Johannesburg

World Summit on Sustainable Development

2002

What is at stake?

What contribution will scientists make?

Author acknowledgements

We would like to thank the Ministry of foreign affairs, in particular
Madame Beton-Delègue, Director of scientific, university and research cooperation;
Mr. Pierre Colombier, Assistant director of research;
Monsieur Yves Mabin, Had of the Written material and media library division;
Monsieur Alain Leplaideur, Had of the Research project:
— for having given us the opportunity to produce this multidisciplinary contribution to the understanding of the stakes of the world summit on sustainable development,
— and for having given us free reign in terms of conception, thought and style.
This work, published under the aegis of the Ministry of Foreign affairs, belongs to its authors. As such, the Ministry is in no manner responsible for its contents, which are the sole responsibility of the authors.

Philippe Cury and Pierre Fréon, research directors at the IRD, Michel Trometter, senior research scientist at the Inra, Bruno Locatteli, research worker at the CIRAD, and Cyril Loizel of the National Forestry Office have kindly provided us with short articles on, respectively, fishery, genetic resources and coal mines. We extend our kind thanks.

Nicolas Merveille, who acted as technical assistant.

Anne Parian of the Association for the diffusion of French thought, and editor of the work, deserves particular thanks. Delays and imperfections in our work did nothing to disturb her perfect diplomacy and steadfast professionalism. Thank you, Anne.

Ministère des Affaires étrangères.
Direction générale de la coopération internationale et du développement.
Direction de la coopération culturelle et du français.
Division de l'écrit et des médiathèques.

Direction de la coopération scientifique universitaire et de recherche.

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Johannesburg 2002 **World Summit on Sustainable Development**

What is at stake?

What contribution will scientists make?

Preface Born of a collective awareness of the fragility of the planet, sustainable development is a major concern of this new century. It concerns the capacity of our human societies to satisfy their present needs without compromising those of future generations. It questions models of development promoted by the countries of the North, who are the originators of fundamental technological advances, but also of serious environmental problems. It calls into question the ways in which we organize control of the evolutions and the complex interactions existing between man, the production and exchange activities he has generated, and natural resources, which are limited. If the right choices are to be made, the processes in motion must be understood. Science is being asked to locate the real risks, to inspire opinions, and to orient decisions. That task is not an easy one, all the more since in this area, scientific uncertainty predominates, leaving broad areas for debate among specialists. French scientists are contributing actively to the evolution of knowledge and to the international debate on these topics, whether as members of international committees of experts, as actors participating in the thinking expressed upstream and downstream of international conferences, or as researchers involved in the implementation of sustainable development in France, or in partnership with the countries of the Southern Hemisphere.

The idea of this book is to present the contributions of French scientists on certain key topics. In accessible language, they present the state of advancement of research on the subjects of biodiversity, climatic change, desertification, and the underlying economic and social issues. Their work shows their concern for providing enlightened information to the public while adhering to the scientists' code of ethics: Judgment by one's peers; delineation of truth and of controversy; clear separation between expression of the state of the art and personal opinion.

The book is the work of leading figures from several scientific institutions – universities, the Cirad, Cnrs, Inra, Ird, etc. – and many disciplines, who carry on dialogue among themselves in order better to prepare the reader for judgment. Throwing light on the opinions of others, providing readers with the means of forming opinions of their own, and avoiding imposing any single doctrine on them – such is the authors' objective. To achieve this goal, they have traced a path back through the stages in the process of international awareness over the past forty years, ending with the present and the principle of "sustainable development." In so doing they speak in favor of the establishment of new modes of exchange within a picture of globalization that would be humanized and regulated – a need expressed by the President of the Republic at the conference in Monterrey in March 2002. This book contributes to the new debate set to begin at the World Summit on Sustainable Development in Johannesburg.

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Robert Barbault Born in 1943, Robert Barbault is Professor of Environmental Studies at the Université Pierre et Marie Curie. He directs the University's Institut Fédératif d'Écologie Fondamentale et appliquée and is a member of the Conseil National pour la Science, a member of the academia Europa, and President of the French committee on the Unesco "Man and the Biosphere" program. He chairs or participates in several scientific commissions. A specialist in population dynamics and vertebrate populations, he is deeply involved in the development of research on the dynamics of biodiversity and has contributed to the creation of the first French national program in that area, closely linked to the implementation of the international program Diversitas, in which he is involved. He is the author of numerous publications and books.

Antoine Cornet Born in 1945, Director of Research at the Institut de Recherche pour le Développement (IRD), he is an engineer-agronomist and a doctor-engineer in General and applied Environmental Science. A member of the scientific council of the French Fund for the World Environment, he is also Chairman of the French scientific committee on desertification and France's representative on the Committee on Science and Technology of the Conference of the Parties to the Desertification Convention. He has directed the Department of Ecosystems, Environment, and agriculture of Orstom (now IRD) and directs the Ird center in Montpellier. He is the author of numerous contributions on aridity and desertification.

Jean Jouzel Born in 1947, holder of a Doctorate of Science (1974), and Director of Research at the CEA, Jean Jouzel has spent the majority of his career at that institution. He is Director of the Institute Pierre-Simon Laplace (IPSL), which concentrates on research on the global environment, and President of the Institut Polaire Paul-Émile Victor (IPEV). He participated as principal author in the second and third reports of the International Panel on Climate Change, of which he is an officer and Vice-President of the scientific working group. He is the author of nearly 250 publications and a member of numerous international committees. His work, largely devoted to the reconstitution of the climates of the past based on the study of ice in the antarctic and Greenland, has been recognized by prizes and distinctions including the Milutin Milankovitch Medal, awarded by the European Geophysical Society, and a prize from the academy of Sciences.

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Ignacy Sachs Born in 1927, Ignacy Sachs was educated in Brazil, India, and France. He is a socioeconomist and has been Director of Studies at the École des Hautes Études en Sciences Sociales since 1968. He participated, with Maurice Strong, in the preparations for the Stockholm and Rio de Janeiro conferences. Among his principal works in French are: La Découverte du tiers-monde (1971), Pour une économie politique du développement: études de planification (1977), Développer les champs de planification (1984), Quelles villes, pour quel développement? (1996), and L'Écodéveloppement (1997).

Jacques Weber Born in 1946, Jacques Weber is an economist and anthropologist. He was a researcher at Orstom (now Ird) from 1971 to 1983, Director of the Department of Economics at Ifremer from 1983 to 1992, and has been in charge of a research unit on management of resources and the environment at the Cirad since 1993. He has conducted and led research in numerous tropical countries and in Europe. He currently directs the French Institute for Biodiversity. A lecturer at the École des Hautes Études en Sciences Sociales and the University of Paris X-Nanterre, he is a member of several national and international scientific committees, and Vice-President of the French Committee of the Unesco "Man and the Biosphere" program. His principal area of interest concerns the interactions between social dynamics and natural dynamics in the field of biodiversity and renewable resources. He is the author of 80 publications in reviews, collective works, and congress reports, and many research and consultancy reports.

Presentation It is generally agreed that the World Summit in Johannesburg could also be called "Rio +10." That name, though accurate from the point of view of the calendar, can lead to serious confusion. Some may think that the international community waited until 1992 to discuss the relationship between development and the environment. It might be more appropriate to speak of "Stockholm +30," since Stockholm listed, in 21 points, the first measures to be taken as the foundation for later discussions. And also because Stockholm produced the first detailed analysis of what had been looked upon only sector-by-sector until then: The environment. Moreover, because the links between development and the environment were analyzed in depth there for the first time.

A major historic event became the source of an almost traumatic awareness of the "fragility" of the Earth's ecosystem: The Apollo mission's landing on the Moon in 1969. A world that until then had been seen as vast could suddenly be observed from the Moon as a "fragile" blue sphere floating in the black immensity of space. On that day began the history of a world now perceived as being limited; like a "spaceship." What has happened since then? The energy crisis of 1971-73, called the "first oil crisis," generated anxiety about stocks of oil, considered as being limited to some thirty-odd years of worldwide consumption. The Club of Rome published its famous report "The Limits to Growth" in 1972. In 1971, the United Nations organized its first conference on the environment in Founex.

The movement was launched, and would lead, from one conference or convention to another, to Rio de Janeiro in 1992: Stockholm, Nairobi, and Cocoyoc are the major stages along the way. They interact with the signing of international conventions on wetlands, drought, biodiversity, the climate, and ozone-depleting gases.

