NACIONES UNIDAS

COMISION ECONOMICA
PARA AMERICA LATINA
Y EL CARIBE - CEPAL

Distr.
LIMITED

LC/L.580(Sem.56/4)
16 August 1990

ENGLISH
ORIGINAL: SPANISH

Technical Meeting of Government Experts
"Towards an environmentally sustainable form of development"

Santiago, Chile, 12-14 September 1990

POSSIBLE CLIMATIC CHANGES IN LATIN AMERICA AND THE CARIBBEAN AND THEIR CONSEQUENCES

This document was prepared by Mr. Eneas Salati, consultant to the Economic Commission for Latin America and the Caribbean. The views expressed in this unrevised paper are those of the author and do not necessarily reflect those of the Organization.

90-7-1184

CONTENTS

1. Introduction

Over the last decade, possible climatic changes and their ecological, economic and social consequences have aroused increasing interest not only among researchers but also in political and administrative circles. It has been recognized that the main contribution to the so-called "greenhouse effect" is made by the industrialized countries, especially those that produce energy by burning fossil fuels.

Because of their characteristics and stage of industrial development, the developing countries are responsible for a smaller contribution as regards the burning of fossil fuels and the production of CFC gases, but on the other hand they make a significant negative contribution through alterations in land use, especially through the replacement of tropical forests by areas of agricultural production.

In these circumstances, Latin America and the Caribbean are undergoing profound changes in their plant cover, with natural consequences for the equilibrium of the various ecosystems. Although these changes must have begun immediately after the discovery of the Americas, the rates of change were relatively slow, as the ecosystems of greatest agricultural productivity and the areas of easiest access were occupied first. In recent decades, however, the rate of occupation has speeded up and the process of exploration and colonization has spread to the most marginal areas and to ecosystems whose initial productivity is high in natural conditions but which, when converted into areas of agricultural production, present the most serious problems, leading to degradation of the environment and social instability. The most worrying aspect is the rapid rate of alteration observed and the speed at which the systems lose their intrinsic agricultural production capacity.

This paper aims, on the basis of the available information:

a) to determine the possible micro- or mesoclimatic alterations deriving from changes in land use, and especially from deforestation;

b) to determine how the replacement of forested areas with pastures and annual crops may affect global climatic changes;

c) to deduce, on the basis of present levels of knowledge, how possible global climatic changes may affect the ecosystems of Latin America and the Caribbean;

d) to indicate, on the basis of the information obtained, what actions or policies should be adopted in order to minimize these problems and increase knowledge in this field.

2. Global climatic changes

a) The "greenhouse effect"

The Earth is covered with a thin layer of gases called the atmosphere consisting at present of 78.3% of nitrogen, 20.99% of oxygen, 0.94% of argon, 0.03% of CO_2, and smaller concentrations of rare gases such as helium, neon, xenon, etc. As well as the gases, the atmosphere contains a variable amount of water vapour, which is responsible for most of the meteorological phenomena observed, and solid particles of various origins whose concentration also varies with place and time.

The naturally existing gases, especially nitrogen, oxygen and the rare gases, permit the passage of solar radiation, made up mainly of short-wave radiation, and they also allow the passage of the radiation emitted by the surface of the Earth and by the atmosphere itself (long-wave radiation in the infrared spectrum).

The CO_2 and the water vapour also allow the passage of the solar radiation, but they absorb the long-wave radiation emitted by the surface of the Earth.

The Earth is warmed by energy from the sun, whose radiations pass through the atmosphere and heat the surface of our planet. Once the ground is warmed, it raises the temperature of the atmosphere close to it, so that the atmosphere is heated from below by the movements of rising air masses and by the radiation emitted by the surface of the Earth, which is absorbed to a particularly high degree by the water vapour and the CO_2. In the present equilibrium state, the Earth's atmosphere acts as a blanket which keeps the surface of the Earth warmed up to a mean temperature of about 15°C. In principle, all the radiation coming from the sun should be stopped half way and reflected back into outer space.

Without the existence of the gases which retain the infrared radiation, known as the "greenhouse gases", the Earth would be a very cold planet with a mean temperature 32°C below its present temperature, that is to say, -17°C.

This "greenhouse effect" which already exists as a result of the present composition of our atmosphere could be termed the intrinsic or existing greenhouse effect.

The greenhouse gases operate exactly as in a glasshouse. The glass allows the passage of the short-wave solar radiation but prevents the escape of the infrared radiation emitted by the surface of the earth, by other solid surfaces in the greenhouse, and by the air itself within the structure: hence the term "greenhouse gases".

The problem which we are facing now and which is the reason for the present paper and for these meetings is that human activities are changing the composition of the atmosphere and increasing the concentration of greenhouse effect gases in it.

b) Human activities which contribute to the greenhouse effect

Henceforth in this paper, the term "greenhouse effect" will be used in the sense of the increase over the intrinsic greenhouse effect of the Earth: that is to say, the effects of human activities which increase the concentration of greenhouse effect gases in the atmosphere.

The emissions of gases responsible for increasing the greenhouse effect are connected with various human activities, especially:

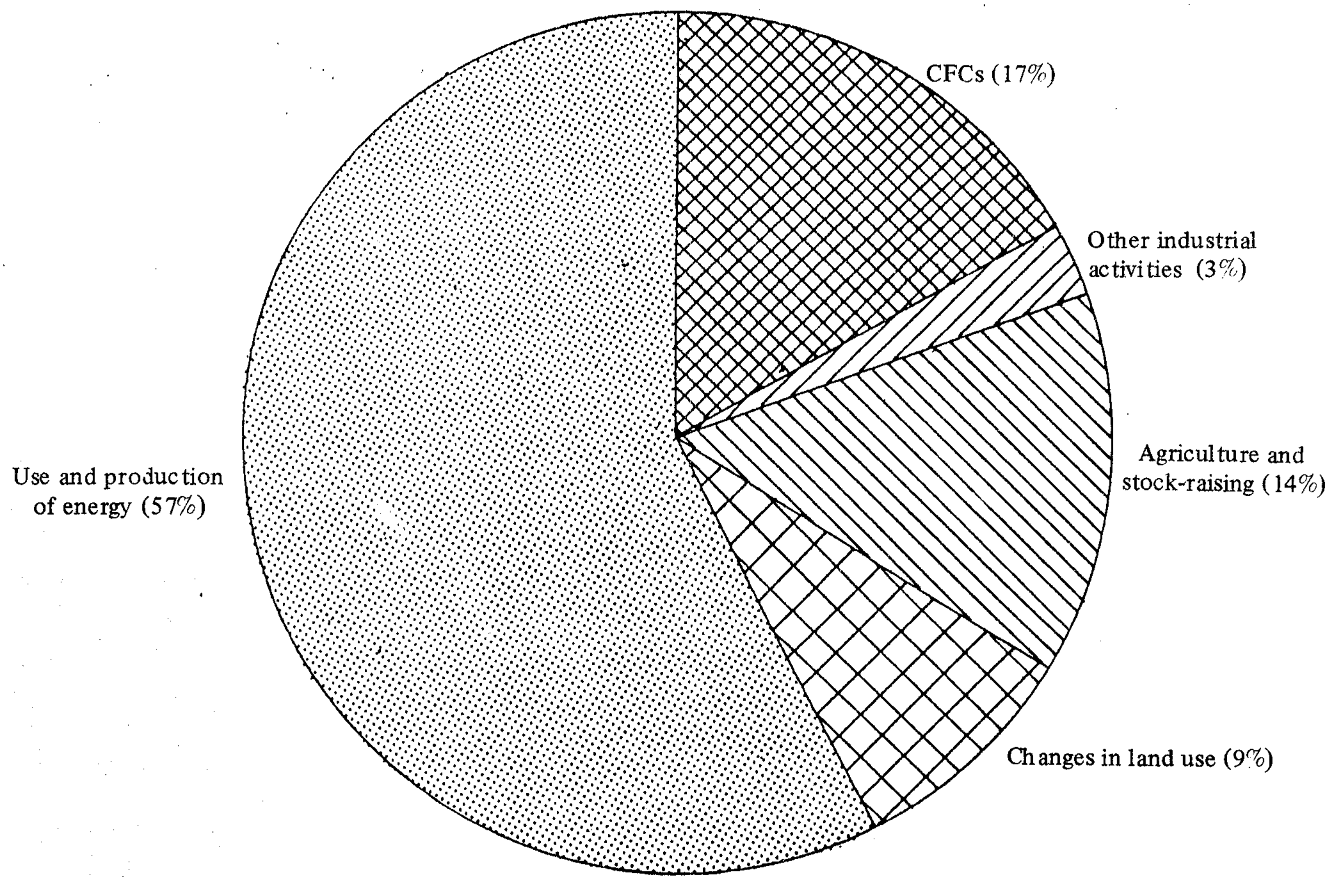
- the production of energy from fossil fuels, which is responsible for the increase in CO_2;
- agricultural activities, which are particularly related with the increase in methane and N_2O;
- industrial activities involving the production and use of chlorofluorocarbons (CFCs);
- changes in land use, which are responsible in particular for the production of CO_2 as a result of deforestation.

Figure 1 summarizes the percentage contributions of the various activities to global warming (1).

In view of the importance of CFCs, not only in connection with the greenhouse effect but also because they are responsible for the reduction of the ozone layer, a plan has been prepared which provides for the reduction and eventual replacement of these gases, through an agreement signed by the main countries involved in their production and use (the Montreal Protocol).

Figure 1

ACTIVITIES THAT CONTRIBUTE TO GLOBAL WARMING



Note: Estimates of the contributions made to the greenhouse effect in the 1980s by various types of activities [1].

c) Experimental observations on the greenhouse effect

The studies on climatic changes due to alterations in the chemical composition of the atmosphere present scientifically proven facts and projections based on mathematical models.

The most important observations are the following:

a) There is a proven increase in the concentration of CO_2 in the atmosphere, which is now 25% greater than in the pre-industrial era. These increases have been registered in various observatories: Figure 2 (1) gives the mean figures recorded at Mauna-Loa, Hawaii. The present emission of CO_2 is of the order of 5.5 PgC/year of carbon for the burning of fossil fuels and 0.4-2.6 PgC/year for deforestation (2).

b) This increase in CO_2 comes from two main sources: the burning of fossil fuels (close to 70%) and deforestation (close to 30%).

c) The present amount of carbon in the atmosphere (as CO_2) is 735 Gton, and the annual increase is estimated at 3 Gton/year.

d) The concentration of methane in the atmosphere is on the increase, as it has at least doubled over the last three centuries. Methane, which is currently increasing at the rate of 1% per year, is responsible for about 20% of the greenhouse effect. Figure 3 (3) shows the increase in this gas in the Earth's atmosphere.

Methane is produced by anaerobic decomposition in biological systems; it is the most abundant constituent of natural gases. The production of methane from various sources is shown in figure 4 (3).

e) There is also an increase in the amount of N_2O in the Earth's atmosphere: its concentration has grown by some 5-10% since the pre-industrial era, and it is now increasing by some 0.25% per year. Figure 5 (3) shows the increase of this gas in the atmosphere.

