barrios.

Industry and energy systems

In general, the world studies that manage to be carried out on energy and industry within the framework of global climate change are centered on how to reduce greenhouse gas emissions. The **relatively** low sensitivity of these systems in the face of this phenomenon (with respect to impacts on ecological systems and agriculture), added to the widespread idea that they have a great capacity for adaptation, has resulted in a lack of information regarding their vulnerability to climatic change.

The objective of this study is to fill that informative gap. In order to achieve this, factors influencing the vulnerability of industry and energy systems and the extent to which these factors affect them. Also, a diagnosis of the two systems was carried out, both in the framework of a base or present scenario and in case a climatic change actually occurred. For this, the dynamic of territorial behavior was determined and particularities and regional differences present in Mexico were defined, based on the application of the General Circulation, CCCM and GFDL-R30 models. The zones identified as most vulnerable, following this procedure, appear in Maps 30 and 31 for each of the sectors and for the intersections existing between them.

MAP 30. ZONES OF HIGH AND VERY HIGH VULNERABILITY. ENERGY AND INDUSTRY. CCCM MODEL

Energy	Industry
Very high	Very high
High	High

Energy $\cap$	Industry
Very high	Very high
Very high	High
High	Very high
High	High

500 km

MAP 31. ZONES OF HIGH AND VERY HIGH VULNERABILITY. ENERGY AND INDUSTRY. GFDL-R30 MODEL

Energy	Industry
Very high	Very high
High	High

Energy $\cap$	Industry
Very high	Very high
Very high	High
High	Very high
High	High

It is important to remember that, given that these sectors are two of the main emitters of greenhouse gases, measures to mitigate these emissions will affect them directly. In any case, it should not be overlooked that the vulnerability of these sectors may translate into variations in their participation in the country's economy. As for their capacity for adaptation, this can vary greatly from one company to another, according to their economic situation and capacity for providing themselves with resources (both financial and technological). We find, for example, that although the big industries (especially the heavy industries) have greater resources, they are also more vulnerable in needing large volumes of fuels and raw materials.

Geographical location is another factor that will influence the industries' capacity for adaptation. Those that are located in centers with a great industrial concentration, such as Monterrey, the D.F. and Guadalajara, will be more vulnerable because of having greater competition for the resources.

The vulnerability factors that were identified are the following:

- Rise in sea level. In this case, the greatest vulnerability will be found in industrial or energy generation plants, energy supply and distribution terminals, and **linking** infrastructure located near the coasts.

- Temperature increase. The main consequence of the temperature increase will be the redistribution of water resources. Here the vulnerability will be reflected in the need for the supply of certain volumes of water and in the regularity with which these are supplied. If there were a shortage of water, its cost would increase, directly affecting the cost of electric power and of fossil fuels. This rise in temperature will also mean an extra problem for companies that require freezing or cooling processes.
- The variations in temperature and distribution of water will have unavoidable repercussions on land use and the distribution of living beings. This will damage the companies that depend on raw materials derived from activities that are affected by climatic change, such as the lumber, textile, cellulose and paper, food industries, etc..

Based on these criteria, a classification was made of the industries according to their sensitivity to climatic change:

- Industries that depend on natural resources sensitive to climate (agricultural, forest, marine, water and energy).
- Industries whose industrial process is directly sensitive to climate both for its water and energy consumptions (and consequently, their cost) and for the incorporation of heating or cooling processes (production of electric power, oil and gas, **smelting** industries and metal refineries, foods and textile, etc.).
- Industries vulnerable to climatic change due to their geographical location (electric stations, oil, fishing, steel, petrochemical and chemical and food industries).
- Industries whose markets are susceptible to climatic change. Variations are expected in demand for energy, clothes, drinks, air conditioning and water.

Table 14 summarizes the above and indicates which energy and industrial sectors and subsectors are most sensitive to the climate in Mexico.

TABLE 14. INDUSTRIAL AND ENERGY SECTORS

VULNERABILITY BY SECTOR

HYDROCARBONS

VERY HIGH

HIGH

ELECTRICITY

VERY HIGH

HIGH

MINING INDUSTRY

VERY HIGH

HIGH

HEAVY INDUSTRY

VERY HIGH

HIGH

FOOD INDUSTRY

HIGH

TEXTILE AND PAPER INDUSTRY

VERY HIGH

HIGH

## BASIC SCENARIO

Regions with highest oil (96.4%) and natural gas (95.8%) production in southeast of country, besides Tula, Hidalgo and Salina Cruz, Oaxaca.