At Rio de Janeiro, the world provided itself with a real program, Agenda 21, which detailed the measures to be taken in order to move towards integration of the environment and development – towards "sustainable" development. Conventions were signed, including the Convention on Biological Diversity, and the international community set up a financial instrument: the Global Environment Facility (Gef).

Since Rio, much has happened. International, multidisciplinary groups of experts have been set up to refine the analysis of the dynamics at work on the planet, one of the most famous of which is the International Panel on Climate Change (Ipcc). Instrumentation has evolved considerably, resulting in extremely precise and credible measurements. It has also been seen, through various controversies, that even those measures that are best prepared for and accepted can be the object of divergent interpretations. Major innovations have taken on considerable importance, the first among them being genetic engineering, which has inspired many hopes and just as many fears.

New concepts have appeared. Sustainable development was defined internationally in 1987, in the report of the World Commission on Environment and Development, known as the Bruntland Report, after its president. Another concept, the precautionary principle, appeared in 1987 in the Ministerial Declaration of the Second International Conference on the Protection of the North Sea: It was to be important as the justification for political decisions where a situation of scientific uncertainty prevailed. Biodiversity is also a concept that existed prior to Rio but which gained political legitimacy at the 1992 Conference, with the International Convention on Biological Diversity. Finally, one acronym has taken on major importance in the debates surrounding sustainable development and biodiversity: Gmo, for Genetically Modified Organism. These existed well before Rio, but have exploded in the decade separating Rio 1992 from Johannesburg 2002. Social and political issues have also taken on major importance. Poverty has increased from one structural adjustment to another, from one crisis to another, from one collapse to another. "Thirty years have passed since the signing of the United Nations Charter launched the effort to establish a new international order. Today that order has reached a critical turning point. Its hopes for creating a better life for the whole human family have been largely frustrated. It has proved impossible to meet the 'inner limits' of satisfying fundamental human needs. On the contrary, more people are hungry, sick, shelterless and illiterate today than when the United Nations was first set up." This work is being edited in 2002, fifty-six years after the signing of the Charter of the United Nations, and there is nothing that needs changing in this first paragraph of the Cocoyoc Declaration of 1974. The events of September 11, 2001 hang over preparations for the Johannesburg Summit and everyone is aware that the developed countries cannot – can no longer – come to a worldwide summit held in 2002 and get away with making non-binding declarations. To paraphrase the title of a recent book by Gérard Winter, "the poor are impatient."

What is the nature of this book, whose vocation is to aid readers in understanding the major issues, both in the foreground and in the background, of the Johannesburg Summit? First, it is the result of a choice. Demographics has been cited from 1970 on as being responsible for environmental degradation, based on strictly Malthusian reasoning: Since the population is growing more quickly than the "carrying capacity" of the planet can handle, "galloping" (sic!) demographics will mean the end of humanity. A great many works have been published on this theme, and they are mentioned in the general bibliography. We have chosen not to deal with the question as such in this book. Not out of disinterest or minimization, but because demographics is dealt with in its implications in terms of resources, access to resources, biodiversity, the struggle against drought, climatic change, and, above all, poverty. The issues we have chosen to deal with are the following: Biodiversity, the very foundation of life on Earth, is a major issue today, due to the threats that hang over the planet's future. Robert Barbault explains what is at stake. Climatic change is presented by Gérard Mégie, President of the Cnrs and a professor at the Université Pierre et Marie Curie, and Jean Jouzel, Director of Research at the Institute Pierre-Simon Laplace. The fight against desertification and issues relating to water are the subject of the article by Antoine Cornet, Director of Research at the Institut de Recherche pour le Développement and Chairman of the French Commission to Combat Desertification. The economic and social issues and the stages of international awareness are the subject of the first chapter, by Jacques Weber, a researcher at the Cirad and Director of the French Institute of Biodiversity.

The book ends with a consideration of what is expected of Johannesburg, by Ignacy Sachs, Director of Research at the École des Hautes Études en Sciences Sociales and scientist secretary of the Rio de Janeiro conference. A glossary of the principal terms used in the publications on sustainable development and the environment is provided for the reader following these contributions. There is an annotated bibliography, a selection of World Wide Web sites, and audiovisual sources for readers who wish to continue their study.

Economic and Social Issues in Sustainable Development

Jacques Weber
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Introduction.

Public opinion and the States existing on our planet have slowly become aware of the importance of their interdependence and their common dependency on the future of the Earth. It has taken more than thirty years, more than a generation, for global dynamics – outside the control of human goodwill and the power of the States as separate entities – to be recognized and taken seriously, and to become the object of decisions at the planetary level. This slowness becomes understandable if we take into consideration the significant work that has been done during those thirty years. In the first part of this study, we will recall the stages of this global awareness, from Founex (1971) to Johannesburg (2002).

Major environmental dynamics such as climatic change, biodiversity, and desertification, as one can easily imagine, have impacts on the future of economies and societies. What is less obvious for many people, and for many governments, is the global scale of the disaster of poverty and of its present and potential consequences. Even less obvious are the interactions between poverty, renewable resources, and the environment. The second part of this study will be devoted to the economic and social issues underlying the World Summit on Sustainable Development in Johannesburg.

There is no clear separation between, on the one hand, a changing environment with a strong tendency towards degradation and, on the other, human beings, governments, societies, and economies. Rather, social dynamics and natural dynamics evolve in interaction, and the global phenomena to be discussed at the Summit are the product of these interactions. The third part of this text will be devoted to them.

Stages of international awareness.

Events and conferences on development and the environment.

Thematic conferences and conventions.

In parallel with the general conferences, and as a result of them, numerous specialized conferences have been held over the past thirty years. Studying them aids us in understanding why the development of international awareness and the shift from discussion to application can seem so slow. In fact, very important steps have been taken. But, alas, time measured in terms of problems such as poverty, the greenhouse effect, the erosion of biodiversity, and desertification is not the same as the time that governs the process of making decisions and applying them in an international context.

Climatic Change.

The stages of awareness are analysed in detail in Jean Jouzel and Gérard Mégie's contribution to this book. A few of the stages deserve to be looked at thoroughly, due to their importance in the international decision-making process.

In 1979, twenty-three years ago, the worldwide program of research on the climate was launched. It was not an initiative of Governments, but of the World Meteorological Organization[Tab.1]. And in 1986, six years before Rio, the International Council of Scientific Unions (ICSU) developed the International Geosphere-Biosphere Program (IGBP). At the start, awareness was limited to scientists, and it was they who sounded the alarm about climatic change and the greenhouse effect. It was not the first time that scientists had taken the initiative in this way. But, concerning the depletion of the ozone layer and the accusations levelled against chlorofluorocarbons (CFCs), for the first time the work initiated by the scientists was to lead to a decision of worldwide scope: The Montreal Protocol, signed in 1987, which prohibited the use of CFCs.

Thus, decisions aimed at managing global environmental problems due to very unequally distributed anthropogenic pressure from one State to another, could be made within a short time at a global level and with worldwide application. Many other decisions have been made based on proposals by scientists, but this was the first binding decision. What is more, the potential

Table 1. Stages of awareness of climatic change.

1979 World Climate Research Program originated by the Wmo

1986 International Geosphere-Biosphere Program, launched by the Icsu (International Confederation of Scientific Unions)

1987 Montreal Protocol, prohibiting Cfcs for the protection of the ozone layer: The first example of a binding worldwide decision related to the environment

1988 Creation of the International Panel on Climate Change (Ipcc)

1992 Rio Conference, discussion of the United Nations Framework Convention on Climate Change (Unfccc), ratified in 1994. The Kyoto conference in 1997 and the one in Marrakech in 2001 were Conferences of the Parties to this Convention.

1997 Third Conference of the Parties (Cop3). The Kyoto Protocol called for an overall reduction of co2 emissions by 5% in 2008 compared to 1990 levels. The United States, which was to have reduced its emissions by 7%, has already increased them by 24% since Kyoto. The Kyoto Protocol adopted the principle of managing emissions through the institution of a worldwide market for emissions permits. It also sets up a "Clean Development Mechanism" authorizing compensation of emissions in one location by carbon storage in another location

2001 Marrakech (Cop7) approves the counting of "carbon sinks" in calculating the reductions for each country.

consequences of the disappearance of the ozone layer were a decisive factor in international awareness of global environmental issues.