The sources of N_2O have not been clearly determined: it is known, however, that this gas is produced during combustion and also in the soil as part of the nitrogen cycle.

f) An increase is observed in the concentration of the gases known as chlorofluorocarbons (CFCs), which were emitted into the atmosphere for the first time only in the present century. Although their concentration is very small, their influence in the greenhouse effect is 20 times as great as that of CO_2. These gases have increased very rapidly, by close to 4% per year since 1978. They are products of the chemical industry. The concentrations of

Figure 2

CONCENTRATIONS OF CARBON DIOXIDE RECORDED AT THE MAUNA LOA STATION AND EMISSIONS OF CO_2 DUE TO THE BURNING OF FOSSIL FUELS[1]

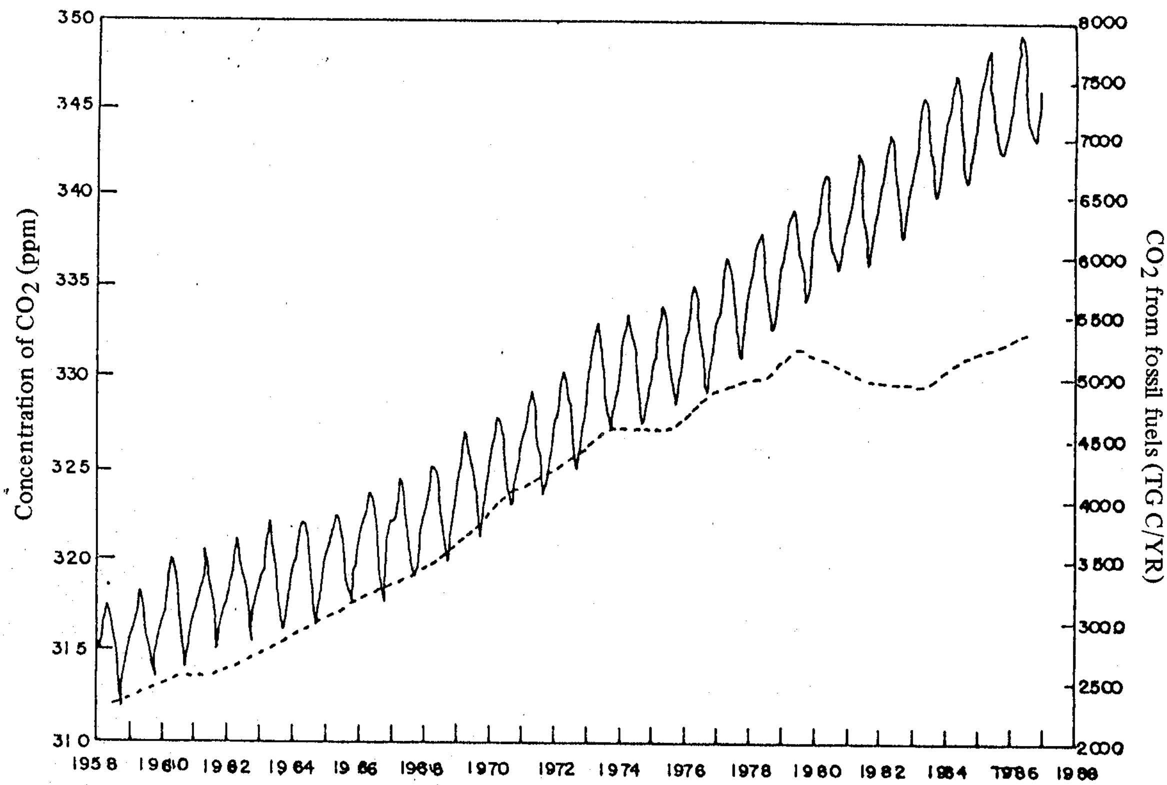
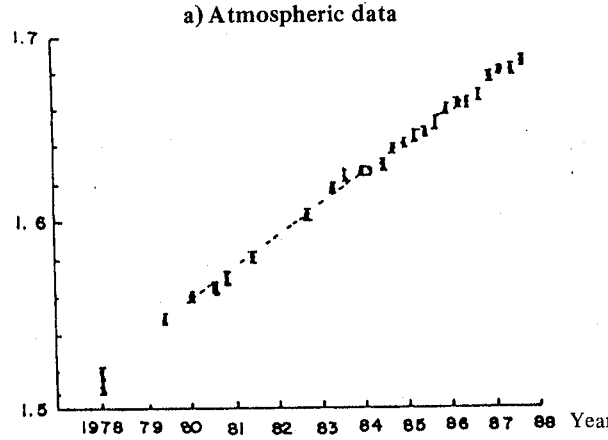


Figure 3

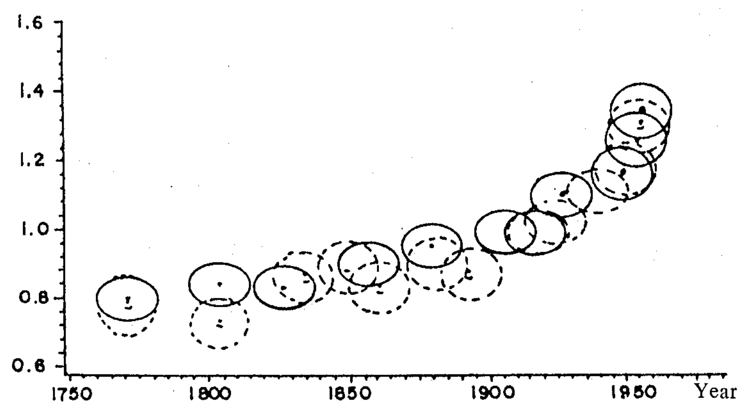
CONCENTRATION OF METHANE

Parts per million

a) Atmospheric data



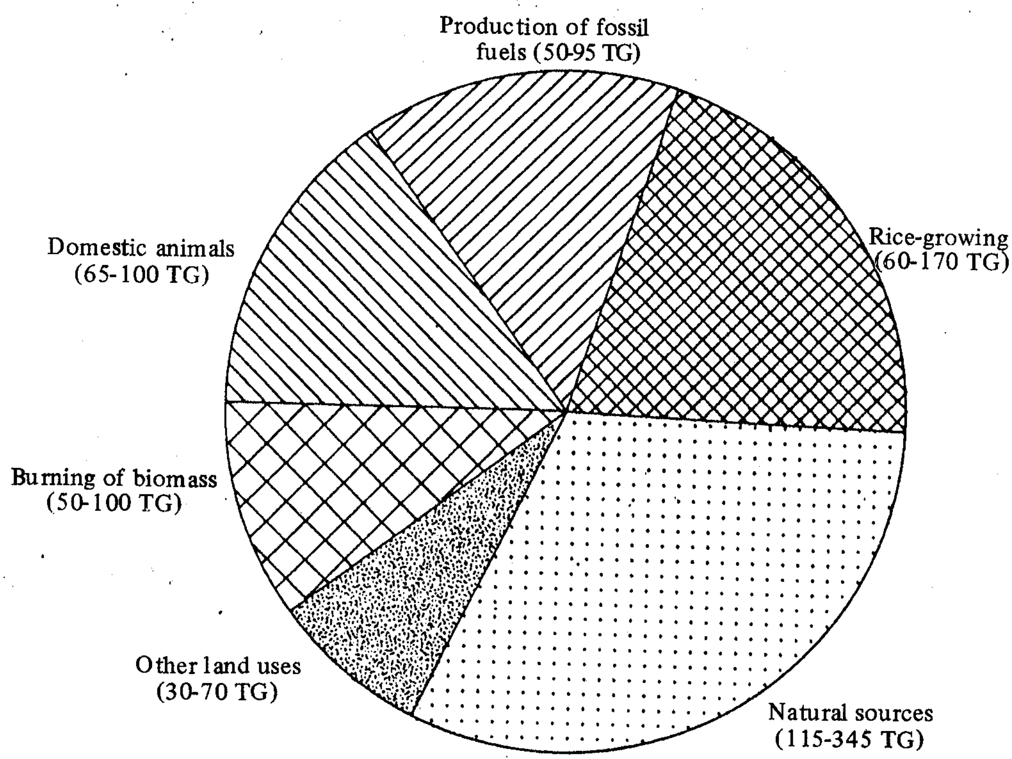
b)Data from ice samples



Source: Blake and Rowland (1988); Stauffer *et al* (1985)[2].

Note: Recent measurements of the concentration of CH_4 in the atmosphere show that this gas has been increasing at the rate of 1 per cent per year during the last decade. Measurements of the CH_4 concentrations in ice samples from the Antarctic show that the levels were relatively constant over the period 1800-1900 but began to rise rapidly as from the beginning of the Twentieth Century.

Figure 4
METHANE EMISSIONS FROM DIFFERENT SOURCES



The three main producers

Through rice producing	Through the raising of domestic animals	Through the production of fossil fuels
1. India	1. India	1. United States
2. China	2. Soviet Union	2. Soviet Union
3. Bangladesh	3. Brazil	3. China

Source: Cicerone and Oremland (1988); Crutzen *et al* (1986); Lerner *et al* (1988); United Nations (1987); IRRI (1986)[2].

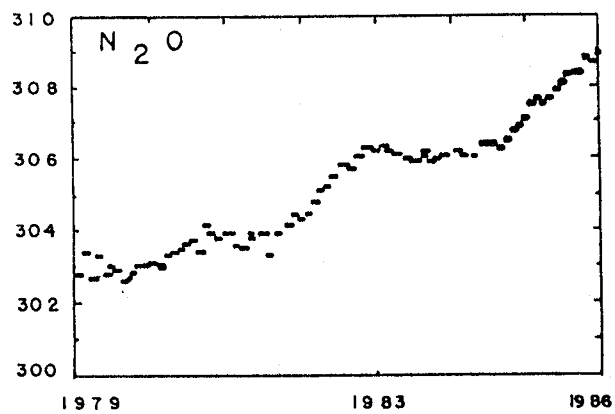
Note: Human activities in the agricultural sector (raising of domestic animals, rice-growing and burning of biomass) and the production of energy from fossil fuels are the most important sources of the release of methane into the atmosphere. Natural sources such as oceans, lakes and wetlands may account for less than 25 per cent of the total emissions.

Figure 5

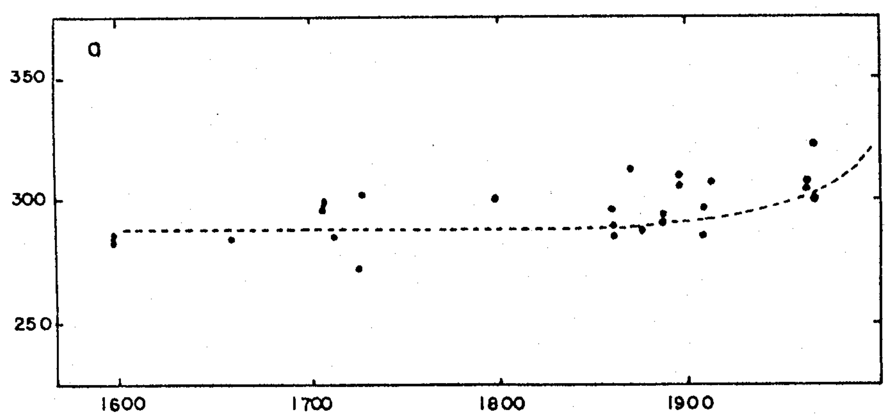
CONCENTRATION OF NITROUS OXIDE

Parts per billion

Atmosphere data



Data from ice samples



Source: Khalil and Rasmussen (1987); Pearman *et al* (1986)[2].

Note: The concentration of N_2O in the atmosphere has been rising at the rate of 0.25 per cent per year over the last decade. Ice samples show that the concentration of N_2O remained more or less constant from 1600 to the beginning of the Twentieth Centur but has began to increase rapidly over the last 50 years.

these gases measured in 1976 were 392 parts per trillion (ppt) by volume for CFC-12 and 226 ppt for CFC-11.

g) The above facts show that human activities can alter, and are altering, the chemical composition of the atmosphere and that the natural mechanisms which exist for their removal have been overwhelmed by emissions due to human activities.

h) By their nature and molecular structure, these gases have the capacity to absorb infrared radiation, so that their increase in the Earth's atmosphere leads to a change in the radiation balance of the Earth, tending towards an increase in global temperatures.

i) There is convincing evidence that temperature increases in past ages were associated with an increase in the amount of CO_2 and methane in the atmosphere. This information was obtained from measurements of the concentration of CO_2, O^{18} and D in samples of Antarctic ice, which reflect the prevailing temperatures of the atmosphere in the past.

d) <u>Evidence of climatic changes in the last century, and the time scale involved</u>

Measurements show that the atmosphere of the Earth grew warmer in the last century, and that in past periods the increase in temperature was associated with increases in the concentration of CO_2. The estimated increase in the last century is of the order of 0.3-0.5°C. These data were obtained from direct measurements of the temperature in meteorological stations. There are also observations pointing to shrinking of the icecaps, especially since the end of the last century. The tendency towards temperature increases is different in the Northern and Southern Hemispheres. In the last decade, however, there have been episodes of unusually high maximum temperatures in both hemispheres compared with the variations in the last 100 years (this was the warmest decade in the whole of that period).

What is difficult to prove is that the recent increase in temperature is due to the greenhouse effect, since there are natural oscillations in climate due, in particular, to variations in solar activity and in the parameters of the Earth's orbit. The variation in solar activity means a variation in the solar energy received by the Earth, while variations in the parameters of the Earth's orbit lead to spatial variations in the distribution of solar energy over the surface of the globe. These two effects can lead to climatic changes without any variation in the chemical composition of the atmosphere, or they may set off a sequence of events which can lead to global temperature changes, especially through changes in the dynamic equilibrium of CO_2 between the oceans and the atmosphere or similar changes in the processes of the biosphere and its interaction with the atmosphere.

On the other hand, an increase in the concentration of greenhouse effect gases can likewise lead to an increase in temperature such as has been observed in the last century.