Zones of low capacity, refining industries in Guanajuato and Tamaulipas.

Steam thermoelectric plants in arid, dry and warm-subwet climates

Zones with great productive capacity or intensive energy consumption in Sonora, San Luis Potosí, Puebla and Colima.

Zones with petrochemical industries in Veracruz, Tamaulipas, Guanajuato, Oaxaca, northern Chiapas and Puebla, as well as industrial zones in Mexico, Monterrey, Nuevo Leon and Guadalajara, Jalisco.

Basic metallurgy and chemical industry of Sonora, Chihuahua, Coahuila and Durango in the north; Michoacan, state of Mexico, Morelos, Querétaro and Guanajuato, in the centre; Yucatán in the southeast.

Zones with competition for water resources or with high industrial concentrations in Baja California, Sonora, Chihuahua, Nuevo León and Sinaloa in the north; Hidalgo, Metropolitan Area of Mexico City, Veracruz and Campeche.

Industries located in the large urban centres of Baja California, Chihuahua, Nuevo León, Tamaulipas, Durango, Jalisco, San Luis Potosí, Querétaro, Mexico and Puebla.

## CCCM MODEL

Productive areas of Hidalgo and Guanajuato.

Hydroelectric plants located in the north and north-east regions of the country.

Hydro- and thermal-electric plants in the center, west-center, east-center and north-west regions of the country.

Productive units of Sonora, Chihuahua, northern Coahuila, Nuevo León, Colima and Veracruz.

Productive units of Durango, Zacatecas, San Luis Potosí, Hidalgo, Guanajuato and Querétaro. Metallurgy industry Puebla and salt and plaster districts of Baja California Sur.

Industriales zones of Baja California, Sinaloa, Sonora, Chihuahua, Durango, Tamaulipas and Colima.

Petrochemical and metallurgical industries in Chihuahua, Coahuila, northern Nuevo León, Veracruz and Oaxaca.

Baja California, Sonora, Sinaloa and Durango. Most of the center, west and southeast.

Baja California, Chihuahua, Nuevo León, Michoacán, Veracruz and the outlying areas of Mexico City.

Durango, Aguascalientes, Jalisco, Michoacán, the center of the country from Guanajuato to Puebla.

GFDL MODEL

Tula, Hidalgo.

Thermo-electric plants in Baja California.

Regions in north, northeast and northwest of country.

Coal districts of northern and northwestern Coahuila and Nuevo León.

Some areas in Sonora, Chihuahua, Coahuila in the north.

Baja California in north-west.

In Metropolitan area of Monterrey, Sonora and Baja California.

## VII. INTERNATIONAL COOPERATION

### MULTILATERAL TECHNICAL AND FINANCIAL COOPERATION

#### Inter-American Institute for Global Change Research (IAI)

Representatives of twenty-six countries and international organizations participated in the "Workshop for the development of an institute in the western hemisphere for climate change research" (July 16-19, 1991, San Juan, Puerto Rico). In this workshop, participating nations proposed the establishment of the Inter-American Institute for Global Change Research (IAI), a regional network of research centers dedicated to the study of global change and its impact on society.

The Treaty to establish this institute was signed by eleven countries (including Mexico) in May, 1992 and went into effect as of March 11, 1994.

The representatives of the States that make up the IAI met in the City of Mexico from Sept. 12 - 14, 1994, to hold the First Meeting of the Conference of Parts. At this meeting the functioning of the IAI as an international institution was established.

#### Scientific agenda of IAI

##### Topics:

- Tropical ecosystems and biochemical cycles
- Impacts of climate change on biodiversity
- The phenomenon of El Niño: southern oscillation and year-on-year climate variability
- Ocean-atmosphere-earth interactions in **intertropical** America
- Comparative studies on coastal and estuarial oceanic processes in temperate zones
- Processes at high latitudes
- Comparative studies on temperate land ecosystems

The participation of Mexico in the IAI includes the following activities:

- In 1994, the Workshop on the study of climate change impact on biodiversity was given in the city of Guadalajara, Jalisco.
- In 1995, it was agreed that a research center on global change would be established in Mexico.
- On July 20, 1995, the National Ecology Institute of Ecology of SEMARNAP signed the agreement for carrying out the project titled: "Activities in regional cooperation in support of research into climatic change in IAI countries". As a contribution to the establishment of centers for research into global change contemplated in the "Agreement for Establishing the Interamerican Institute for Research into Global Change (IAI)."