At that point, the logic for creating the International Panel on Climate Change (IPCC), in 1988, became more compelling. The IPCC proved to be fundamental in what was to follow, occupying as it did the ground between scientific knowledge and implementation of decision-making processes. The IPCC's reports, which included scenarios of climatic change with analyses of their economic and social consequences, are now central to political reflection at national and international level.

Biodiversity.

The International Convention on Biological Diversity was signed in Rio de Janeiro in 1992. Again it can be said that Rio unified, rationalized, and strengthened processes that had begun decades earlier. In 1946 the International Convention for the Regulation of Whaling was signed, and though it did not prevent the near extinction of the great cetaceans, it did make it possible for a moratorium to be imposed later, and to at least partially reconstitute the population of these mammals.

Beginning in 1959, the Antarctic Treaty provided for measures to protect fauna and flora. Later, more specific conventions were to further detail and strengthen the Treaty: In 1964 and 1980 for the conservation of fauna and flora and in 1972 for the protection of seal populations. Then, in 1979, came the Bonn Convention on the Conservation of Migratory Species.

In the marine domain, the international Geneva Convention on the High Seas was signed in 1958, specifying that coastal zones be considered as being under the sole sovereignty of States. In its Article 2, the Convention bears the stamp of the scientific consensus of the period, which still holds sway today: "As employed in this Convention, the expression 'conservation of the living resources of the high seas' means the aggregate of the measures rendering possible the optimum sustainable yield from those resources so as to secure a maximum supply of food and other marine products. Conservation programmes should be formulated with a view to securing in the first place a supply of food for human consumption."

This Convention did not live up to the hopes it generated. In 1973, a United Nations Conference on the Law of the Sea was held, ending nine years later, in 1982, with the signing of a Convention. One of the very important measures of this Convention is the institution of Exclusive Economic Zones (EEZS) in the area stretching

1 FAO: Food and agriculture organisation of the united nations.

2 IUCN: International union for the conservation of nature.

3 WWF: World wildlife fund. The world strategy, revised after Rio, was republished in 1994 and translated into French by the Office of genetic resources (BRG).

300 miles beyond the national coastlines, with national sovereignty. The institution of the EEZs awakened hopes that States' control over their coastal zones would make it possible for them to control levels of catches by long-distance fleets and implement systems of licensing that would provide funds for covering, among other things, the costs of controls.

In 1995, the FAO[1] developed a "Code of Conduct for Responsible Fisheries," signed by the majority of States. Given that the state of fishing resources was continuously worsening, the States agreed to a whole series of modifications of fishing behaviour, aimed at protecting certain groups of species and prohibiting the use of non-selective fishing gear. But, even more importantly, the FAO Conference in 1999, which revised the Code of Conduct, abandoned the concept of "optimum sustainable yield" in favour of "greater consideration (…) given to the development of more appropriate eco-system approaches to fisheries development and management." In so doing, the Conference was falling in line with the advances made by the international scientific community. These advances were approved and extended in the Reykjavik Declaration on Responsible Fisheries (October 2001).

The World Conservation Strategy, whose first version was published in 1980, two years before the Stockholm conference, is an important event for international awareness. Published by the IUCN[2], the WWF[3], and the UNEP, this strategy adopts a global vision of the dynamics of biodiversity in its relations with societies. It clearly posits that the conservation of nature has as its final goal the satisfaction of human needs and must therefore take economic and social constraints into account. This was a fundamental stage in the development of conservationist thoughtst which until then was seen above all as being intended to preserve pieces of nature from anthropogenic pressure. The World Strategy recognized the approach of UNESCO based on the concept of "biosphere reserve," which considered that humans are part of the ecosystem that must be conserved. Robert Barbault discusses this point at length in his contribution to this work, and we will not go into it further here.

If one year were to be singled out as being particularly important on the road to Rio 1992, it would be the year 1982. This was the year of the Stockholm Conference, of course, but also that of the World Conservation Strategy and of the Convention on the Law of the Sea. The Rio Convention on biological diversity would be the final achievement of these international negotiations in specific areas.

Water.

The issue of water is not tackled thoroughly in this work. Like population, it is an important area. Chapter XVIII of Agenda 21 is devoted to water, and several international conferences have been devoted to it, the most recent in Paris in 2000 and in The Hague in 2002. These conferences took stock of the availability, usages, and accessibility of water. The World Water Council is circulating a petition for the holding of a specific conference leading to a framework convention on water, which does not yet exist.

The UNDP estimates that 1.3 billion persons do not have access to drinkable water. Already, humans use 40% of water resources, three quarters of it for agricultural purposes. Access to water, like other resources, is subject to inequalities around the world. In some places water is privatised, and in others its cost is prohibitive: In the cities of developing nations, the poorest people buy water from bearers, at a higher cost than that paid by the rich for the water they receive in their homes. The major water multinationals are aware of the problem and the market and are designing systems for bringing water to the poor areas of cities in developing nations, such as the "Water for All" program conducted by Ondeo.

The Paris conference disseminated the idea that water will be the cause of wars in the 21st century. The history of the second half of the 20th century tends to show that conflicts take place for irrigated spaces (an example is the Senegal-Mauritania war) or for access to water in conflicts between farmers and ranchers. On the other hand, water itself, as a "rare" resource,

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Table 2. Principal international conventions in the area of biodiversity.

1959 Treaty on the Antarctic

1972 Convention for the protection of seals in Antarctica

1980 Convention on conservation of marine fauna and flora in Antarctica

1946 International Convention for the Regulation of Whaling

1971 Ramsar Convention on Wetlands of International Importance

1973 Washington Convention on Trade in Endangered Species of Wild Fauna and Flora

1979 Bonn Convention on Conservation of Migratory Species

1992 Rio Convention on Biological Diversity

1994 Paris Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa has not been a generator of conflicts, and most rivers on the planet to date have tended more to create ties and be factors of peace rather than war – despite dramatic cases like the Tigris and Euphrates, the Mekong, or the Jordan, one of the principal causes of which is the absence of international co-ordination of usage.

It is likely that water will be discussed in Johannesburg. But one might wonder whether the issues will be correctly perceived in a context marked, on the one hand, by massive extension of irrigated spaces, which tend not to conserve water, and on the other, by the growth of the power of the major water multinationals. Water is not addressed by a specific contribution in this work because it is a resource that involves issues similar to those for other resources such as living species – vegetable and animal, terrestrial and marine. The choice for this book was to focus on the major dynamics and their economic and social impacts.

Desertification.

Elsewhere in this book, Antoine Cornet describes the evolution of views and actions regarding desertification. He shows, among other things, that concerns related to water and to desertification coincide only very partially. Yet they do concur on at least one point: The lack of concrete commitment on the part of the international community in both cases.

Discussed in Rio, the Paris Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa was signed in 1994. This question is the subject of Antoine Cornet's contribution to this work, which shows that the issue has been the topic of many debates centering on the very existence of drought. These scientific debates have shown that drought is a variable and not always irreversible phenomenon, in which human activities can play an aggravating or a moderating role, depending on the modes of land usage. As with all renewable resources, it appears that the systems of access to resources, to the land, and to water, heavily condition the dynamics of the economic and social impacts of desertification. Correctly defined systems of appropriation are an essential lever for any management of the environment, and such systems cannot be reduced to simply private property or state property. The existence of a broad diversity of common-property regimes has been shown to have a real capacity to manage resources and ecosystems over the long term.

From development to sustainable development.

At the Founex conference, economic development was the central concern, and the environment was seen as a constraint, a cost. In Stockholm, the environment was a priority, jointly, with the economy, and the same was true in Rio. It may be hoped that in Johannesburg, social development will take precedence over the economy and the environment, since humans are the sole raison d'être of both economic and environmental progress[Fig.1].

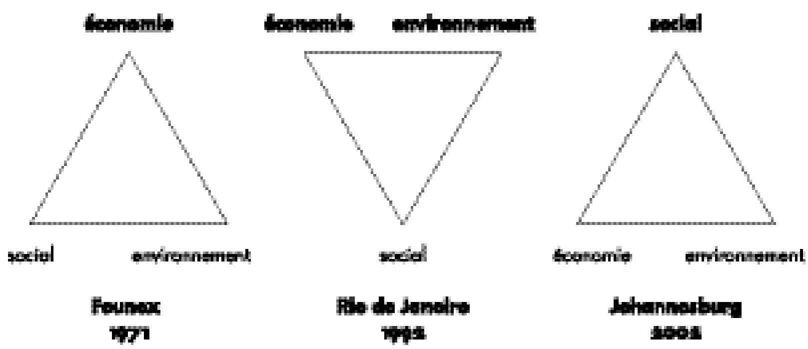
Evolution of scientific concepts.