The results obtained from climatic models are based on the hypothesis of the doubling of the concentration of CO_2 in the atmosphere, that is to say, its increase from 300 ppm to 600 ppm (or, alternatively, an increase in the concentration of other greenhouse gases, together with CO_2, which would have the same effect as the doubling of CO_2).

In reality, these gases are indeed gradually increasing with time. Initially, the increased heat is partly absorbed by the oceans, leading to a more gradual increase in the temperature of the atmosphere.

The fluctuations due to natural causes and those due to the greenhouse effect must initially be superimposed; later, as the phenomena due to the greenhouse effect become more evident, these fluctuations can be studied separately. The time scale for the above-mentioned observations is given in figure 6 (4).

e) <u>Forecasting of global climatic changes through models</u>

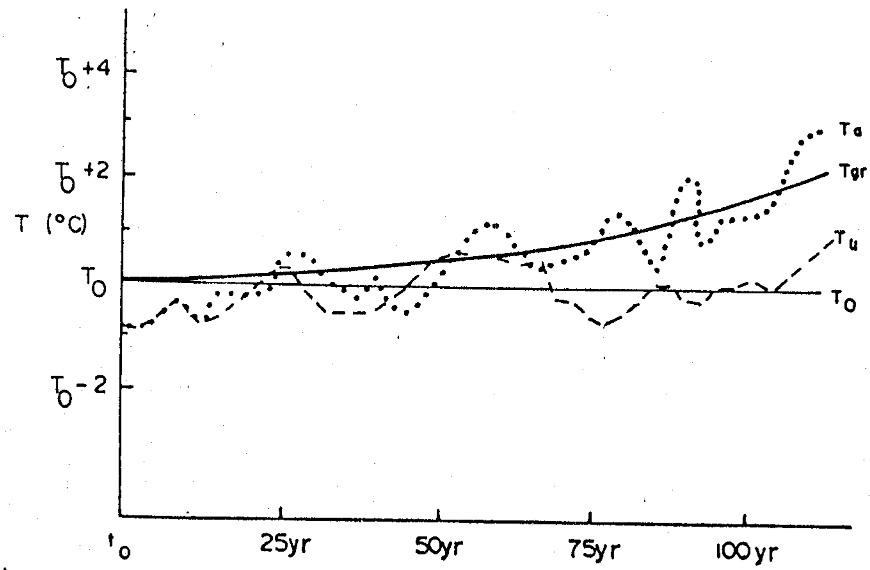
On the basis of the measurements which indicate an increase in the concentrations of the greenhouse effect gases, climate simulation models were developed which assumed a doubling of the concentration of CO_2 compared with that existing in the pre-industrial era. This also means that the models can be used to determine the action of the greenhouse effect gases as a whole, since that action is equal to twice the effect of the CO_2.

It is important to emphasize that these simulations make it possible to infer the probable climatic changes for the Earth in a general manner. Although there are divergences in the application of these simulations, by reason of the constant improvement of the models and the parameters used in them, some of the conclusions are common to all of them, thus permitting a higher degree of reliability of the forecasts.

Most of the models predict an increase in temperature ranging from 1.5 to 4.5°C. Although this range of discrepancy may seem small, however, a variation of a few degrees centigrade in the mean global temperature may mean big oscillations in the climate. Suffice it to recall that at the end of the last Ice Age, which covered much of the continents of the Northern Hemisphere with ice 18 000 years ago, the mean temperature of the planet was only 4°C below its present level.

Figure 6

SCHEMATIC ILLUSTRATION OF THE PROBLEM OF DETECTING THE GREENHOUSE EFFECT



Note: The thick line (T_{gr}) represents the evolution of a hypothetical mean of the temperature rise due to the greenhouse effect. The thin line (T_o) represents the temperature without any disturbances. The broken line (T_u) represents the real variations in temperature in a climate which has not been subject to disturbance. The dotted line (T_a) represents the real fluctuation in the Earth's temperature due to the increase caused by the gases responsible for the greenhouse effect. It is important to note that many years may be needed in order to separate the fluctuations due to the greenhouse effect from those observed in undisturbed conditions (T_u) 4.

Moreover, the predicted increase will not be uniform, as it will be greater at high latitudes and less marked in the equatorial regions. The increases will also depend on the hemisphere in question, being smaller in the Southern Hemisphere because of the greater thermal inertia of the oceans. Figure 7 shows the temperature variations in the two hemispheres over the next 60 years, assuming an increase of 1% per year in the concentration of CO_2.

As a result of the general rise in the temperature on Earth, it is expected that there will be an increase in the amount of precipitable water, that is to say, an increase in the amount of water vapour in the atmosphere. This will be bound to cause changes in precipitation patterns, with fundamental changes in the climatic characteristics of some ecosystems. It is expected that these changes will be most marked in middle-latitude continental regions.

Other expected changes are the following:

a) A drop in temperature in the stratosphere (this prediction is of high reliability) (4).

b) An increase in mean global precipitation. With the increase in temperature, there will be an increase in evaporation, thus leading to a larger amount of water in the atmosphere, which may lead to an increase in precipitation in some regions. Other areas, however, may suffer a decline in precipitation. (This prediction, too, is of high reliability.)

c) An increase in the air temperature of the North Pole region in winter. In this period, polar temperatures may rise as much as 10°C over their present levels (another highly reliable prediction).

d) Increased precipitations in high latitudes of the Northern Hemisphere (probable).

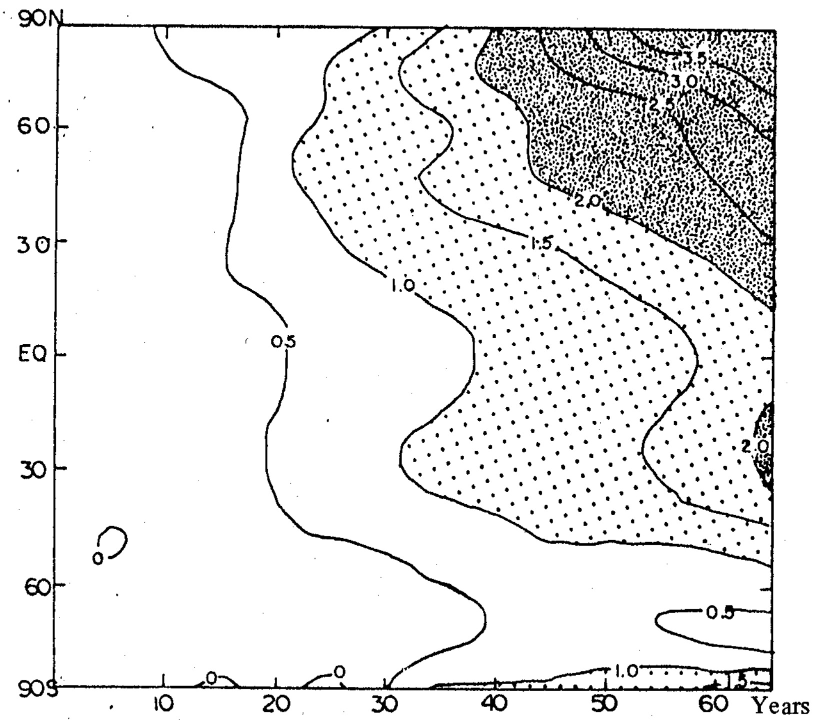
e) Reduction of the available ground water and increased temperatures in continental areas in summer (probable).

f) A rise in the mean level of the oceans (probable).

g) Variations in plant cover. The climatic changes will lead to variations in temperatures and precipitations, which will inevitably lead to changes in plant cover. The exact nature of these changes at the regional level remains uncertain, however.

h) An increase in temperatures in the tropics. Although there is no certainty regarding the occurrence of a larger number of tropical storms, it is predicted that the increase in the temperature and humidity of the atmosphere could increase the frequency of hurricanes.

Figure 7



Note: Evolution over time of mean temperature values (°C) for each decade for the different zones of the Earth, using a GFDL/NOAA model and assuming a constant increase of 1 per cent in the concentrations of CO_2. The differences in distribution between the Northern and Southern hemispheres reflect the effects of the ocean flux[4].

The uncertainties in the present models are due mainly to the difficulty of predicting the role of the clouds, which could significantly alter the reflection of the atmosphere, and the difficulties which still persist with regard to the inclusion of some dynamic processes of the oceans. From the point of view of regional predictions, the greatest limitation is in the spatial scale used, which employs cells of approximately 5° of latitude by 5° of longitude (approximately 5 400 x 5 400 km).

It is important to emphasize at this point, however, that although the climatic models used in these predictions give reliable results for global (planetary) changes, they are still deficient for simulating regional climatic changes, although better predictions can be made in some specific cases, as for example the prediction of the displacement of climatic zones in the northern United States and Canada.

Thus, detailed studies of climatic shifts in Latin America and the Caribbean due to global changes are still extremely deficient and must be viewed with caution.

In the specific case of South America, for the months of December, January and February (depending on the model adopted) the temperature increase could range from 2°C for the Amazonian region to 8°C for southern South America. In the regions of greatest agricultural production (including Brazil, Argentina, Chile, Uruguay and part of Paraguay) the increase could be up to 4°C (4).

Some studies (4) indicate that in some areas the final hydrological balance will be such that there will be a smaller amount of available ground water, thus tending towards a régime of semi-aridity or greater aridity. This information is particularly important for the north of Mexico and for the semi-arid region of northeast Brazil, where there would be a reduction in the amount of water available for growing plants.

3. <u>The contribution of deforestation to the increase in CO_2 in the atmosphere</u>

The main contribution of the developing countries of Latin America and the Caribbean is connected with the production of CO_2 through deforestation, since their contributions through industrial activities and the use of fossil fuels to produce energy are relatively small.

In 1987, CO_2 emissions into the atmosphere through the burning of fossil fuels came to 5.5 GtonC.*/ The net emission of CO_2

---

*/ 1 Gton = 10^9 tons.

through changes in land use was estimated at 0.4-2.6 Gton per year (5). We thus see that deforestation could represent up to 30% of the total contribution to the increase in CO_2 in the atmosphere. Such deforestation occurs almost exclusively in tropical regions. Table 1 shows the emissions for the 15 largest contributors, five of them from Latin America (7).

Table 1

CARBON EMISSION FROM DEFORESTATION

(Million tons)

Brazil	336
Indonesia	192
Colombia	123
Ivory Coast	101
Thailand	95
Laos	85
Nigeria	60
Philippines	57
Burma	51
Peru	45
Ecuador	40
Vietnam	36
Zaire	35
Mexico	33
India	33
TOTAL	1 659

Figure 8 shows the net emission of carbon through deforestation in tropical regions (5), (3), (20).

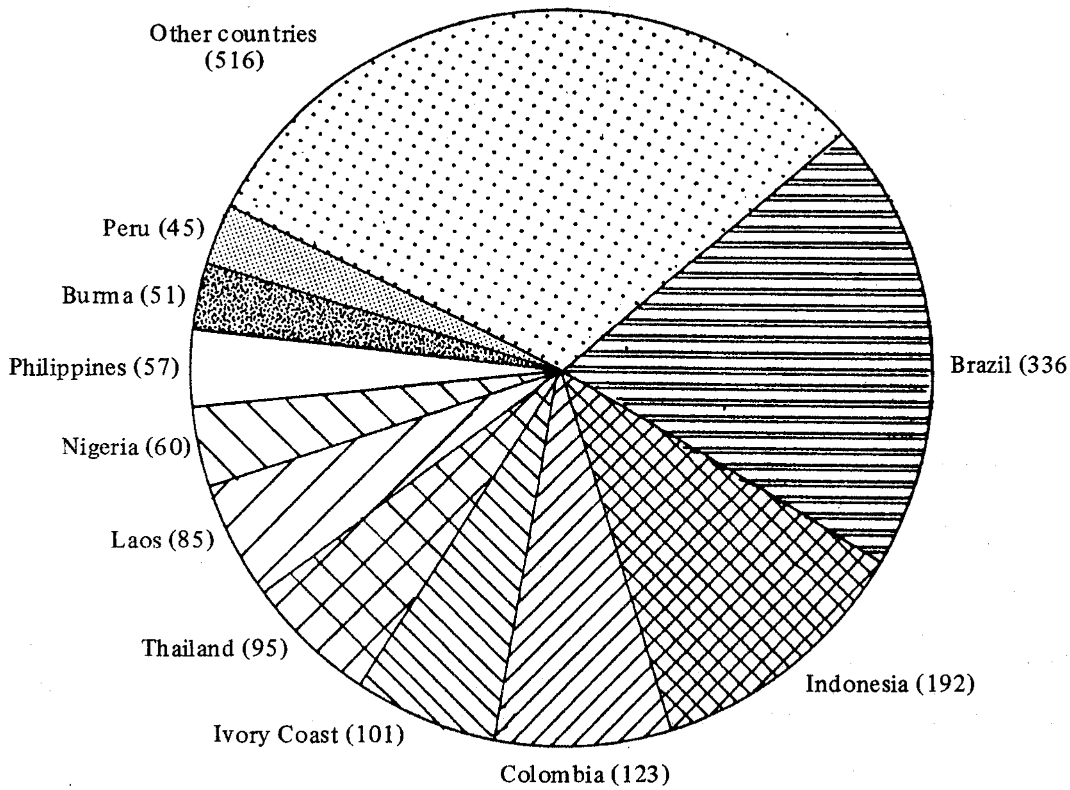
These figures must be viewed with caution because of the uncertainties due to the parameters used in their calculation. These uncertainties are due mainly to the lack of more precise knowledge about the rate of deforestation, the rate of conversion of organic material into CO_2 and the value of the biomass of the ecosystems thus transformed.