The object of this project is to improve the capacity of the participating countries for carrying out research into global change and for using the data, scientific results and other products of this type of research in treating questions of policies regarding these topics. In this project, the INE proposed the UNAM Center for Atmospheric Sciences as the center for IAI research in Mexico.

The functions of this center are: to carry out and support inter-disciplinary research into global change at the internal and external (extra-mural) levels, to concentrate data and promote the efficient, complete and open exchange of the Institute's data and information with countries in the region, to strengthen the capacities and facilities of existing institutions, to create a regional capacity and provide advanced training in fields relevant to global change.

- In addition to the above, the IAI has offered financial support, equipment and computing packages to the Center for Atmospheric Sciences in order to begin scientific activities related to climatic change in the participant countries.
- The IAI has given two regional courses in Costa Rica and Brazil (1995 and 1996) in which Mexico participated, and a course in each country member (1996) for training in the SPRING system of geographical information, developed by the Brazilian National Institute for Space Research (INPE, for its initials in Portuguese) and donated to member countries of the IAI. The IAI has also awarded scholarships for training internship in SPRING for two months in Brazil (1997), of which Mexico has obtained two.
- A regional course of training in the METVIEW system, used for handling meteorological data (1997), was given in Mexico, organized by the IAI.

Joint Declaration of the Meeting of Heads of State and Governments of Central America and Mexico. "Tuxtla II"

The presidents of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, the president of Mexico and the Prime Minister of Belize, meeting in San José City, Costa Rica, February 15-16, 1996, decided to adopt a Plan of Action in order to advance toward achieving the purposes and objectives of the San José Declaration (Tuxtla II). This Plan establishes the determination to carry out actions in the area of climate change, as well as to promote measures for saving energy and using it rationally, and to support the Pact of San José.

Among the actions contemplated by this Plan concerning climate change is the development of joint programs and projects to promote the fulfilling of commitments acquired in the framework of international instruments, giving workshops on the management of forest resources and alternate productive processes, the encouragement of joint research to develop alternatives to traditional energy uses and carrying out activities oriented toward preventing atmospheric pollution related to the United Nations Framework Convention on Climate Change.

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## PROTECTION OF THE OZONE SHIELD

In 1985, the **Vienna Convention for the Protection of the Ozone Shield** was signed with the fundamental objective of protecting human health and the environment against the adverse effects that can result from the modification of the ozone layer. This international instrument has two annexes: in one, important points are presented with respect to scientific

research and the systematic observation of the ozone shield, and the other describes the types of information that must be collected and shared by virtue of this Convention.

Later, in 1987, an agreement was reached on concrete measures, and the Montreal Protocol was signed.

Parallel to the evolutionary process of the Montreal Protocol, Mexican industry has started to protect the ozone shield since 1989. The strategy that Mexico has followed in complying with the Protocol has been based on the following:

- The negotiation of voluntary agreements with industry.
- The regulation of the importing and exporting of controlled substances.
- The development of programs of dissemination and technical training.
- The development of investment projects using clean technologies.
- Obtaining financing for industry to adopt clean technologies.

Joint collaboration among national, foreign and international organisms for promoting technology transfer. With this strategy, the following achievements have been obtained:

- Production and importing have been limited to 40% of the base year (1989) for 1996, which represents more than 6 thousand tonnes of CFCs eliminated.
- Projects have been developed in the following sectors: domestic and commercial refrigeration, solvents, foams, central and automobile air conditioning. Progress by agency: World Bank (WB): 13 projects with technical assistance of the United States' Environmental Protection Agency (USEPA); United Nations Development Programs (UNDP): eleven projects. The projects represent a reduction in consumption of approximately 2,500 tonnes. Before the end of 1996, all projects entered the implementation phase. Four additional projects were developed in the sector of commercial refrigeration for the WB, three of which are already approved.
- Every week, more than 10 companies and government and parastate entities receive information and assistance from the Ozone Protection Unit of the INE.
- To date, 10 technological workshops have been given with the participation of over a thousand technicians trained in the sectors of: central air conditioning, solvents and automobile air conditioning.
- It has participated in national forums, giving technical consulting to the companies participating in **chambers of commerce** and industrial associations. In the international arena, Mexico has collaborated in different forums, sharing its experience with other developing countries.