What has taken place? Environmental problems are not new on the planet; neither are problems of development. On the other hand, the way in which we view the problems has changed almost completely since the late 1960s.

Due to their number and the technology they have created, human beings influence the future of the planet. It is possible that industrial growth produces irreversibilities in the evolution of the global terrestrial ecosystem. Humans are beginning to be afraid of the consequences of their acts for the future of the planet, and therefore of what their descendants will face.

Our instruments of observation and measurement are not the same as they were in 1969. Technological progress, considerable in the areas of aerospace, technical information, and models of interpretation of the physical and biological world, has changed the lenses through which we look at the planet.

Figure 1. The evolution of the hierarchy of concerns, from Founex to Johannesburg.



Through the middle of the 1980s, the world was widely viewed as being in equilibrium. The literature of the environmental movements spoke of "preserving" or "restoring" "natural balances." But scientific ecology, for its part, taught us to live in a world where change, instability, and variability are the norm, and equilibrium the exception. It has been discovered, contrary to what common sense would seem to dictate, that instability generates biodiversity, at least within the limits of viability. The notion of "natural balance" is not what it once was, either for researchers or for practitioners concerned with management of "natural" spaces.

At the same time, we are confronted with points of view that are contradictory depending on the scale of observation on which they are based. For example, a tropical forest is stable if looked upon as a whole: Low temperature amplitude, nearly constant hygrometry. On the other hand, the tropical rain forest ecosystem is made up of ecological niches at various scales, nested and interacting, and thus generating instability at all the interfaces between niches. And this local instability can be considered to be the first explanation for biological diversity in these systems.

Thus, there is the reality of the world on the one hand, and on the other the interpretations of that reality. There is the future and the interpretations of that future. Of reality as of the future, we know only the interpretations human beings have, and those interpretations are a function of the instruments and scales of observation, as well as philosophies and the state of public opinion. Scientists are made of flesh and blood, and not only of neurons.

New concepts, new approaches.

Numerous concepts have come out of these conferences on the environment and development, or out of evolutions in research.

That of sustainable development is doubtless the most famous. Its definition, issued from the Bruntland Report, has been given. Let us recall it nonetheless: Development that satisfies the needs of the present generation while preserving for future generations the possibility of satisfying theirs. Based on this single definition, interpretations will diverge, supported by varying conceptions of the relations between humans and nature. On one side are the proponents of "strong sustainability," for whom species and ecosystems are not replaceable, and for whom sustainability imposes the conservation of nature intact. On the other are the advocates of "weak sustainability," for whom technological progress makes it possible to substitute products for a nature which is no longer indispensable (Godard, 1994). The proponents of weak sustainability even envisage that the "services" provided by nature (see Robert Barbault's article) might be replaced by technological progress.

This is the same dichotomy as that between conservation – which authorizes the exploitation of the ecosystem on the condition that the elements necessary to its reproduction over time be conserved – and preservation, which implies total conservation of ecosystems.

The precautionary principle, which was also to strongly influence the process of decision and be much discussed in the media, also emerged (Godard, 1997; Kourilski and Viney, 2000). Often interpreted as a refusal to act, the precautionary principle is just the opposite: a principle and an obligation to act: "In the presence of a clear risk, the absence of scientific certitude must not serve as a pretext for failing to decide." The precautionary principle makes a political responsibility of a decision that cannot be based on science given the current state of knowledge.

In the field of the social sciences, the past twenty years have seen the emergence of "environmental economics." This discipline was created both from the economics of resources and the economics of energy. The development of environmental economics has been strongly influenced by environmentalism. Following Odum, economists have tried – and continue to try – to construct systems of energy accounting.

For example, to compare processes based on their energy content: How many PET (Petroleum-Equivalent Tons) does it take to produce a ton of corn in the Andes or in Mexico, and with intensive agriculture as practiced in the Southwest of France? That comparison could lead to a system that would tax energy-intensive processes in order to subsidize processes that save energy.

Another example of ecological influence is that of Holling, who stresses the study of and research on adaptive behaviours in nature and environmental management strategies that would be similarly adaptive. Instead of eliminating variability from the equation, variability should not only be taken into account, but also used in managing the environment.

The expansion of environmental concerns, coupled with scientific developments, has led to new concepts of agricultural development, known under the media-friendly name "Doubly Green Revolution." The approach starts with the awareness that the first Green Revolution had succeeded in countries with excesses of water and population, at the price of artificialization of land resources, extreme selection of plants, and intensive use of inputs, fertilizer and pesticides, but that the cost of the success of this revolution – such as degradation of land, residual pesticide pollution, and losses of biodiversity – will have to be borne by future generations. On this basis, the idea of a "Doubly Green Revolution" suggests a search for models of agriculture based on biodiversity, which use natural variability instead of rejecting it, working with biodiversity without compromising its future. Numerous experiments have been conducted around the world in this direction. Direct seeding on plant cover, widely used today and in which French research played an important role, is an example. It consists essentially of abandoning cultivation and sowing directly on plant cover, which ensures maintenance of humidity and prevents the growth of "weeds." It may be hoped that the advances made will lead to a rebalancing of the research effort in favour of agricultural alternatives to the industrial-productivity model.

What has perhaps evolved most during the past twenty years is the way in which scientific work is conceived. It has evolved from strict disciplinary orthodoxy to the recognition that the complexity of environmental questions makes interdisciplinarity – not simply in word but in deed – imperative. Accordingly, where France is concerned, the CNRS created interdisciplinary programs starting in the mid-1980s, while other Institutes created thematic departments grouping multiple disciplines.

And, recently, the CNRS has decided to place interdisciplinarity at the core of its strategy. The numerous calls for research proposals launched in the context of the CNRS's Environmental Program, as well as by Orstom (now IRD), at INRA, CIRAD, and other research institutes, have contributed to the formulation of environmental questions in interdisciplinary terms. This is a major evolution for research, even if it is far from having reached its full expression after twenty years.

Finally, since Stockholm, the Internet has revolutionized communication and access to information. The Internet has brought scientists closer and given them access to sources of data. The work of scientists is not quite the same as it was before the Internet era. Yet this considerable progress is reserved only for the richest, since the Internet remains inaccessible to the immense majority of humans.

Social and economic issues.

Poverty as dispossession.

Taking future generations into consideration has tended to make us forget the present generations. A world that is inequitable today cannot be sustainable. The report of the Bruntland Commission, in 1987, made that clear. Yet it must be stated just as clearly that the numbers of the very poorest people have increased, and that their poverty has worsened since independence. The initial observation of the Cocoyoc Declaration, cited in the presentation of this book, still holds true after so many years, so many conferences placing poverty at the centre of their concerns, and so many non-binding international commitments whose history unfortunately proves that they were nothing more than petitions of principle.

For the World Bank, poverty is defined as a daily income equal to or less than one US dollar. That definition applies to some 1.3 billion individuals. For its part, the UNDP, in its 1999 report, again pointed out that the richest 20% of the global population possesses 86% of the world's wealth. And *everything* proves that terrible truth. The wealthiest 20% account for 93% of all users of the Internet, and the poorest 20% only 0.2%. During the past thirty-five years, the disparity of income between the five wealthiest countries and the five poorest has more than doubled.

Status report and definition of poverty.
The World Bank defines a threshold of poverty as an initial approach, and as a means of international comparison. And it is a useful criterion, making it at least partially possible to say that there are more poor people in one place than in another... The critics retort that with one dollar, it is possible to sustain oneself sufficiently for a day in some places, whereas in others it is at best enough to buy a little bread. They also point out that poverty is a social, psychological, cultural fact, and cannot be reduced to material poverty alone. Poverty, they say, is the expression of an even greater misfortune.