Consequently, in the light of an analysis of current knowledge of the above values, Brazil's contribution was recalculated (13), (6), and it was found that the contribution through deforestation of the Amazon region is between 0.24 and 1.60 Gton per year.

Figure 8

CARBON EMISSIONS IN 1980 DUE TO TROPICAL DEFORESTATION

(Terragrams of carbon)



Source: Houghton *et al* (1987)[3].

Note: Deforestation in tropical regions contributes approximately 10-30 per cent of the anthropogenic emissions of CO_2 into the atmosphere. In 1980, approximately 50 per cent of the emissions were due to only six countries: Brazil, Indonesia, Colombia, Ivory Coast, Thailand and Laos.

Figure 9 shows the CO_2 emissions for various countries. In the case of the Latin American countries a distinction is made between the contribution from commercial energy consumption and that due to deforestation. Figure 10 shows the same contributions on a per capita basis (7).

Noteworthy among these data are the contributions of Brazil, Colombia, Mexico, Peru and Ecuador: indeed, Colombia's per capita contribution is comparable with that of the countries with the biggest emissions --the United States and West Germany.

4. Local and regional climatic changes due to changes in land use

a) Expansion of the agricultural frontier

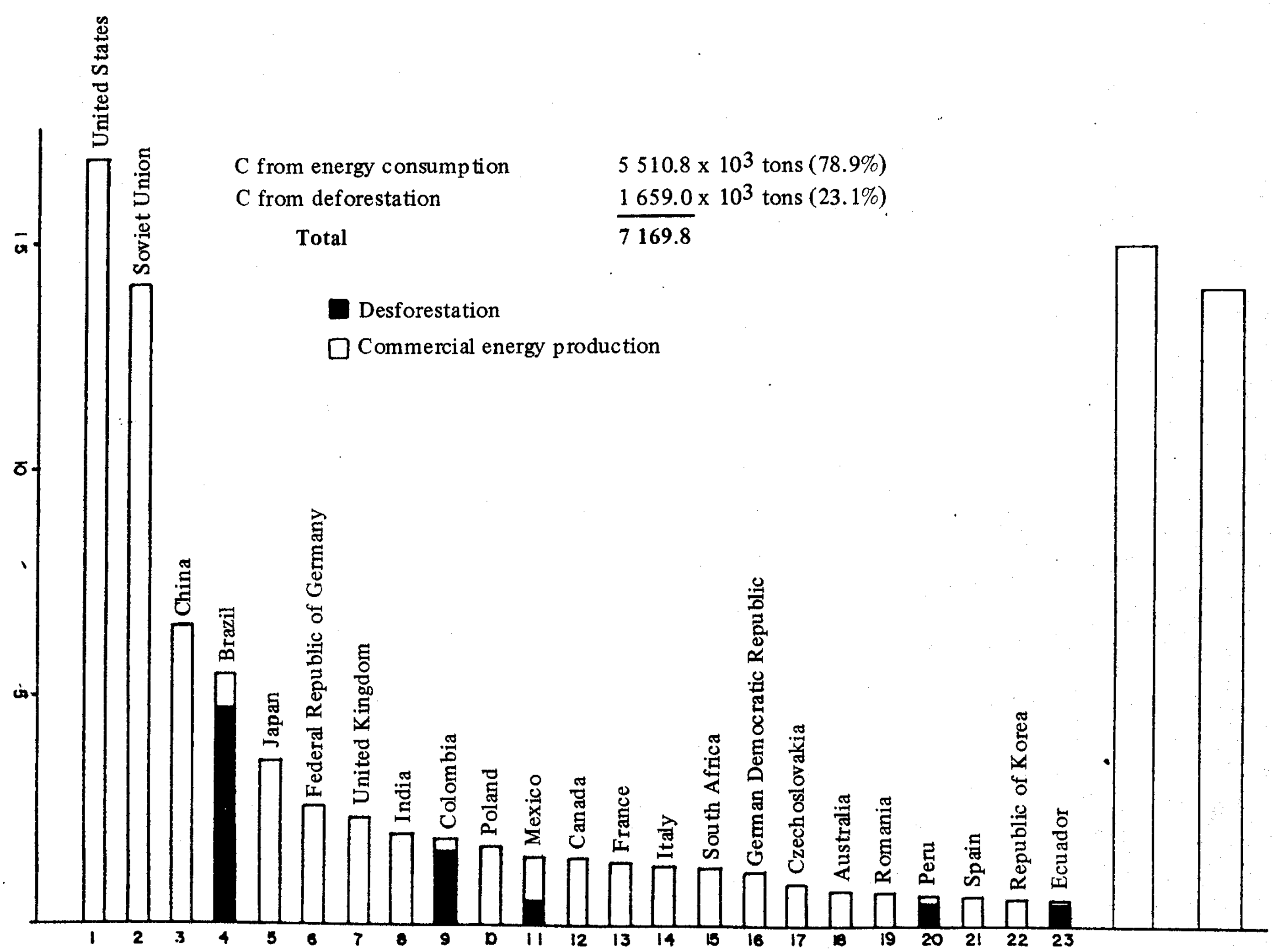
The search for fresh areas in which to initiate agricultural activities takes place constantly in all those countries which still have areas that can be colonized. For the present study, a feature of particular importance is the transformation of forests into areas of agricultural production. Deforestation is going on in all the countries which still have forest reserves, especially in the wet tropics.

Table 2 shows the annual rates of deforestation in the tropical zone of Central America and Mexico, the Caribbean subregion and South America in the period 1981-1985 (16). Over this period, the annual rate of deforestation was 5 650 000 hectares per year, made up of 4 604 000 for South America, 24 600 for the Caribbean subregion, and 1 021 000 for Central America and Mexico (16).

Because of its magnitude, we shall dwell here on the rate of deforestation in Amazonia, which is a region of approximately 7.5 million km^2 including parts of Brazil, Colombia, Peru, Ecuador, Venezuela, Suriname, Guyana and French Guiana. In these countries, a number of economic activities are exerting pressure on the ecosystem through the expansion of the last great frontier of colonization in South America. Outstanding among these activities are:

- the installation of extensive agriculture and stock-raising;
- lumbering;
- the introduction of perennial agricultural activities such as the growing of cocoa, rubber and the planting of single-species forests for pulp and paper production;
- the introduction of annual agricultural activities such as the growing of sugar cane, soya, rice, millet, etc.;

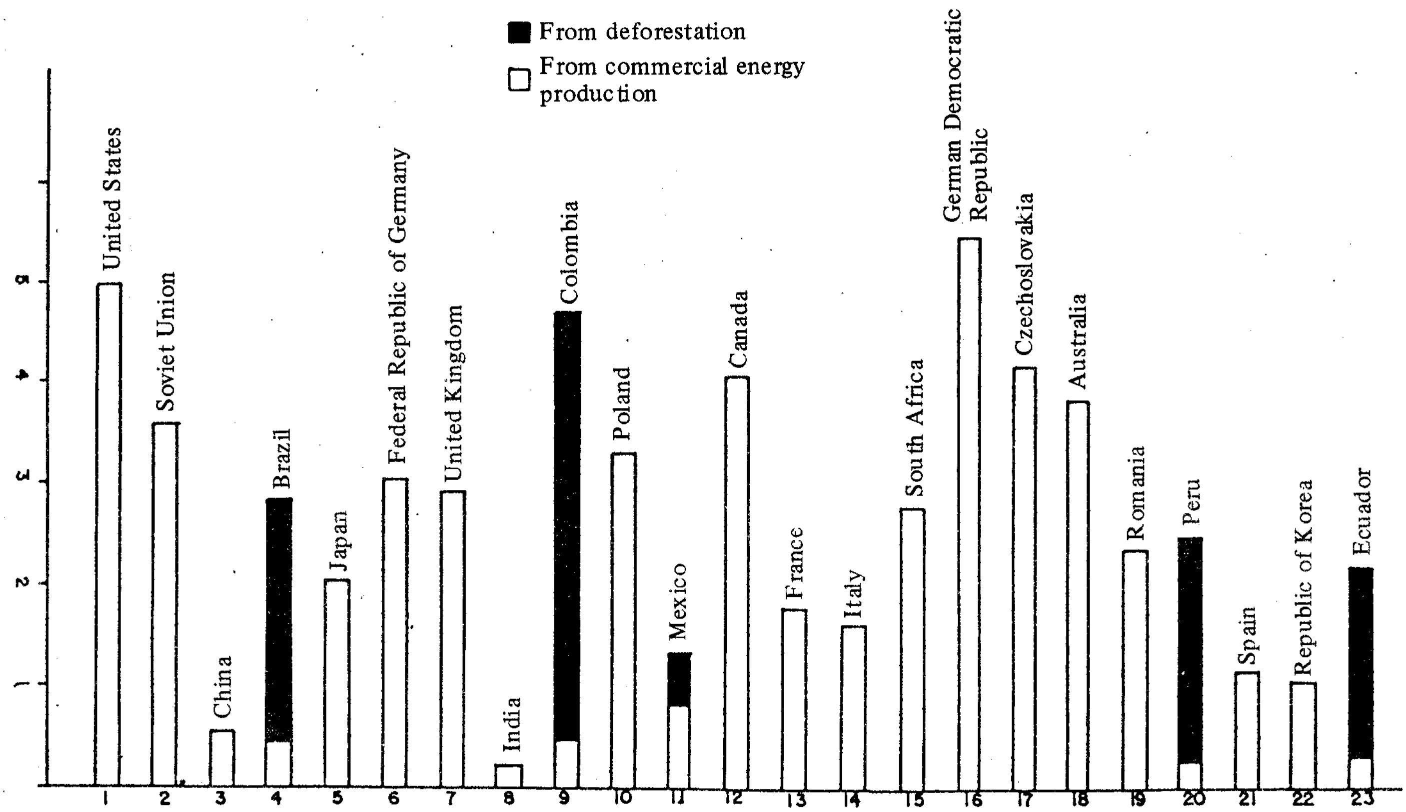
Figure 9



Source: Goldemberg, 1989[7].

Figure 10

PER CAPITA EMISSIONS OF CO_2



Source: Goldemberg, 1989[7].

- the installation of iron smelting activities using charcoal as an energy source and reducing agent;
- the construction of hydroelectric power stations;

Table 2

Countries	Total area deforested (x 1 000 ha)
Costa Rica	-65.0
El Salvador	-4.5
Guatemala	-90.0
Honduras	-90.0
Mexico	-615.0
Nicaragua	-121.0
Panama	-36.0
Central America and Mexico	-1 021.5
Belize	-8.5
Cuba	-2.0
Dominican Republic	-4.0
French Guiana	-0.5
Guyana	-2.5
Haiti	-1.8
Jamaica	-2.0
Suriname	-2.5
Trinidad and Tobago	-0.8
Caribbean subregion	-24.6
Bolivia	-117.0
Brazil	-2 530.0
Colombia	-890
Ecuador	-340
Paraguay	-212.0
Peru	-270.0
Venezuela	-245.0
Tropical South America	-4 604.0

- widespread prospecting for gold and precious stones;
- prospecting for petroleum (with the construction of roads to facilitate prospection and exploration: migration to these regions is stimulated by the progressive deforestation that takes place all along these roads).

For the installation of these activities, highways have been built which have permitted the entry of great waves of colonists: in the Brazilian part of Amazonia, for example, the population has grown by over 15 million in only two decades.