#### Mexico and the Montreal Protocol

- Mexico is the only developing country with high consumption that has been able to significantly reduce its consumption of CFC, halons and methyl chloroform.

On September 14, 1993, the governments of Mexico, Canada and United States signed the agreements parallel to the Free Trade Agreement (NAFTA) regarding Environmental and Labor Cooperation, simultaneously, in the cities of Mexico, Ottawa and Washington, D. C. This agreement went into effect on January 1, 1994, immediately after the Treaty itself went into effect.

### North American Commission for Environmental Cooperation

One of the most important consequences in the North American Agreement on Environmental Cooperation was the creation of the North American Commission for Environmental Cooperation.

This authority is the one in charge of supervising the application of the Agreement; it is a forum for trilateral discussion of environmental matters that promotes and facilitates cooperation among the governments of the three countries. One of its functions is that of solving issues and controversies that may arise regarding the interpretation and application of the Agreement and serving as an institutional link with the Free Trade Commission of NAFTA.

### Letter of Intention for Cooperation in Climatic Change and Joint Implementation

On October 13, 1995, in Oaxaca, Mexico, the governments of Canada (through the Ministry of the Environment), Mexico (represented by the Department of the Environment, Natural Resources and Fisheries) and the United States (by the Environmental Protection Agency) signed the Letter of Intention for Cooperation in Climate Change and Joint Implementation. The objective was to facilitate cooperation in topics of mutual interest in the area of energy efficiency and climatic change, including joint implementation in order to promote:

- The market-oriented dissemination of mitigation technologies, including energy efficiency and renewable energy technologies.
- Education, training and programs of information exchange.
- The restoration and amplification of carbon sinks in forest, agricultural, and grazing areas and other lands.
- The environmentally sound economic and social development.

The forms of cooperation contemplated in this Letter of Intention include the following:

- The promotion of internationally recognized methodologies for carrying out national inventories and predictions of anthropogenic emissions, by sources and sinks, of all greenhouse gases.
- The exchange of information on actions to reduce net greenhouse gas emissions.
- The application, advancement and dissemination of technologies, practices and processes to mitigate net emissions of these gases.
- The conservation and amplification of sinks and reservoirs, including oceans, forests and other types of biomass.
- Adaptation to climate change impacts.

- The consideration, when appropriate, of climate change factors in policies and economic and environmental actions.
- The exchange of research and other relevant information related to global and regional climate systems, in order to reduce uncertainties linked with the intensity, cause-and-effect relationships of climate change and environmental, economic and social consequences of the different response strategies.
- The support for programs for education, training and public awareness of climate change that promote the broadest possible participation in this process and that include the collaboration of non-governmental organizations.

In the same way, the Parties agreed that forms of cooperation, related to Joint Implementation, should include:

- Interaction opportunities between the offices of the national program of climatic change of each country.
- Exchange of information on criteria for joint implementation projects, recognizing the importance of national programs in establishing these criteria.
- Exchange of information on methodologies and mechanisms to establish processes to determine the bases, monitoring and external verification of the net reductions of greenhouse gas emissions, as well as follow-up and corroboration of these reductions, according to the criteria for selecting projects developed by pilot programs of joint implementation set up at the national level.
- Fostering joint implementation and other activities to promote sustainable development among public and private sectors and non-governmental organizations, including the dissemination of information about the criteria of the Parties for joint implementation projects, and supporting technical assistance through workshops, conferences and networks of information.
- The support, in international forums, of the pilot phase of joint implementation.
- The design of activities and projects implemented according to this Letter of Intention in order to:
  1. favor the growing participation of the private sector, especially in sustainable development and potential projects of joint implementation.
  2. facilitate the exchange of information between governments and the private sector in joint implementation, including information on potential sources of financing for projects and frameworks of policies necessary for access to these sources of funding.

#### Organization for Economic Cooperation and Development

Since 1996, Mexico, through the National Ecology Institute (INE), has participated in the forums of the Organization for Economic Cooperation and Development (OECD) on climate change held both in OECD headquarters in Paris and in meetings of the subsidiary bodies of the Conference of Parties of the Framework Convention on Climate Change.