The French, as a whole, see inequality as the leading cause of poverty, and the struggle against these inequalities the principal means of combating poverty. A book by Gérard Winter (2002) reflects that position, which is also to be found in the criticisms French economists made of the World Bank's report on poverty (2000). More precisely, their primary concern is the relation between equity and growth. Is an equitable distribution of income indeed inimical to growth? Economists know very well that equity and equality are very different: Equity as judged by a socially accepted norm can correspond to inequality of income, of status, or other forms of inequality. The Bank does say that poverty is not only a matter of lack of money, but also includes illiteracy, the impossibility of access to health care, or even the inability of self-expression. Nevertheless, the World Bank report on poverty is based on categories of poor people, women, and elderly, and divides poorest and richest into statistical categories. We are still a long way from social reality and its norms, which contribute to the persistence of poverty.

Progress in the comprehension of poverty and of the means of reducing it is, in large part, due to the UNDP and to Amartya Sen, the Nobel economics laureate, whose concepts the international organization uses – in particular that of "capability." This concept refers to an individual's realizable potentials, which are reduced to very little in a situation of poverty. For Sen and for the UNDP, poverty is first of all the result of an absence of rights, or of insecurity – or more precisely insecurities.

Economic insecurity, first of all, in a context of globalisation and of structural adjustments that have reduced expenditures for health and education and condemned a large number of workers to unemployment, as the Asian crisis and the one currently affecting Argentina have shown... Globalisation generates local instability in the system, and the poor are its first victims. Global competition has led States to reduce security and increase flexibility.

Insecurity of access to public services, such as health, education, justice, and administration, aggravated by poverty... The poor may be able to benefit from public or private actions of a charitable nature, but have only uncertain access to the basic services associated with citizenship. In countries that have "benefited from" structural adjustments, "true pricing" for health, education, and justice has made these public rights inaccessible to the common people.

To measure poverty and wealth on the same scale, one which is non-monetary, Amartya Sen and the UNDP created an Indicator of Human Development, or IHD, of between 0 and 1, which takes into account income, health, education, and life expectancy. Such an index shows clearly that poverty cannot be reduced to a lack of money. Kerala, a very poor State in India, has an IHD near that of France (approximately 0.8, in eleventh place worldwide, while India itself is in 132nd place).

Consistently with the UNDP's definition, the author of these lines would suggest that poverty can be defined as the absence of control over one's present circumstances, and thus over one's future.

Poverty and environment, poverty and sustainable development.
Why are we devoting so much space to poverty in an article dedicated to the stages of environmental awareness? Because humans are an integral part of the environment; they derive their livelihood from it and contribute to modifying it – often deteriorating, sometimes improving. Since the Stockholm Conference, official and respected voices have been raised to the effect that the poor are principally responsible for the deterioration of ecosystems. That accusation was formalized by the World Bank (1993), with the term "Poverty-Environmental Nexus." Demography is seen as "galloping," with that of the poor galloping faster that that of the rich. Due to their very precariousness, the poor are seen as often being directly dependent on renewable natural resources, which they overexploit according to a dynamic called the "Tragedy of the Commons," to use the expression of G. Hardin (1968). The result is said to be accelerated deterioration of the ecosystems. The survival of the planet pre-supposes, according to the proponents of a fundamental Malthusianism, that the population be brought to a level compatible with the "carrying capacity" of the planet, which they estimate at 500 to 600 million inhabitants, as opposed to the 6 billion currently.

The solution consists, according to Hardin (1993), in blocking international migrations, then sterilizing poor women after their second child. In France, these concepts have drawn radical criticism, from Hervé Le Bras (1993), among others.

The notion of carrying capacity is pertinent only in a closed environment with a constant technology. At the local level, the concept makes little sense for studying the relations between humans and nature, since the conditions under which the concept would be valid do not exist: the environment is open and technology evolves. At the planetary scale, there is doubtless a limited capacity of the biosphere to absorb both the growth of the population and that of industry. But to calculate it appears quite impossible at the present time.

In fact, the only difference between poor and rich is that the poor consume less renewable resources than the rich, but are directly dependent on them, while the wealthiest can feel independent of the natural environment because they procure these products on the market and notat their source. For the UNDP and the UNEP, and consistent with the declarations of all the conferences since Founex in 1971, the poor are the principal victims of environmental deterioration, as regards health, as regards the resources accessible to them, and by reason of the impoverishment of the ecosystems. What has become more understandable in the past twenty years is the importance of modes of governance in the treatment of poverty. This term, in frequent use today, is not often defined. The UNDP gives a precise definition: "Governance is the framework of rules, institutions and established practices that set limits and give incentives for the behaviour of individuals, organisations and firms" (UNDP, 1999: 8).

In opposition to the point of view of the sociobiologists, numerous researchers feel that the deterioration of ecosystems is the result, among the poor, not of poverty in itself but of precariousness: It is what leads people to take all they can from an ecosystem, as quickly as possible and without concern for its renewal. This behaviour and its effects are well known in the exploitation of renewable resources in situations of open access. Ending poverty, then, begins with the formal recognition of secure rights of access to the land and to resources as well as to public services.

Access to and use of resources.

In the case of the atmosphere, fish, game, forests, water, and any renewable resource, the issues can be reduced to questions of access, use, and the dynamics of the interactions between resources and uses.

How?

Problems involving management of nature are generally still approached in a way that is too strictly ecological, and the measures taken regarding human beings are based on ecological observations and still far too little on human social organization. The protection of ecosystems and protected areas requires that the rights of access and use of local populations be called into question, without compensation. A situation of open access can be put in place where a system of common property once regulated that access.

Most renewable resources are communal resources, owned communally. National legislation has expropriated local communities, either by attaching these resources to the private domain of the State, or by granting them – whether or not in full ownership – to private interests. On the African continent, these laws date from 1929-1930. Local communities are dispossessed and have no motivation to participate in control of access.

The State's ownership of resources brings about the necessity of controlling access and use of these resources at a cost which quickly becomes prohibitive, even for fairly well developed countries. The impossibility of assuming these costs of control transforms the resources of the private domain of the State into resources to which there is de facto open access. In the very great majority of situations of open access observed around the world, this situation has been created by the States or, indirectly, by projects to develop or to conserve nature, initially due to a lack of knowledge of the social sciences. The major non-governmental organizations, such as the IUCN[3] (International Union for Conservation of Nature and Natural Resources) and the WWF (World Wildlife Fund), have progressively learned the necessary skills.

On renewable resources.

Renewable resources should be set apart and not lost in the poorly defined entity called "natural resources." Mines and oil wells can only be made to last by slowing the pace of their depletion. On the other hand, it is possible to draw on renewable resources eternally, provided that more resources than can be renewed are not exploited.

Among these renewable resources are fisheries, water, wild fauna and flora – and therefore the natural terrestrial and marine biodiversity – as well as forests and the atmosphere. The problem at hand is the following:

what is the possible means of co-ordination between users, under the twofold constraint of the permanence of the resource and the profitability of the exploitation?

In the absence of limitation of access to these resources, new users constantly arrive, for as long as profit is still possible. The system of open access leads both to the deterioration of the resources and to economic ruin. This is what Hardin incorrectly called the "Tragedy of the Commons;" incorrectly, because common property excludes open access.

Biologists have attempted to manage these resources based on norms of selectivity, quotas, and spatial and temporal restrictions on exploitation. In forests, a minimum diameter is set for trees to be felled, and marine biologists propose minimum sizes for catches and minimum mesh sizes; quotas exist for all renewable resources – except, for the time being, for the atmosphere. Spatial and/or temporal restrictions are in place for all resources, except, again, for the atmosphere.

Economists first approached the question on the basis of the interactions between users of these resources, considered a priori as being under open access. Any decision made by one of the actors in an exploitation in common, constrains the decisions other actors can make, to the extent that what one removes will not be available to the others and will reduce their share. Thus a technical externality is defined. If a decision by my co-user hurts me, I can't demand compensation, in the absence of a contract or a market mechanism, or a regulating institution. We will call this a case of negative externality. If, on the other hand, the action of my co-user is favourable to me, then conversely, this is a positive externality. Posed in terms of externality in this way, there can be a set of solutions to the question: What is needed is to internalise the externalities – that is, to construct mechanisms or institutions that can make possible compensations and coverage of the costs by the actors themselves. These instruments are taxes, guaranteed loans, permits and transferable licenses, property rights, and rights markets. The systems of appropriation must be precisely defined. These systems cannot be reduced to private property or State property. They therefore involve multiple forms of common property, of a type which have made the maintenance of numerous local ecosystems possible over the long term. In France, there are numerous examples. The commons, spaces that are the property of communities and accessible to all citizens of the community following very diverse rules; the Camargue in the Department of the Gard, called the "Petite Camargue," has been managed communally since the fifteenth century, while the space has continuously evolved and is still evolving as regards the usages of these wetlands, with activities perfectly integrated into the European market and the world market.