Up to the 1960s, Amazonia was practically untouched with regard to its plant cover, since the total reduction in this was only of the order of 1%. The great colonization projects which took place in various countries occurred after the Second World War and speeded up in the 1970s with the construction of the highways crossing the region from East to West and from North to South. The deforestation was accompanied by this process of organized or spontaneous colonization. There are some doubts about the exact extent of deforestation in Amazonia, since in many countries the process of occupation has not been monitored by satellite photos. For the Brazilian part of Amazonia, there are various estimates of the deforestation up to 1988, ranging from around 7% (343 975 km^2) (8) to 12% (589 921) (9) (as percentages of Official Brazilian Amazonia, which has a total area of 4 906 784 km^2).

At all events, the rate of deforestation is high and is rising exponentially, since the rate for 1989 must be over 4 million hectares for Amazonia as a whole. Indeed, already in 1987 it was 8 million km^2 per year for Brazil alone (10).

One of the regions which has been most closely studied as regards deforestation is that of Rondônia, where the rates were as follows: (11)

Year	Area deforested (km^2)
1920	Beginning of process
1975	1 216
1978	4 148
1980	7 579
1982	11 400
1983	13 955
1985	27 658
1987	36 900
1988	41 521
1989	46 142

The State of Rondônia has an area of 243 044 km^2, so that, in only 14 years, 17% of the State has been deforested: a truly exponential rate.

In Peru it is estimated that over 6 million hectares were deforested in recent decades, and indeed the process of colonization through deforestation is common in all the countries of the Amazon region. It is probable that the rate of deforestation of the wet tropical forests of South America is of the order of 5 million hectares per year. It is important to bear this value in mind in subsequent considerations, both with regard to intrinsic changes in the ecosystem and because of its contribution to the global greenhouse effect.

The same alterations --smaller in absolute terms but of the same order of magnitude relatively speaking-- are to be observed in the Caribbean island countries and in Central America (see table 1).

In many of these islands, the problem of deforestation is reaching critical proportions because heavy soil erosion is making the land unproductive. The most serious problem observed in this respect is that of Haiti.

b) <u>Changes in the water and radiation balances due to deforestation</u>

The cutting down of tropical forests for the installation of agricultural activities brings with it serious changes in the original ecosystem. Generally speaking, there is a reduction in the number of species of plants and animals, an increase in laminar erosion, and loss of nutrients through leaching. There is also a complete change in the biogeochemical cycles, with destruction of the processes of recycling of nutrients in the ecosystem.

In addition to these general changes, there are some specific changes which alter the water and energy balances. After the elimination of the forests, the capacity of infiltration of water into the soil goes down, so that there is greater surface runoff. This means that there is less water available for the process of evapotranspiration, with an increase in the proportion of energy that goes to heat the air (sensible heat) and a reduction in the amount of energy used in the evapotranspiration of water (sensible vapour).

These changes are reflected in microclimatic changes, and in particular it is possible to observe an increase in maximum ground and air temperatures.

Depending on the size of the region undergoing the changes, regional changes may take place. Thus, microclimatic changes are to be observed in practically all the tropical forest ecosystems altered through the introduction of pastures or annual crops.

The regional changes also depend on the intrinsic changes, their size, and the surrounding conditions in the continent.

The most closely studied case in Latin America is that of Amazonia, which will be taken as an example because it accounts for almost half of the South American continent.

i) <u>The present situation of the water and energy balance of Amazonia</u>. In order to be able to forecast changes, it is necessary to understand the dynamics of the processes which maintain the current equilibrium of the region. Let us look at the energy balance flows for the Amazon Basin, with its 6.5 million km^2 of area. Figure 11 shows the water and water vapour flows involved in the interaction of Amazonia with other regions.

The most important points to note here are:

a) The primary flow of water vapour, of the order of 8-10 x 10^{12} tons per year, originates from the Atlantic Ocean and is brought to the region by the Trade Winds which blow from East to West.

b) A flow of water vapour of 3-5 x 10^{12} tons per year leaves the Amazon region for other regions of the globe. This vapour carries with it to other regions a mean energy flow equivalent to 4.34 x 10^{14} watts, forming part of the process of transfer of energy from the equatorial region to other regions in higher latitudes.

c) The flow of water to the ocean is of the order of 5.5 x 10^{12} tons per year.

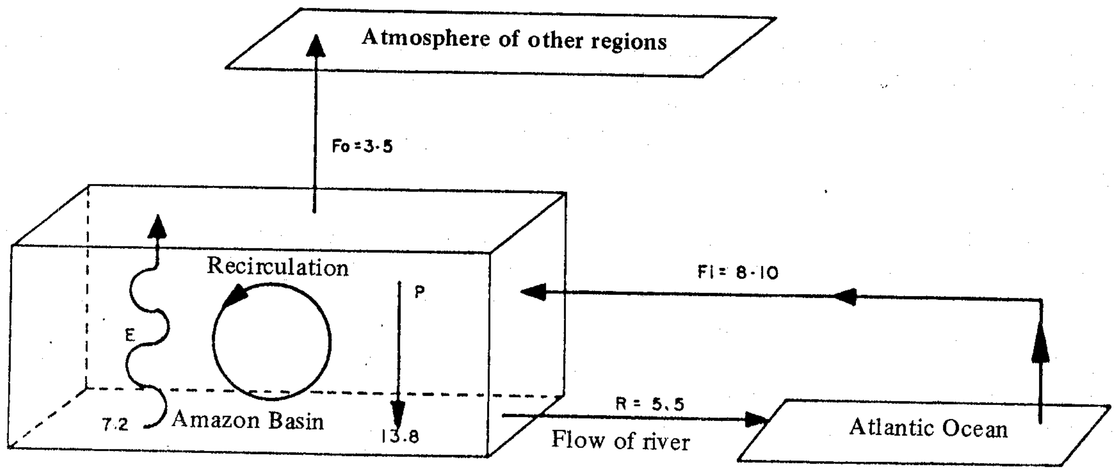
d) The precipitation amounts to 13.8 x 10^{12} tons per year, while evapotranspiration amounts to 7.2 x 10^{12} tons per year.

In order to explain this water balance, it is necessary that there should be heavy recirculation of water vapour in the region. This hypothesis is strongly supported by various studies of the water balance and the isotopic breakdown of the water (12).

This conclusion means that 50-60% (13) of the precipitations come from the recirculation of water vapour, and an extremely important role is played in this process by the plant cover as regards the absorption of water, since it can lengthen the residence time of the water, increase catchment and regulate transpiration. Alterations in the plant cover will bring with them changes in the components of the water balance and consequently in the distribution of the net energy balance ratio. The reduction of evapotranspiration means a reduction in the proportion of the radiation balance which is converted into latent heat and an increase in the proportion corresponding to sensible heat: that is to say, to an increase in temperature.

In addition to these local changes which would result in a reduction in precipitations and a rise in temperature, there would also be a reduction in the flow of water vapour in the regions

Figure 11
SCHEMATIC MODEL OF THE WATER CYCLE IN THE AMAZON BASIN



Note: E represents evapotranspiration.
P stands for precipitation. Recirculation of water vapour accounts for approximately 60 per cent of total precipitation. The flows must be multiplied by 10^{12} tons/year.

around Amazonia. The immediate consequence of this process would be a reduction in the rate of flow of the rivers and in the hydroelectric potential of the Amazon and its tributaries.

ii) Estimation of regional climatic changes by modelling. Various attempts have been made to predict, through models of the global circulation of the atmosphere, the probable regional climatic changes if the Amazonian forest were replaced with pasture land (14).

One of the most recent studies is that by Nobre and others (1989) (17), which used a high-resolution model of the global circulation of the atmosphere. In this model, the simulation assumed the substitution of 100% of the Amazonian forest with degraded pasture land. The most important results were the following: the temperature in the region increased by 1-4°C; evapotranspiration went down by 20-40%, and precipitations were reduced by 20-30%. It was also observed that the greatest influence on precipitations would take place in the driest months, so that there would be a more pronounced dry season, possibly turning regions with a temperate (A_w) climate into much drier (A_m) climatic areas: that is to say, a tendency towards conversion into savannas.

Figure 12 (a, b, c, d) and figures 13 and 14 show the spatial and temporal variations caused by these changes.

iii) The time scale. The changes in the components of the hydrological cycle take place immediately after the change in land use, especially when forests are replaced with pastures or annual crops. Observations indicate an increase both in the amount of water lost through surface runoff and in the incidence of erosion. The changes in the physical characteristics of the soil --increased compactation and a reduced rate of infiltration-- constitute an ongoing process which begins to be observed one or two years after the change in land use. These changes lead to an alteration in the radiation balance, so that microclimatic changes take place in a very short space of time, being in some cases virtually simultaneous with the process of change.

Changes at the regional level through the combination of the microclimatic changes will depend on the degree of alteration and the time scale covered by the effects in question. The mean period of retention of water vapour in the Amazon Basin, for example, is of the order of 3-4 months, and the hydrological cycle is repeated each year. It may therefore be expected, within the degree of precision of the meteorological measurements, that these regional effects could be observed within a time scale of only a few years when the changes are sufficiently great. There are indications that, as far as changes in the hydrological régime are concerned, the effects of the deforestation of the upper reaches of rivers can be felt within a single hydrological cycle. Deforestation along

Figure 12

DIFFERENCES BETWEEN 12-MONTH MEASUREMENTS (JANUARY-DECEMBER 1987) FOR SIMULATIONS WITH PASTURE LAND AND FOREST FOR THE SOUTH AMERICAN REGION