#### Bilateral cooperation

The government of Norway has collaborated with the Federal Electrical Commission (CFE, its initials in Spanish) and the Global Environment Facility (GEF) in the Ilumex project for efficient lighting, by means of which approximately 1.7 million incandescent lamps will be exchanged for compact fluorescent lamps in the cities of Monterrey and Guadalajara between 1995 and 2006. It is hoped that a reduction in emissions of 726,675 tonnes of carbon dioxide and 18.57 tonnes of methane will be achieved in this way.

#### Country Study: Mexico

Mexico maintains a tradition of active participation in international forums in which topics related to the environment and climate are discussed. For many years, our country has made efforts to coordinate studies aimed at understanding the causes of environmental problems, as in the case of those related to global climatic change and its possible impact on society, in order to be in better conditions to face it in the future.

In 1993, the U.S. Country Studies Program offered Mexico financial support in carrying out analyses attempting to reveal the possible impacts of climatic change on the country's different production activities and resources.

The Country Study: Mexico, included studies conducted in three big areas:

1. National Inventory of Greenhouse Gas Emissions.
2. Scenarios of climate and of future greenhouse gas emissions.
3. Studies of the country's vulnerability to climatic change.

In preparing the inventory, support was received from the government of Canada in the form of equipment and computing packages. In addition, the mitigation studies carried out during 1995 and 1996 received funding from the World Bank, while the project "Study of coefficients of greenhouse gas emissions from live systems in central Mexico and the development of a related system for handling information", now being developed, has received financing from the Global Environment Facility through the United Nations Development Program (UNDP).

#### NOTES

##### Intergovernmental Panel on Climate Change (IPCC)

During the eighties, scientific evidence of the possibility of global climatic change grew, arousing great concern for its possible consequences among scientists and decision-makers. The United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) responded to growing international concern in 1988 by establishing the Intergovernmental Panel on Climate Change (IPCC), in order to evaluate the available information on climatic change, to evaluate the environmental and socioeconomic impacts of climatic change and to formulate strategies of response.

The phenomenon of "El Niño"

A large part of the world's population is affected by the phenomenon of "El Niño" that consists in an anomalous heating of the surface waters of the Pacific Ocean. With its atmospheric partner, the "Southern Oscillation", "El Niño" affects temperature and precipitation patterns around the world. The social and economic impacts of this natural interaction between the ocean and the atmosphere can be extensive and long lasting. Since precipitation is closely related to many aspects of society, including the availability and quality of water, agriculture, fisheries, energy, tourism, transports, and human health and safety, a strong "El Niño" event, such as that witnessed in 1982-83, can contribute to causing not only tens of billions of dollars' damage all over the world, but also human responses such as migration or market effects that have much longer-lasting repercussions than the effects of this phenomenon.

"El Niño" is characterized by the expansion of the normally hot waters of the tropical west of the Pacific Ocean toward the eastern Pacific, the west coast of South America. The introduction of abnormally hot waters into this area inhibits the rising to the surface of cold waters rich in nutrients, and alters the precipitation distribution in the Pacific basin. At the same time, the Trade winds of the southeast and the winds of the eastern Pacific are significantly weakened and become reversed. These winds are affected by the "Southern Oscillation", a large-scale fluctuation of atmospheric pressure between the eastern and western Pacific. Although the phenomenon of "El Niño-Southern Oscillation" (ENSO) is located in the tropical Pacific, it is associated with such climatic anomalies as droughts and flooding that occur far from this region.

The manifestations and impacts of an ENSO in a particular region depend on both physical and regional factors and on the socioeconomic structure of the area affected.

The abnormal cooling of the waters of the tropical eastern Pacific is known as "La Niña" and also produces climatic fluctuations throughout a large part of the world. In general, the signs of "La Niña" in a particular region are the opposite of those of "El Niño" (for example, increases in precipitation as opposed to reductions). (International Forum on Forecasting "El Niño": Launching an International Research Institute, November 6-8, 1995, Washington, D. C. Executive Summary. September, 1996).

### Energy intensity

Proportion of energy consumption and economic or physical yield. At the national level, energy intensity is the relationship between the total consumption of primary domestic energy or the final consumption of energy and the Gross Domestic Product or physical yield. (Technologies, Policies and Measures to Mitigate Climate Change. Technical Document I of the Intergovernmental Panel on Climate Change (IPCC). World Meteorological Organization - United Nations Environmental Program. 1996).