There is nothing exotic or folkloric about communal management, and it has made it possible to maintain the viability of the ecosystems and societies that have been living from them for centuries.

In the 1980s, the belief in private property as a universal regulator found its legitimisation in Hardin's "Tragedy of the Commons." If what he calls "common property" (in fact open access) led to ruin, then private property was the solution. In addition, it was supposed that the generalization of private property would contribute to the emergence of markets, markets being considered as one of the crucial objectives of development. But unfortunately no one knows whether the property creates the market or the other way around! In any case, attempts at privatisation of common grazing lands, in the Ferlo in Senegal and among the Masai in Kenya and Tanzania, have resulted most notably in the disappearance of rules of reciprocity and the departure of the dependents to shanty towns. On the ecological level, the result was overgrazing around wells and deterioration of grazing lands, since with the end of transhumance they are no longer used optimally in keeping with the seasons.

The recognition of very diversified systems of appropriation, which can secure temporary or permanent access and use rights, is one of the surest means of combating poverty. It is in this way that local governance can allow local communities to recover possession of their present, and thus face the future. Today, in most poor countries, herdsmen practicing transhumance face growing difficulties stemming from the formal non-recognition of their access rights – which are often ancestral, and are now denied due to nature-conservation projects, ranching, or simply agricultural development. The Arctic peoples of Europe are also experiencing problems of this type. As for the Pygmies, their citizenship is often little recognized in reality. These are only a few illustrations of the recurring problem of recognition of the rights of the poorest populations as a key element to their regaining control over their present and their future.

Principal measures in use for management of renewable resources.

Selectivity refers, generally, to designing tools of exploitation in such a way as to limit their negative effects. In fishing, the trawl net is not very selective, and this is only partially compensated for by the limitations placed on mesh sizes. Selectivity, then, is based on standards: The size or age of fish or the minimum diameter of trees to be felled, for example. The ecological effect depends on the modalities of application. In situations of open access, these standards have little chance of being respected, unless there is sufficient control – the cost of which would be prohibitive.

Quotas Quotas set a maximum quantity or volume per user. They are imposed as a way of preserving the renewal of the resource. Their enforcement implies high costs of control. Their biological impact can be positive but, in the absence of limitations on the capacities of exploitation of the actors, the economic effect cannot be positive. It amounts to limitation of the accessible stock for an identical production capacity.

Taxes Taxes, the reverse of subsidies, weigh down production costs. They reconstitute a rent which is at best equal to the volume of the tax and can be used, if necessary, to compensate the users they force to cease exploitation. Taxes can also be used in a motivational way, following the example of the "Ecotax": Imposed on polluting activities, it can be used to subsidize those actors who implement innovations to reduce pollution. The tax, directly tied to the activity and put back into the activity, is considered "fiscally neutral." However, decades of international observation tend to indicate that though taxes are a very good instrument for halting an undesirable dynamic of exploitation long enough to design and put in place a system of management, they are not a regulatory mechanism over time. It takes at least a year to modify a tax, which is too long in the case of speculative resources (such as shrimp, for example), they are costly to collect, and they tend to evaporate through diminution of the tax element in the system of production.

Licenses and permits A permit is not a limitation but a simple condition of access. Everyone can have access to a permit. On the other hand, a license rests on a numerus clausus: Only a strictly defined number of users may have access to exploitation. Open access no longer exists. The biological effect is similar to that of quotas at the initial stage. In later stages, licenses, to be effective, must be accompanied by limitations on harvests and by technical standards. On the other hand, the economic effect is direct: The reduction in amounts harvested is obtained via reducing the number of users, and thus of production capacities. The rent derived from licenses via the reconstitution of the abundance of the resource can be used to compensate the users who do not gain access to a license. However, historical observation shows that the implementation of licenses represents an initial cost for the State and that non-limitation of harvests limits the effectiveness of the licenses.

Negotiable licenses A license can be defined as being resalable on a market. In France, permits, though accessible to all, are not resalable. Licenses, which constitute a use privilege, are. The fact that licenses are negotiable provides an indication of the productivity of the activity, reflected in the prices being paid for them.

Rights markets With the exception of quotas, provided that they are respected, the instruments mentioned above do not offer a guarantee of limitation of harvests over time. The idea was therefore introduced, in the second half of the 1970s, of distributing quantitative rights in negotiable amounts. In the case of the fisheries, these are Individual Transferable Quotas or ITQs; in agriculture, quotas on milk; in the area of pollution, emissions rights (commonly called "pollution rights"). In the case of renewable resources, the idea is to completely "internalise" the "externalities." The user can use his negotiable quota as he sees fit, using whatever means he wishes, within the limits of his rights. If he wishes, he can sell or purchase rights from other users. The manager (most often the State) can itself repurchase rights to reduce the global volume, or place more on the market. The biological effectiveness is significant, since the exploitable quantities are subject to a ceiling, each actor having defined rights. The economic effectiveness lies in a significant decrease in the costs of production through the disappearance of externalities and in the perpetuation of a rent equal to the value of the total of the negotiable rights. This ends what economists call "rent dissipation."

The specific case of genetic resources: Access and "sharing of benefits."

Genetic resources are life elements removed in situ to be used for purposes of varietal improvement, in pharmaceuticals, or in genetic engineering. The International Convention on Biological Diversity (CBD), signed in Rio and ratified by the majority of States (but not by the United States), distinguishes between problems of access and questions of sharing of benefits.

Access is left up to the sovereignty of States. In many tropical countries – where the majority of the diversity, both marine and terrestrial, is found – this amounts to mandating open access, given the difficulty of controlling removals in nature. Though all the instruments mentioned above for control of access to renewable resources could be used here, they are not – or not yet. And returning the problem to the responsibility of the States, where the poorest populations are concerned, is a way of obtaining the maintenance of open access. The definition of common rules at the international level would have made the task of these States easier.

Concretely, it is compulsory, in principle, for the removal of any living material within a country must adhere to the laws of that country or be covered by an explicit convention with the State. Research, be it public, private, or associative, is not exempt. For French public research, the convention must cover both the framework for access and that for the sharing of benefits.

The issue of sharing of benefits was timidly introduced in Rio in 1992, in the form of encouragements to finding equitable forms of sharing. At the Conference of the Parties to the Convention on Biological Diversity in The Hague (COP 6), the issue was again discussed, without any internationally admissible and binding rules being envisaged. Yet the OECD (1999) discussed the question at length and the group of experts showed that sharing of benefits and access could be handled simultaneously, through contracts and rights markets. The experts felt that the definition of "adequately defined" property rights,* that is, collective as well as public or private depending on the case* was a necessary preliminary to the implementation of an equitable system for sharing of benefits. A concrete case will help explain the interest of recognized rights. A researcher from the Institut de Recherche pour le Développement, working in Bolivia, discovered a family of molecules that are active in the treatment of leishmaniosis, thanks to the knowledge of the Chimane Amerindians. Their name was given to the family of molecules, called Chimanines. The association of the Chimanes in the patent rights and in future royalties is made difficult by their lack of legal status. The Institut therefore filed the patent in its name, with a unilateral commitment to return the totality of any royalties to the Bolivian government. This example illustrates the inseparability of access and sharing of benefits as well as the need for international conventions to establish modalities with universal scope. What can be done by a public research institute does not seem realistic for private companies. What is being called "biorape" is the result, at least in part, of an absence of established rules and of what amounts to open access to resources.

Given the importance and the complexity of the problem, it is difficult to imagine how the governments of poor countries could solve it without involving local populations in control of access, both to resources and to knowledge. Genetic resources are often associated with local knowledge, which is also collected by researchers, be they public, private, or associative. The question of the protection of these bodies of knowledge has progressively emerged and gained importance within the Conference of Parties to the Convention on Biological Diversity. In The Hague, in 2002, the need for protecting local knowledge just as resources are protected was recognized. The OECD and the WIPO (World Intellectual Property Organization) have been associated in the deliberations. Numerous participants at The Hague 2002 fear that the involvement of the OECD and WIPO may lead to solutions of individual protection of resources and collective knowledge. The French point to the example of *Appellations d'Origine* to show that it is possible, when protecting a product, also to protect the knowledge and techniques that make its production possible.