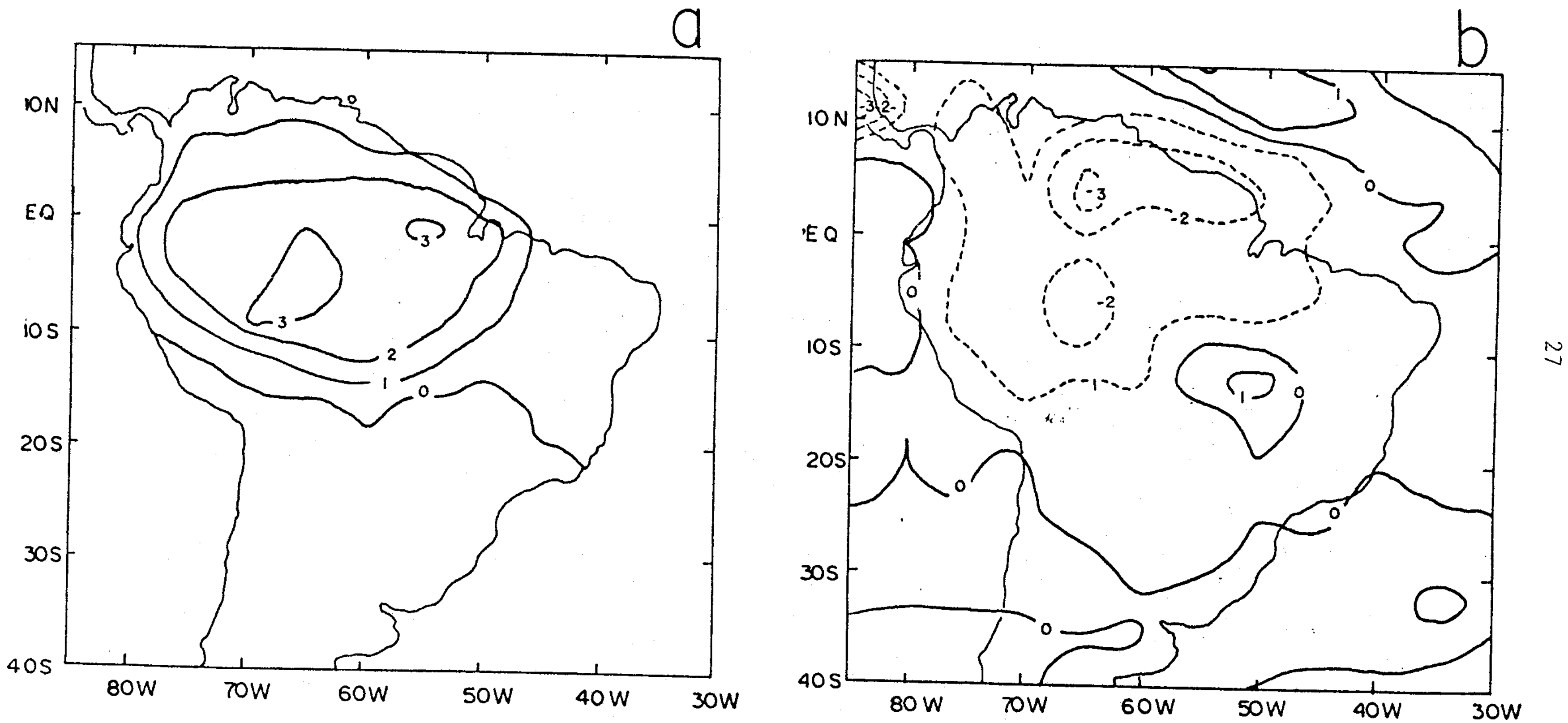
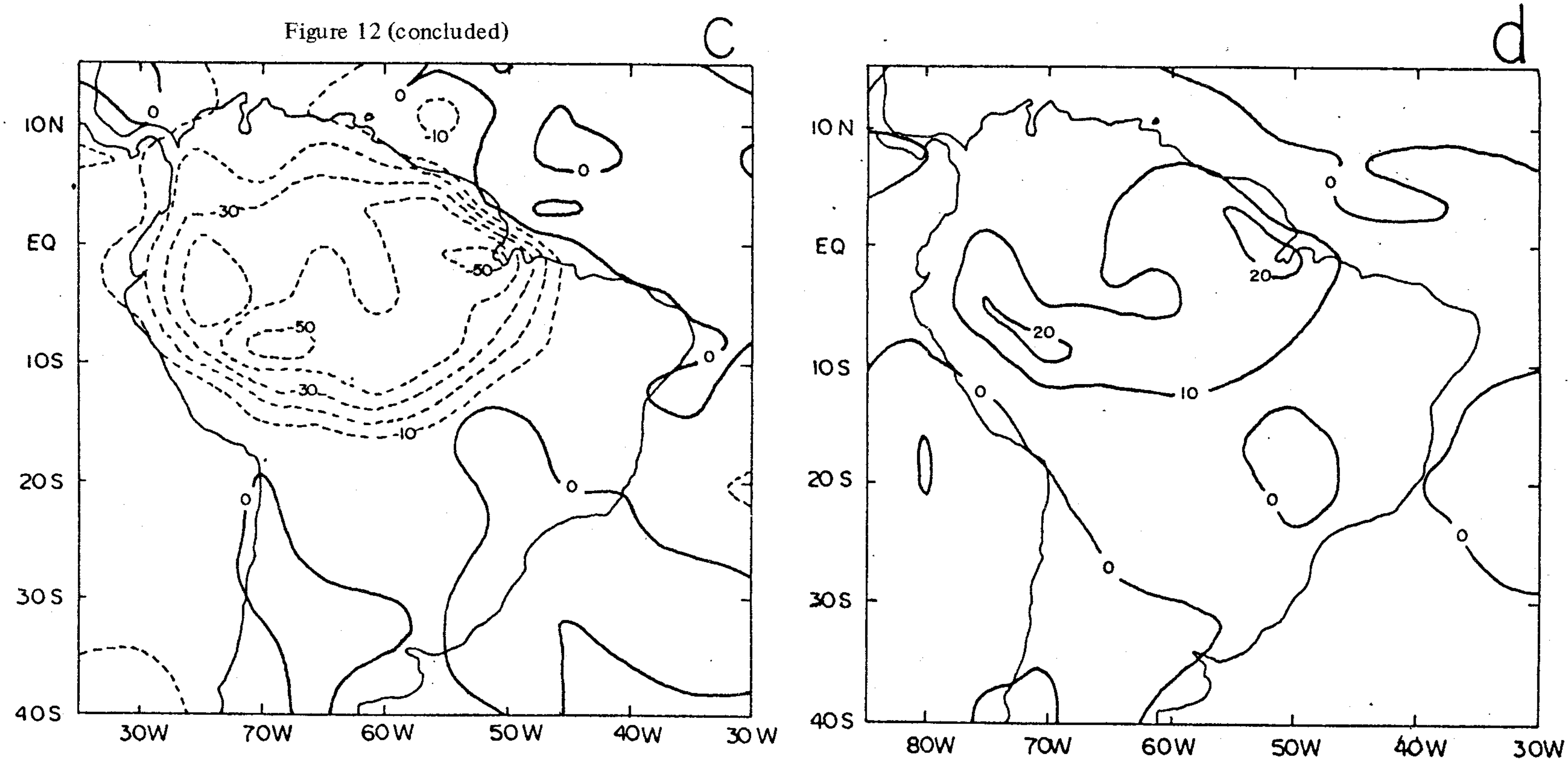


Figure 12 (concluded)



Note: a) Surface temperature in ^{o}C; b) Total precipitation, in mm/day; c) Latent heat flow at surface, in W/m^2; d) Sensible heat flow at surface, in W/m^2 17.

Figure 13

Monthly distribution (January-December) of mean spatial surface temperature, in ^{o}C, for simulations with forests (solid line) and pasture land (broken line). Measurements for area shown in Figure 1[17]

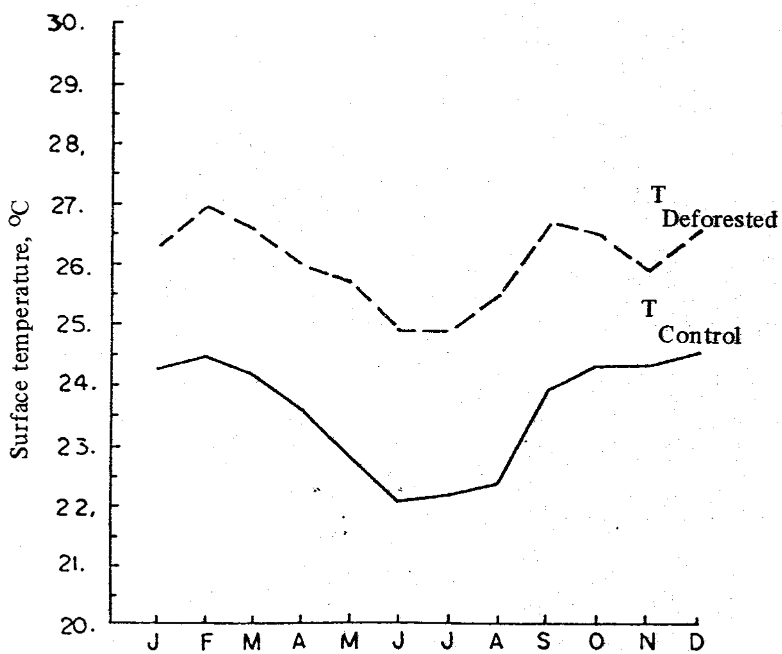
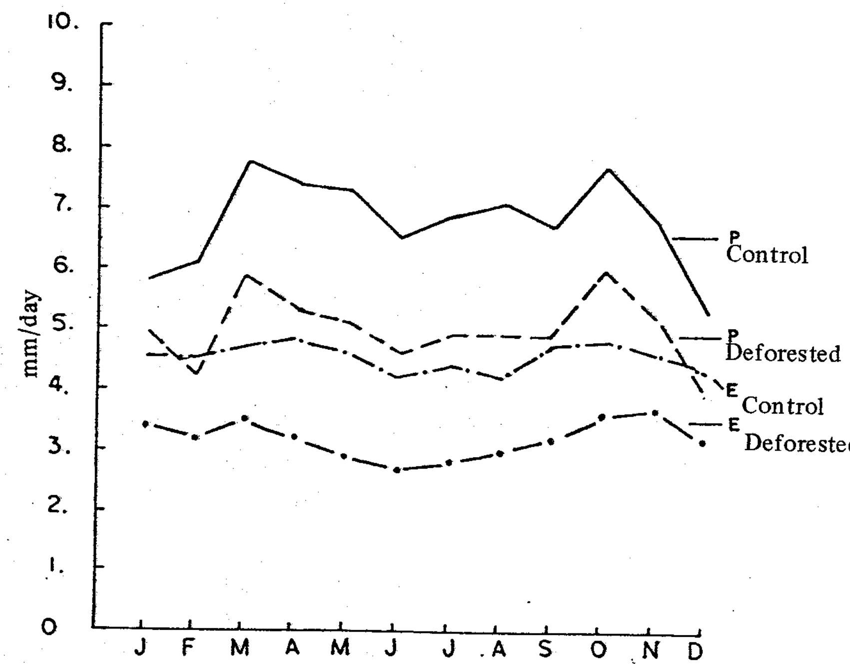


Figure 14

Monthly distribution (January-December) of mean spatial for total precipitation in simulations with forests (P control) and pasture land (P deforested) and for evapotranspiration in simulations with forests (E control) and pasture land (E deforested)



some highways constructed in the watershed between two river basins has caused the channels rising in the upper parts to run dry in dry seasons even in areas where the annual precipitation is over 2 000 mm.

In short, local or regional climatic changes due to deforestation are linked with changes having a relatively short time scale of the order of only a few years.

5. The consequences of global changes for Latin America and the Caribbean

a) Effects on the ecosystems

Global changes, including an increase in the CO_2 in the atmosphere and climatic changes, can affect terrestrial and aquatic ecosystems in various ways. They can influence both changes in the structure of biological communities and the dynamic processes which maintain the existing equilibrium.

Although it is difficult to predict the possible changes with certainty, some responses of the ecosystems can be predicted in a general manner:

a) An increase in temperature will affect the carbon balance of most ecosystems, since temperature influences both photosynthesis and the respiration of organisms in the soil. An increase in soil temperature will increase the total respiration of the soil system, with the liberation of carbon from this reservoir into the atmosphere in the form of CO_2;

b) In certain conditions, an increase in temperature in flooded areas could increase the production and liberation of methane into the atmosphere;

c) In many ecosystems, an increase in temperature will mean faster recycling of nutrients through decomposition caused by soil organisms, giving rise to a tendency towards increased primary production of the ecosystem. In many cases, however, the latter increase will not match the rate of decomposition of organic material in the soil;

d) In natural and agricultural ecosystems, the increase in the concentration of CO_2 in the atmosphere may bring about a higher rate of photosynthetic fixation, especially in the case of plants of the C-3 cycle, which include most of the forest and cultivated species. The influence on plants of the C-4 cycle will be very slight. For these natural or agricultural ecosystems to benefit from the enrichment of the CO_2 in the atmosphere, however, it will be necessary that there should be no limitations on the other factors which determine primary productivity: i.e., there must not be restrictions on the fertility of the soil and the amount of water available;

e) With regard to adaptations in the species of the natural ecosystems, it should be remembered that there is always a process of selection and migration of species to more favourable areas. In the past, during the climatic changes undergone by our planet, these variations were linked with relatively slow processes lasting thousands of years, and there was the possibility of positive adaptation and selection in the sense of greater adaptability. In the case of the changes which must be expected as a result of the present human activities, however, the time scale is only of decades, and it will be very difficult for there to be a process of selection and adaptation, so that many species can simply be expected to disappear;

f) In agricultural ecosystems, it is possible to adapt to climatic changes through the introduction of appropriate cultivation practices and changes in the existing type of agriculture, including changes in the species cultivated. In some cases, however, it is very likely that although this may be technically possible, it will not be economically viable, or can only be achieved at the cost of heavy investments. In some traditional areas of production, the mere change in temperature may make certain crops unviable. The growing of Arabica coffee, for example, is limited by the temperature;

g) Coastal ecosystems will be affected by alterations in the circulation of the oceans, as well as by alterations in the interaction between the continents and the coastal sea water, which can be of vital significance for various species living in the sea and in coastal waters.

b) <u>Variations in the level of the oceans</u>

The level of the oceans, which has probably already risen by approximately 2 cm over the last century (published studies indicate a rise of between 0.5 and 3.0 mm per year during the last 100 years), is bound to keep on rising, and by the end of the next century it will have risen by one metre or even more, depending on the model used for the estimates. If we take conservative values for its rise, then by the middle of next century it will be 20-50 cm higher than at present. The consequences of this phenomenon will have a great impact in various respects, both for the populations of coastal areas and for natural ecosystems such as mangrove swamps and areas at the mouths of large and small rivers.

With regard to large urban population groups, the situation could be catastrophic, and a detailed study of the consequences on a city-by-city basis should be made for Latin America and the Caribbean. There is already evidence of erosion of the beaches, and in the case of a city like Rio de Janeiro, where the sea already swamps the beach-front avenues when there is a storm, an increase of just a few centimetres in the sea level could lead to a most dangerous situation. It is worth emphasizing too that one of the possible climatic changes could be an increase in the number and violence of tropical storms. If this really takes place, together with a rise in the levels of the oceans, even quite modest increases could cause severe problems.

This situation applies to many population centres: in the case of Brazil mention could be made of Porto Alegre, Santos, Rio de Janeiro, and some areas of Bahia, Recife and Belém as places where detailed studies are urgently called for.