### Carbon sequestering

Green plants absorb CO<sub>2</sub> from the atmosphere through photosynthesis. The carbon is deposited in the foliage, stems, root systems and mainly, in the woody tissue of the trunks and main branches of the trees. Overall, forests contain a quantity of carbon 20 to 100 times

higher per unit area than cultivated lands and play a critical part in regulating the level of atmospheric carbon. It has been calculated that the world's forests contain over 80% of the carbon present on the entire earth's surface and approximately 40% of all carbon existing in the earth's subsoil (earth, detritus and roots). This is equivalent to almost 1.146 GtC,  $10^9$  tonnes of carbon. Approximately 37% of this carbon is located in the (tropical) low-latitude forests and 49% in high-latitude forests (Dixon et al., 1994).

When trees die or are cut down, the stored carbon is released. Part of this carbon is integrated into the organic matter which makes up the forest floor, where, depending on climatic conditions, it may remain for a long time. The rest is released into the atmosphere, mostly in form of  $\text{CO}_2$ , but also of  $\text{CH}_4$  and other greenhouse gases.

The factors that influence the indices of carbon absorption are: temperature, precipitation, density of mass, soil, slope, altitude, topographical conditions, growth index and age. In general terms, the denser forests have a greater capacity to store carbon than open forests and wooded areas. Forests that have not undergone interference can store more carbon than degraded forests. Wet forests contain more carbon than forests in arid or semi-arid areas, and mature forests store greater quantities of carbon than young ones.

The proportion of total dry biomass to carbon is approximately 2:1. The forest floor also contains carbon. A recent study indicates that 84.3% of the total carbon contained in high-latitude forests is stored in the soil. In the case of medium-latitude forests, 63% of the carbon is stored in the soil, and in low-latitude forests, 50.4% (Dixon, et al. 1994).

Studies on the percentages of carbon absorption of tropical forest plantations indicate that the maximum growth and absorption of carbon occurs during the ages of 0-5 and 6-10 years (62%). On the other hand, carbon absorption diminishes by 50% in the following 5 years and decreases even more after 16 years of age (Brown, et al. 1986).

Tropical forests play an important role in the global carbon cycle, since they contain almost 50% of the active terrestrial carbon in the world (Dixon et al. 1994). Besides being one of the main sources of greenhouse gases, deforestation can alter the climate directly by increasing reflection (albedo) and diminishing evapotranspiration.

Most plants assimilate carbon by means of two types of photosynthesis that are generally called processes C3 and C4. In the first phase of  $\text{CO}_2$  absorption, C3 plants produce a molecule with three carbon atoms and the C4 plants produce a molecule with four carbon atoms. The C4 molecule allows the plant to assimilate  $\text{CO}_2$  more efficiently. C3 plants depend only on the diffusion of  $\text{CO}_2$  through their tissues and therefore benefit more than C4 plants from high concentrations of  $\text{CO}_2$ . The plants that use the C3 process represent 85% of all plant species and include all trees and woody plants. The plants that use the C4 process are tropical ones and grasses in temperate zones that grow in regions with abundant precipitation in the hot seasons. Sugar cane, maize, sorghum and millet are C4 plants.

"Top-down" methodology

This procedure uses econometric methods as its fundamental tool and, as explanatory variables of energy demand, economic indicators (price, income, added value, GDP, etc.). The greatest disadvantages to this methodology are that it does not allow structural effects to be segregated, and does not take into account the residential sector or passenger transportation because they do not form part of the direct composition of the GDP. Source: " Metodología "Bottom-up" para el análisis de las emisiones de gases de invernadero debidas al uso de energía ", Sheimbaum, C., and Rodríguez, L. Mexico in the face of the climatic change: Records I. 1995.

" Bottom-up" methodology

This approach orients its analysis towards energy demand and not towards its added offer. It consists in disintegrating the energy consumption for the different sectors, that is to say, it builds the total demand of energy like the sum of the different final uses of each sector. Source: "Metodología "Bottom-up" para el análisis de las emisiones de gases de invernadero debidas al uso de energía", Sheimbaum, C., y Rodríguez, L. Mexico in the face of climate change: Records 1995.

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