Evolution of property rights and rights markets.
Putting a price on nature.

In the process used for economic evaluation of nature, surveys are conducted with samplings of persons who must express "consent to pay" (for preservation) and "consent to receive" (for accepting the destruction of environmental resources). This process of creating fictive markets for non-market goods is called "contingent valuation." Direct measurements are also made of use values, by noting the market prices of certain goods or by observation of the prices of market products capable of replacing the goods taken directly from nature.

The universality of the methods of contingent valuation is strongly contested, and in particular their pertinence in places where the market does not function well, or in societies where individual needs are expressed as collective needs. For example, to the question: "What must we give you so that we can do this or that?" the answer might be: "A roof for the school;" "A bridge;" "Paint for the church;" or "A soccer field" in the forest villages of eastern Cameroon.

Considering that the process is of limited range and applicability, despite its praiseworthiness and the interest it has met with on the part of naturalists and decision makers, other approaches have been developed for assessing the interest of a project. In England, "juries of citizens;" in France, the *démarche patrimoniale*, as well as other approaches based on mediation and role-playing associated with modelization. Sources on these methods are given in the bibliography at the end of the book.

Nature of rights markets.

In traditional property, the possible accesses to and usages of a good (animate or inanimate, moveable or immovable) are con-substantial with the right of property (usus, fructus, abusus). Concepts of property have evolved significantly since the mid-1970s and the creation of the first rights markets (milk quotas)[Tab. 3].

In a rights market, the various elements of property are separated and circulate on separate markets. The owner of a cow is not necessarily the owner of the right to put milk on the market. He or she must have obtained this right independently of the cow. In this way, the elements of property, access, and usage generated by a given good can multiply independently of ownership of the good itself.

Patents – temporary monopolies (twenty-five years) on access and use – do not constitute "property rights." One cannot become the owner of genes, but only obtain a monopoly on their access and use. Thus there is not "appropriation of the living," but instead the development of markets on which access and use rights are exchanged. So much so that a patent that is not implemented industrially after three years falls into the public domain.

Generalization of rights markets: A panacea for globalisation?

To the extent that access and use have acquired independence from property rights, rights markets have proven to be an instrument with great flexibility and adaptability. With globalisation confronting property rights that are as diverse as they are complex, the possibility of exchanging certain elements of property without affecting property itself makes it possible to minimize many "transaction costs." But the multiplication of rights markets is not cause for optimism as regards opportunities for the poorest people to regain control of their existence.

Interactions between societies and nature.

Variability and climatic change.

Cyclical variations of the El Niño type: Drought and flood.

El Niño is a cyclical oceanic phenomenon having enormous climatic impact. It is the result of an accumulation of warm water in the western Pacific, which returns towards the east and reaches the coasts of South America over two months, increasing the temperature of the water by several degrees. El Niño is followed by a withdrawal of warm water towards the east and a cooling episode called La Niña. El Niño generates collapses of fish stocks, storms and floods, epidemics, and many other devastating effects on the western side of the South American continent. On the eastern side, in contrast, El Niño causes severe droughts that can be felt as far away as western and southern Africa. For the first time, the El Niño of 1997-1998 was predicted with great precision[4].

The variability of the climate, in the case of cyclical phenomena such as El Niño or the monsoons, is better and better understood. A phenomenon like El Niño causes droughts and floods and disrupts the renewal of living resources through the collapse of biomasses. Understanding it allows its effects to be anticipated and preventive measures to be taken. It also makes it possible to better plan investments and to avoid, for example, commissioning a fishing vessel within a few months of the appearance of El Niño.

4 The consequences of the successful forecasting of El Niño are, perhaps, less predictable. What is the impact of this forecast and what are its consequences, in terms of foreseeing catastrophes, on the predictions of economic events and of crises such as the one in Asia?

Table 3. Examples of rights markets in the environmental sphere.

Late 1970s Milk quotas

Individual Transferable Quotas in the fisheries:

- **1981** Australia
- **1983** New Zealand
- **1985** Iceland and Canada
- **1992** Alaska

1991, 1984, 1989 Water pollution (American watersheds)

1983 Lead in gasoline, United States

1986 Emissions of polluting gases (California)

1990 Emissions of SO_2 (northern and Midwestern United States)

1996 Proposal for a rights market for use of the biosphere by G. Chichilnisky.

Published by the World Bank, Unesco, Undp, Unep.

1997 World market for rights to emission of CO_2 (Kyoto Protocol)

The predictability of these variations should make it possible to take them into account in public policies, in particular regarding agriculture, health, and investments. It will be possible to minimize the costs generated by these cyclical phenomena.

Adaptability of societies to the hypotheses of climatic change: Inequality in the face of "natural" risks.

El Ninõ is to be ascribed more to the variability of the climate than to long-term climatic change. However, the two cannot be independent, and the predicted increases in the temperature of the Earth and in the level of the oceans cannot but have an effect on El Niño.

The article in this book by Jean Jouzel and Gérard Mégie, discusses scenarios of climatic change issuing from the models compared by the International Panel on Climate Change (IPCC). Even the most optimistic of these scenarios, corresponding to a significant reduction in CO_2 emissions, still takes as a given that the climate is in a process of change – with, among other effects, an increase in temperature and rising ocean levels. How will the societies on the planet adapt?

The increase in temperatures generates an evolution of the areas of distribution of fauna and flora. Already, the effects are perceptible, in particular on coral reefs. The rise of the level of the oceans will have tragic consequences for the one fifth of humanity living on coastlines. Countries like Bangladesh could disappear, as could archipelagos like the Maldives or the Seychelles.

Certain societies will succeed in dealing with climatic change at an acceptable cost; others will not, and particularly rural environments in poor countries. The current knowledge of the societies of the world should suffice to conduct a collegial experts' assessment synthesizing the knowledge acquired up to now and leading to recommendations for action and for research. It would be possible, among other things, to conceive of strategies referred to as "No Regrets," which would prepare for changes but be profitable for society even if the change does not take place.

One of the major issues of the Johannesburg Summit will be how the world's States deal with the crucial question of the probable effects of climatic change, the measures that can limit them, and those necessary for anticipating them. Much is at stake and time is short.

CO2 emissions, negotiable emissions permits, and forest sinks: From Kyoto 1997 to Marrakech 2001.

The atmosphere is a renewable, global, communal resource. The atmosphere is in open access and was considered inexhaustible fifty years ago. Following the example of what is practiced for other renewable resources, it was decided to control access to the atmosphere and limit use through reduction of emissions of CO_2. That reduction is to be carried out through the use of a rights market for emissions.

A rights market is established, based on an initial distribution of the totality of the rights (in terms of tons of carbon) among the States of the planet. Once distributed, these rights become negotiable. A State having increased its effectiveness in reducing emissions can resell its excess rights; another State needing to increase its emissions in order to develop will only be able to do so by purchasing the corresponding rights. A worldwide authority, if necessary, could regulate the system by purchasing rights on the market, thus reducing the available total and, in so doing, the total emissions.

Clearly, the initial distribution of rights is closely linked to the initial situation of the emissions. As an illustration, when the Kyoto Conference took place, in 1997, per-capita emissions in the United States were 29 times what they were in India, and per-capita emissions in France were 9 times greater than in India. If the initial distribution is made in the light of the existing situation, for one unit of emission rights granted per Indian, each Frenchman would have 9 times as many, and each American 29 times. Which means

Table 4. Basic data per country in Appendix I
(all values are in MtC/year or million tons of carbon yearly).

Country	Forestation reforestation and deforestation	Management forestry	Other activities	Total
Total European Union	-1.3	39.1	0.3	38.1
Canada	-4.4	9.1	4.6	9.3
Russian Federation	-8.2	117.5	109.3	
United States	-7.2	288.0	10.4	291.2
Total Appendix I	-14.0	500.7	17.5	504.2
Total Appendix I without Usa	-6.8	212.7	7.1	213.0

that in order to develop, India would have to purchase rights from the rich nations. If, on the other hand, the Indian position – that human beings are equal as regards the atmosphere and that the industrialized nations should pay the price of their past behaviour – is followed, then to remain as they are the rich countries should purchase emission rights from the poor countries. Many economists saw this as a possible powerful mechanism for financing development, with the past of the rich financing the future of the poor.