In addition to the implications for urban areas, it is important to bear in mind the problems of port areas, since changes in the level of the ocean could bring alterations in the water dynamics of coastal areas which could compromise the operations of existing ports.

The rise in the level of the oceans and the consequent choking of the mouths of rivers will increase the areas flooded or at risk from flooding on many large and small rivers all along the coast of Latin America and the Caribbean. If, in some of these coastal areas, there is an increase in precipitations (as is indeed expected), the already critical situation could become absolutely disastrous. Typical examples are the Ribeira Valley, south of São Paulo, and the rivers in the Recife area.

In the case of specific areas of production, especially of shrimps in coastal areas, the problem could also be quite serious, since any alteration either in the level of the oceans or the water quality could affect the production capacity of these man-made systems. Among the most important such areas in Latin America are those producing shrimps on the coast of Ecuador.

c) <u>Changes in the water balance</u>

With regard to changes in water régimes, including variations in the amount of soil moisture, it is evident that those regions where there is already a deficit of such water may very well find themselves in an even more critical situation. Thus, with regard to the forecasting of agricultural production, special studies should be made envisaging the expansion of irrigated areas. More studies are needed, however, in order to be able to make more detailed recommendations. It will be particularly important to determine not only the increase in the annual mean temperature but also its seasonal variation associated with seasonal variations in the humidity of the air and precipitations.

d) The problem of Amazonia

Specifically in the Amazon region, there are two forces acting on the internal changes in the water and thermal régimes, due to deforestation and changes brought about by the greenhouse effect. In the present study, we can say that the first-mentioned factor tends to lead to a drier climate with a longer dry period and higher temperatures, occurring a few years after the initial changes. The second factor also indicates a rise in temperature, but probably with an increase in precipitations. The models are still not completely reliable, but they indicate a possible increase in soil moisture in a first phase if there is a doubling of the greenhouse effect, but a deficit in the water available in the ground if this effect is quadrupled. Within the limits of present knowledge, it is difficult to predict the synergy of these two tendencies, since the second one will take place over a time scale of several decades.

At all events, the maintenance of the forests is advisable for various reasons, since it obviates the first effect, which will inevitably lead to a drier and hotter climate. Furthermore, it will help to slow down the greenhouse effect and reduce possible tendencies towards change.

In this respect, a programme designed to reduce or prevent deforestation and restore forests in areas which have already been degraded would be of priority importance for the Amazon region.

e) The problem of the Wider Caribbean (the Wider Caribbean Basin)

The Wider Caribbean comprises 33 nations and territories ranging from the coastal areas of the countries on the Gulf of Mexico and the Caribbean Basin to the Guianas, including all the Caribbean islands and the Bahamas (see figure 15) (15).

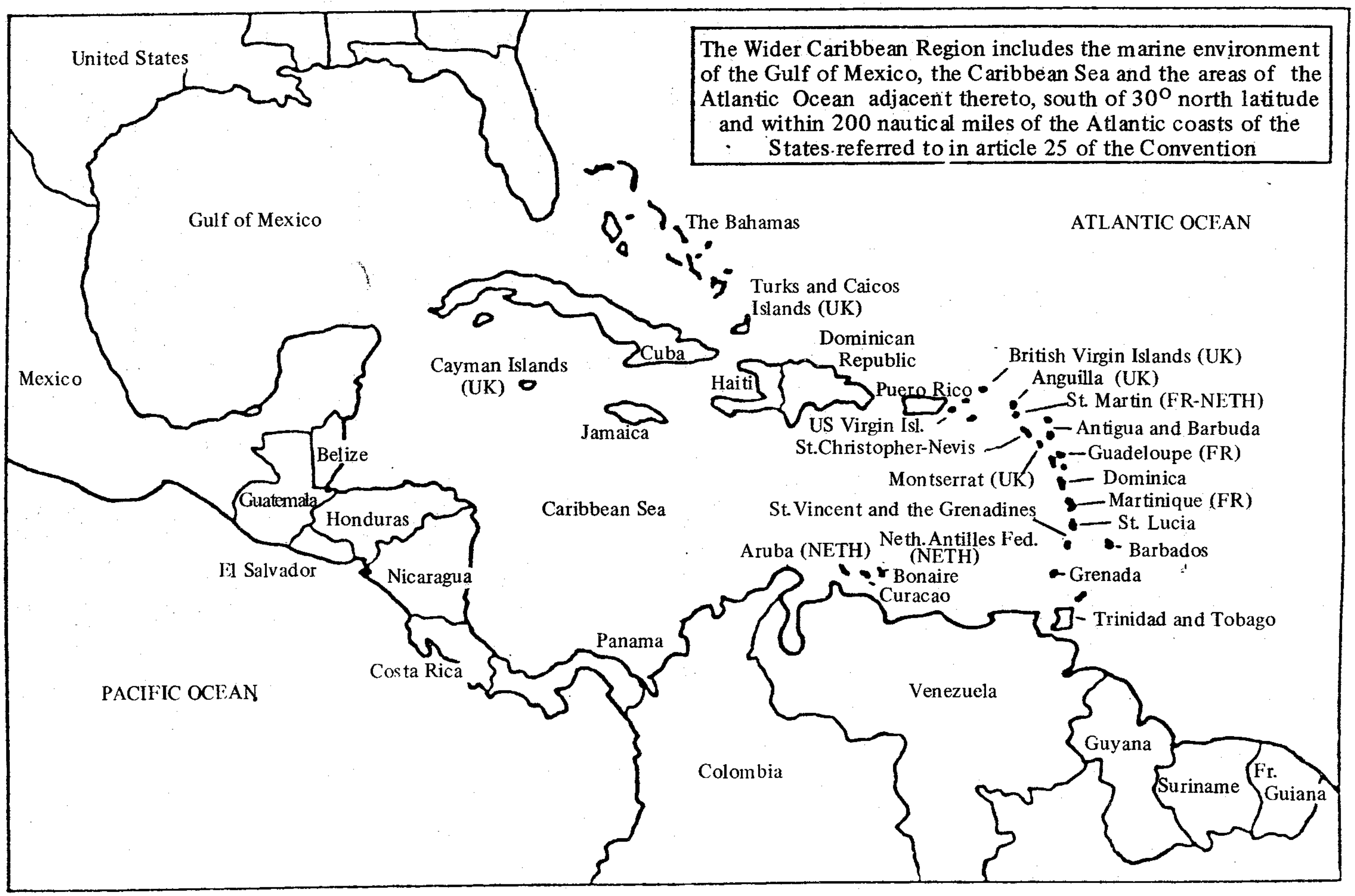
This subregion has a wide variety of land and marine ecosystems, as well as great cultural diversity due to its colonial past.

In addition to the different ecosystems, the subregion has a wide variety of different ethnic groups and cultures reflecting the influence of various developed countries. What the countries and territories of the Caribbean have in common are the regional seas of the Gulf of Mexico and the Caribbean and different degrees of economic difficulties, except in the case of the United States.

This subregion already displays innumerable environmental problems which will be further aggravated by the probable climatic changes in the region and the rise in the level of the oceans. Among the most important problems are:

Figure 15

MAP OF THE WIDER CARIBBEAN REGION



Note: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

a) Deforestation, with increased soil erosion and declining productivity of the agricultural production systems. With the probable increase in temperatures and precipitation, these problems can only become still more serious;

b) The unplanned growth of cities, even on low-lying land subject to flooding. With the probable increase in the number of hurricanes and the rise in the level of the oceans, these areas will become even more vulnerable, bringing serious problems for the communities living there;

c) There is also now a growing problem of destruction of areas producing fish and shellfish, due to various kinds of contamination. Changes in ocean dynamics can have influences that reinforce those already observed, although at the moment it is difficult to predict the exact areas affected or the intensity of the changes;

d) There are already obvious problems of beach erosion due to the illegal and technically unsatisfactory removal of sand and the destruction of coral reefs. The rise in the level of the oceans and the probable increase in the intensity of meteorological phenomena, which could lead to bigger waves, together with the likelihood of more frequent hurricanes, are potential dangers that must be borne in mind;

e) In addition to the above-mentioned problems, there is also a growing number of accidents involving contamination with dangerous chemicals or petroleum and its derivatives. The increase in meteorological activity (increase in fluctuations of temperature, humidity and precipitations), as well as the greater likelihood of hurricanes, could make the problems of contamination of the sea and beaches even more critical.

f) <u>Highland plateaus</u>

Mountainous highlands cover an area of 3 990 000 km^2 (8% of Latin America and the Caribbean) and extend from the Sierra Madre to the Andes. Highland plateaus with altitudes generally over 1 500 metres occupy around 598 900 km^2 of these formations (18). On these plateaus which are productive ecosystems great population centres and agricultural areas have grown up (Mexico City, San José, Costa Rica, Guatemala City, Bogotá, Quito, La Paz, Mérida, etc.).

Many of these areas had productive forests of conifers, podocarpus or cedars which protected the soil against erosion. Because of the geomorphological characteristics and the style of development, one of the most serious environmental problems encountered is that of soil erosion. It is estimated that 50% of the land with agricultural potential suffers a serious process of erosion at rates of over 30 tons/hectare per year.

The rural population of these regions is estimated at between 45 and 55 million inhabitants.

The main ecological problem with medium and long-term economic consequences is the rate of soil erosion, which not only reduces the agricultural production potential but also represents a growing danger as regards the silting-up of electric power generation dams. Although it is impossible to determine in detail the changes that will take place as a result of the climatic variations due to the greenhouse effect, it is expected that in some areas, especially on the plateau north of Mexico City, there may be temperature increases of up to 4°C, with a marked reduction in available soil moisture. The regions between latitudes 3° North and 10° South will probably suffer smaller climatic changes, but in view of the possible mean increase in the humidity of the air and hence of precipitations, it is possible that the problems of erosion may be aggravated even though in some areas there may be a heightening of the soil moisture deficit through the increase in evapotranspiration.

g) The humid pampas

The ecological region known as the Pampas covers an area of 870 000 km^2 in the southern part of South America, of which 440 000 km^2 is in Argentina and 426 000 km^2 in Uruguay (19). The relief is flat or gently rolling, and there are no forest formations except for woods along some of the rivers which form ciliary forests. The soils are generally deep and rich, and because of their natural characteristics of relief and fertility these are the areas of greatest agricultural production in these countries, so that they are subject to growing exploitation pressures which could lead to a disturbance of the natural equilibrium. Such disturbance is due in particular to inappropriate soil management and intensive farming practices in the growing of cereals.

The most serious existing environmental problems are soil erosion, loss of fertility through the degradation of organic matter and compactation, and the contamination of surface water resources with substances used in agriculture.

It is obvious that the economic activities carried on there are in equilibrium and derive from the existing climate, geomorphology and soil. Some models predict an increase of up to 4°C in the temperature in some regions, with an increase in precipitation.

It is difficult to know for sure if there will be a deficit of soil moisture, but the increase in precipitation will probably make up for the rise in temperature. However, the increased precipitation will alter or increase the existing ecological problem due to erosion. It is difficult to forecast if the present agricultural activities will be affected by this.

6. How the governments of the various countries and regional bodies should act in order to seek the right decisions

The basic purpose of all the international discussions on problems of global changes, especially the possible climatic changes, which could speed up in the coming decades, is to find solutions which will make it possible to reduce or slow down the changes that are taking place in the chemical composition of the atmosphere.

In the light of what was stated in the preceding chapters, it is obvious that in order to attain these objectives it is necessary to reduce the emissions of CO_2, methane, N_2O and CFCs.

Leaving aside the problem of CFCs, which is already covered by the Montreal Protocol, the approach would generally speaking be as follows (2):

a) To reduce emissions of CO_2 from the burning of fossil fuels, which is responsible at present for the emission of 5.6 Gton of carbon per year;

b) To reduce or completely halt deforestation, especially in tropical regions, which is currently responsible for the emission of around 1-3 Gton of carbon per year;

c) To implement a vigorous programme of reforestation in order to withdraw CO_2 from the atmosphere by fixing it in forest systems and the soil.

The countries of Latin America and the Caribbean must determine with the necessary precision their own contributions to these global changes, by analysing the various sectors of human activity and their current demands.

Reducing the emission of CO_2 due to the burning of fossil fuels will involve a change in the most common energy sources currently used for many purposes, namely, petroleum and coal.

In many countries, as in Brazil, most of the electricity comes from hydroelectric stations, but in some regions of the country there is already a tendency to install thermoelectric stations using petroleum derivates. In the study in question, it will be necessary to prepare energy matrices for each country and predict their tendencies for several decades ahead in the light of various economic and social development scenarios.

Everything indicates that the people of the Latin American and Caribbean countries will desire and seek the same level and style of development as the currently developed countries of Europe and North America. This tendency will inevitably bring an increase in energy consumption, which so far is being supplied by hydroelectric power and fossil fuels.

Thus, even though the present contribution of the countries of Latin America and the Caribbean to the greenhouse effect through the use of fossil fuels may only be small, it is to be expected that if the present conditions continue, this contribution will keep on growing.

With regard to alterations due to changes in land use, including deforestation, the problem is deeply rooted in the distribution of land and the processes of utilization of renewable natural resources. Throughout the entire history of colonization, both before and after the independence of the countries, the common feature --with only slight variations-- was deforestation in order to grow annual or perennial crops. The existence of great latifundia and the intrinsic difficulties in the implementation of agrarian reform have caused governments to encourage the colonization of the last remaining forest reserves, whether in great ecosystems like Amazonia or in small wooded areas such as those of the Caribbean islands.

In analysing this problem, every country will have to determine its own level of responsibility in contributing to the global changes and analyse the economic and social implications of the attitudes that must be taken.

On the basis of the information deriving from the energy matrix and its trends and the changes in land use and their local and global consequences, as well as the economic and social implications involved, every country or regional body will have to establish a plan of operations to serve as a basis for future negotiations and orient its own development on a sounder basis for ensuring more ecologically appropriate conditions for its people.

With regard to changes that affect the whole world, such as the rise in the level of the oceans, the importance of the study for each country will depend on the problems it is likely to suffer from those changes.

For taking the final decisions, it will be necessary to make a detailed study of the regional implications of the global changes. This will only be possible if there is a knowledge of climatic changes and their effects on agricultural and urban activities based on reliable regional models, which are as yet not available. The approximations and studies which could provide the most useful information in this respect will be those based on the most recent climatic events and their consequences for economic and social activities.

Studies of episodes such as heavy rains, floods, prolonged droughts, hurricanes and high winds, cold spells, hailstorms, etc., can easily show the importance of climatic changes for the economy and living conditions of small communities and even whole countries.**/

On the basis of this information, and in the light of the predictions provided by the very cautious interpretation of global models for the areas in question, some guidelines could emerge which could indicate the attitudes that should be adopted by governments.

In addition to the attitudes already referred to, it is necessary to decide on the possible scenarios for the increase in greenhouse gases, the possible changes involved, and the attitudes governments may take in the light of these scenarios.

Recently, the EPA (1989) (1) analysed scenarios for four world development trends:

i) A slowly changing world (SCW). This scenario is based on slow growth of the gross domestic product, rapid growth of the present population, a minimal increase in energy prices, slow technological change, an increase in deforestation and low participation by the countries in the implementation of the Montreal Protocol;

ii) A rapidly changing world (RCW). This scenario foresees rapid GDP growth, moderate population growth, small increases in energy prices, rapid improvements in technology, moderate deforestation, and active participation in the Montreal Protocol;

iii) A slowly changing world, but with the application of stabilization policies (SCWP). This scenario is based on slow GDP growth, rapid growth of the present population, a minimal increase in fuel prices, a rapid improvement in efficiency, a moderate increase in the contributions of biomass energy and solar energy, rapid reforestation, and the elimination of CFCs;

iv) A rapidly changing world, with the application of stabilization policies (RCWP). This scenario foresees rapid GDP growth, moderate population growth, a small increase in energy prices, a rapid increase in efficiency, rapid growth in the use of

---

**/ The meteorological episodes associated with the "El Niño" phenomenon are an excellent example of the economic and social implications of climatic changes.

solar and biomass energy, rapid reforestation, and the elimination of CFCs.

For each of these scenarios, there are different responses as regards temperature increase and the associated climatic changes. It is important that the developing countries of Latin America and the Caribbean should analyse these scenarios in order to see the positive and negative aspects of their implementation and to suggest alternatives better adapted to their economic and social realities.

7. Conclusions and recommendations

On the basis of the information briefly set forth in the preceding chapters, a number of conclusions may be drawn (some of them only of a preliminary nature) and some suggestions may be made to regional bodies and to the countries of Latin America and the Caribbean.

a) Conclusions

i) Human activities are producing a number of gases which, because of their amount and nature, are altering the chemical composition of the Earth's atmosphere. Among the most important of these gases are CO_2, CH_4, CFCs and N_2O.

ii) The production of these gases is steadily increasing, and the capacity for their absorption by natural self-regulation processes through the bio-geochemical cycles is not sufficient to maintain the values which existed before the industrial era.

iii) There is experimental evidence that in the present century the temperature of the Earth has increased by 0.6°C, and that it is extremely likely that this effect has been caused by the increased anthropogenic changes in the atmosphere.

iv) Mathematical simulations using models of the general circulation of the atmosphere predict that if the concentration of CO_2 is doubled, there will be an increase of around 1.5-4.5°C in the temperature of the Earth, with the increase being greater in the polar regions and less marked around the equator.

v) This temperature increase will cause a rise of the order of 1-2 metres in the level of the oceans by the end of the next century. At the moment, the rate of increase is estimated to be 1 cm/year.

vi) These climatic changes and the rise in the level of the oceans could bring changes in the coming decades in the natural and agricultural ecosystems of Latin America and the Caribbean.

vii) Although most of the contributions causing these changes come from the developed countries, Latin America and the Caribbean are also helping to accelerate this process. The biggest contribution of the latter countries currently comes from deforestation, but depending on the economic and social development style there could be increasing contributions from other sources, especially the use of fossil fuels.

viii) In addition to the global changes, various ecosystems of Latin America and the Caribbean --especially the humid tropical forests-- are undergoing changes that can themselves bring about profound alterations in the water and energy cycles of those ecosystems. These changes are intimately linked with the rates of deforestation and the land areas involved.

ix) At present, there is great uncertainty in the attempts to estimate the contributions made by each of the countries of Latin America and the Caribbean to the changes in the chemical composition of the atmosphere. This difficulty is because of the lack of continuous monitoring and the fact that there are no suitable estimates of the biomasses of the affected ecosystems and the rates of conversion of the carbon of the biosphere and the soil into the atmosphere.

x) The climatic simulation models currently in use generate information on areas of 5° x 5°: that is to say, areas of the order of 250 000 km^2 on average.

Thus, the information available at this scale does not permit detailed study of ecosystems unless relatively large areas are considered. Consequently, while trends of change can be determined for large regions such as Antarctica, the tropics, etc., the present level of precision in modelling does not permit a picture to be gained of the effects on specific ecosystems.

b) <u>Recommendations</u>

In order to take better precautions to prepare to tackle the climatic changes of anthropogenic origin which are already occurring and to minimize their effects, the following recommendations may be made to regional bodies and to the countries:

i) Surveys and projections should be made through the preparation of energy matrices for the current energy sources and the trends foreseeable in the coming decades.

ii) Realistic surveys should be made of the rates of deforestation and the changes occurring in natural ecosystems.

iii) More intensive studies should be made so as to gain a better knowledge of the bio-geochemical and water cycles of the natural and agricultural ecosystems.

iv) Efforts should be made to determine, in the light of the various scenarios for the coming decades, what measures and attitudes could be adopted by the countries, both individually and throu_h programmes of regional and intergovernmental collaboration.

v) Special emphasis should be given to the study of the energy sources to be used in development programmes.

vi) In view of the big contribution of the tropical countries to the increase in CO_2 and deforestation, consideration should be given to programmes and actions designed to reduce the rate of deforestation and increase the rate of reforestation.

These programmes would bring various benefits in addition to the reduction of the greenhouse effect, including in particular the preservation of biodiversity, soil conservation, maintenance of the water and energy balances, conservation of hydroelectric potential, and an increase in the wealth of the country through growth in the stocks of wood and pulp.

The aim of the reforestation programme would be the transfer of CO_2 from the atmosphere to the biosphere, while it would also permit proper management of energy sources and coal stocks.

vii) Working groups should be set up to ensure technical and scientific development commensurate with the consequences of the global warming of the atmosphere. These groups must keep their governments supplied with the latest information needed to permit the adoption of preventive and corrective administrative measures.

8. Final remarks

There are researchers who maintain that the changes discussed in this article could be even greater, more rapid, and consequently more catastrophic, especially if measures are not taken to reduce or stabilize the current levels of emission of greenhouse gases. This view is based on the belief that there are possible feedback processes, not as yet well understood, which could activate various processes involved in the carbon cycle. One example of this is that an increase in soil temperature in areas of the Northern Hemisphere which are currently very cold could lead to a sharp increase in soil microbial activity, causing the release of CO_2 into the atmosphere in amounts beyond the expected levels. Another aspect is related with possible rapid changes in the ocean/atmosphere interaction, with the liberation of large amounts of CO_2 through the heating of the ocean waters. On the other hand, there are other authors who hold more conservative views and maintain that the models in use are not yet complete enough to predict the effect of clouds on the final radiation balance, since increased cloudiness would mean the reflection of the sun's rays (a change in the Earth's albedo, with negative feedback).

The ideas and figures presented in this article, however, represent the most commonly held and generally accepted findings of the scientific community, discussed at innumerable scientific congresses attended by specialists from different areas of human knowledge.

References

(1) Daniel Lashof and Dennis Tirpak (eds.), Policy Options for Stabilizing Global Climate. Draft Report to Congress. Executive Summary, Environmental Protection Agency (EPA) of the United States, February 1989.

(2) G.M. Woodwell, "The warming of the industrialized middle latitudes 1985-2050: causes and consequences", Climatic Change, vol. 15, No. 1-2, Kluwer Academic Publishers, October 1989.

(3) Daniel Lashof and Dennis Tirpak (eds.), op. cit., vol. 1.

(4) J.D. Mahlman, "Mathematical modeling of greenhouse warming: how much do we know?", Global Change and Our Common Future, National Research Council, Washington, D.C., National Academy Press, 1988.

(5) R.A. Houghton and others, The Flux of Carbon from Terrestrial Ecosystems to the Atmosphere in 1980 due to Changes in Land Use: Geographic Distribution of the Global Flux, Tellus 39B, 1987, pp. 122-139.

(6) R.L. Victoria and others, "A Amazônia brasileira e seu papel no aumento da concentração de CO_2 na atmosfera", 1990 (in the press).

(7) J. Goldenberg, "Amazônia and the greenhouse effect", Anais do Simpôsio "Amazônia: Facts, Problems and Solutions", July 31-August 2, 1989, São Paulo University, mimeo.

(8) Instituto de Pesquisas Espaciais (INPE) Avaliação da alteração da cobertura florestal na Amazônia Legal utilizando sensoriamento remoto orbital, Brazil, 1989.

(9) Dennis Mahar, Government Policies and Deforestation in Brasil's Amazon Region, Washington, D.C., World Bank, 1989.

(10) A.W. Setzer and M.C. Pereira, "Amazon Biomass burning in 1987 and their atmospheric emissions", Science, 1989 (in the press).

(11) Philip Fearnside, A ocupação humana de Rondônia. Impactos, limites e planejamento, Relatôrio de pesquisa, No. 5, Programa Polonoroeste, 1989.

(12) Eneas Salati and José Marques, "Climatology of the Amazon region", The Amazon: Limnology and Landscape. Ecology of a Mighty Tropical River and its Basin, Harald Sioli (ed.), Dordrecht, The Netherlands, Dr. W. Junk Publishers, 1984.

(13) Eneas Salati and others, "Deforestation and its role in possible changes in the Brazilian Amazon", Global Change and Our Common Future, National Research Council, 1989.

(14) A. Handerson-Sellers, "Effects of change in land use on climate in the humid tropics", The Geophysiology of Amazônia, R.E. Dickinson (ed.), New York, John Wiley & Sons, 1987.

(15) United Nations Environment Programme (UNEP), Implications of Climatic Changes in the Wider Caribbean Region, CEP Technical Report, No. 3, 1989.

(16) Food and Agriculture Organization of the United Nations (FAO), Relatório da FAO, 1988.

(17) C. Nobre; J. Shukla and P. Sellers, Impactos climaticos do desmatamento da Amazônia, São José dos Campos, São Paulo, Instituto de Pesquisas Espaciais (INPE), 1989.

(18) L.A. Ferrate, personal communication, 1989.

(19) Ruan J. Novara, personal communication, 1989.

(20) R.A. Houghton and others, "Net flux of carbon dioxide from tropical forests in 1980", Nature, No. 316, 1985.