This point alone gives an indication of the complexity of the negotiations on CO_2 emissions, from Kyoto 1997 to Marrakech 2001. Other important questions, such as controlling of the observance of emission rights, sanctions, and their application, add further complexity to the discussions.

In Kyoto, a "Clean Development Mechanism" had been decided upon, allowing industries to compensate for their CO2 emissions in one place by storing carbon in another place, or by financing "sustainable development" projects. Extending the reasoning on carbon storage, the United States wanted the "initial situation" to take stored carbon (in the forests, among other places) into account, thus reducing the amount of emissions. Taking "carbon sinks" into consideration was agreed upon in Marrakech. But in the meantime, the United States had decided to withdraw from the Kyoto Protocol...

Biodiversity issues.

The arrival of genetic engineering: What impact on sustainable development?

The explosion of genetic modification is certain to have effects on development and on the environment. Rich in possibilities for improving human, animal, and vegetable health and increasing agricultural production by minimizing the use of inputs, genetic engineering is also the bearer of risks. Environmental risks, through contamination of cousin species or breaking of species barriers; risks of dependency due to the obligation of repurchasing seed; economic risks weighing on the weakest; geopolitical risks, of two orders: (a) the development of genetically modified crops or productions without public control in certain countries, (b) risks tied to the possibility of substitutions of productions: the possibility of making one plant manufacture the product of another plant – for example rapeseed oil by soy plants – has the potential to destabilize entire economies.

The crux of the issue is (a) the way in which GMOs are used; they are not "good" or "bad" in themselves, but they can be well or badly used; (b) the regulation of genetic engineering activities in each country and at the international level, since the States need to establish legal means of controlling their extension; (c) the transfer of knowledge from the wealthy nations to the poor countries to allow them to also become actors in this major technological evolution.

Agricultural issues.

Diversity is important for humans, for their nutrition and for their quality of life. Among the nearly 13,000 edible plants known, 4,800 are cultivated, but only four species represent nearly 50% of the world's food supplies – wheat, corn, rice, and potatoes –, and 18 plants represent 80%. The small number of plants on which our food supply is based and the reduction of genetic diversity result in fragility and a major risk in case of epidemic or climatic change. The globalisation of exchanges, coupled with progress in the selection of varieties with high yield, leads to a situation in which human nutrition relies on a very small number of plants and animals which are becoming more and more fragile.

Regarding food production, while production is increasing at approximately the same pace as population growth in sub-Saharan Africa, such is not the case in the Maghreb or in Latin America. And the same disparities of development exist: an African lives on 2,100 calories per day as compared to 3,400 for a European. These global figures mask even greater disparities. In Madagascar, 75% of the population lives on 1,600 calories per day.

Agriculture is the activity that is most sensitive to environmental factors. Climatic change could significantly alter the world's agricultural map. Climatic variability means uncertainty for farmers all over the world, but particularly for those in developing countries who have no insurance of any kind. The peasants of the Sahel and the Brazilian Sertão have little possibility of receiving indemnities for natural catastrophes, prolonged drought, or the collapse of prices. This absence of insurance is seldom taken into consideration when speaking of resistance to innovation. Innovation is a risk that can be mortal. In the absence of insurance, there is no right to error.

Ecosystemic approaches to agriculture are raising hopes for a new type of Green Revolution, as was explained earlier. The interactions between society and nature are being revolutionized. It is no longer a question of "exploiting" or "dominating" nature, but of acting in connivance with nature. Of working with rather than working against nature. Humans cease acting on nature to act with nature (Griffon, 1996). And the world's poorest people may stand to gain the most. Experiments now under way show that it is possible to produce more and better with much less input and without deep tillage.

Societal issues.

It is unwise to think that since facts are objectively observed and recorded, the modes of interpretation of these facts and the uses that are made of them also bear the stamp of objectivity.

The management of CO_2 emissions has led to the creation of the Clean Development Mechanism and the taking into consideration of "forest sinks." Though not linked, a priori, directly to biodiversity, these will eventually have an effect on it that is not negligible. If the ton of stored carbon becomes an instrument of measurement of natural and artificial systems (among others, agriculture), the pursuit of profit in terms of carbon will have effects that, although difficult to pin down, will be not unlike the consequences of the pursuit of maximization of monetary profit – expressed here in tons of carbon rather than in dollars. And that should be enough to affect the future of numerous forests.

Following the same line of reasoning, the Convention on Biological Diversity has as one of its objectives to fight against invasive species, in order to avoid the disruption of certain ecosystems. A rapid evaluation shows the ecological soundness of the approach. At the same time, any species not indigenous to the national territory is considered "invasive" by many countries. This implies that an "invasive" species is a "foreign" one. In such cases, the struggle against these species can constitute the beginnings of a non-tariff barrier to international trade...

The example given here is meant only to show that the political and international interests of the States are never very far in the background when it is a question of moving from scientific knowledge to international decisions.

Rights markets, if they are generalized for management of biodiversity – based on intellectual property rights and projects for markets for use rights –, will have a major impact in developing countries. Depending on how they are regulated, these markets could either strengthen peasant communities or, what is more likely, further increase their marginalization through co-optation of these rights by those who hold power – be it governmental, customary, or economic.

The scientific issues of biodiversity are also social, economic, and political issues.

Conclusion: what issues for Johannesburg?

The agenda of the Summit has not yet been drawn up as this book is being published. The issues discussed here are therefore issues for Johannesburg, with no guarantee that they will be included in the agenda of the World Summit.

We have attempted to show that the very complexity of the relations between environment, economic development, and social development may explain, at least partially, why it has taken thirty years for the governing bodies of the planet to become fully aware of them.

Scientific progress in the service of sustainable development. Scientists are at the origin of international awareness. Research has made considerable progress since Rio 1992. The means of observation, in particular satellite-based ones, have made a leap forward, and means of calculation and of communication, through the Internet, have progressed greatly. But the progress is not only technical; approaches and concepts have also evolved, and a great number of certainties have collapsed. In addition, scientists, contrary to a widespread notion, feel involved in the future of the planet, and thus in the process of decision concerning global issues. The pace of publication as the major conferences approach is evidence of that, as the cover of this book illustrates. Further evidence is the international authority now wielded by the IPCC (International Panel on Climate Change). The chapters that follow illustrate these advances and throw light on the issues and challenges still to be faced. In particular, the social sciences must take on the role that other sciences would like them to assume, so that scientists may together confront matters that are by nature interdisciplinary.

Unfortunately, the developing countries count for very little in this scientific evolution, due to the lack of resources, the absence of forums for publication, the paucity of remuneration, and the lack of recognition. The best scientific talent ends up being attracted to the exterior by the scientific organizations of the wealthy nations. One of the important issues for this Summit would be to find ways to end the scientific marginality of the poor countries, and to allow them to participate in the global dynamic of science.

The rise of conflicts of access to and use of resources. Everywhere in the world, we see conflicts involving access to, and use of, natural resources, whether renewable or non-renewable, that can reach the point of war – as illustrated by what happened in the Persian Gulf. For some writers, demographic growth is responsible for these conflicts. But close observation leads us to believe that the influence of demographics, though real, is insignificant compared to that of poor governance and an absence of definition of regimes of appropriation and control of access. The conflicts are generally presented as falling into several types: Communitarian (meaning "ethnic"), religious or political. But a close look at a map of the conflicts in the world will clearly show that this typology has to do with the mode of expression of the conflict, and not with its nature. Two conflicts out of three originate with problems of access to and use of resources. Two conflicts out of three are environmental conflicts. The problems involving access and sharing of benefits in the case of genetic resources are among them.

The African continent itself is, unfortunately, an illustration, from southern Africa to Sierra Leone, in the Casamance, and on the coasts of Senegal. These conflicts over resources result in exodus, poverty, dispossession, suffering, and upheaval. No world summit on sustainable development can ignore this. It would be regrettable for the analysis to consider, once again, only the symptoms and not the disease; the mode of expression of the conflict and not its fundamental nature. If biodiversity, as is probable, is of one of the themes of the Summit, then issues of access and use should be at the centre of the discussions.

The social repercussions of sustainable development. The imperative necessity of a change in the existing international order to confront global issues is a further explanation for the apparent slowness of decisions and, even more difficult to admit for public opinion, of their actually being put into practice. The assessment of the world made in Stockholm in 1972 or in the Hammarskjöld Report of 1975 remains valid in its entirety. The only difference is one of scale: The Diagnosis of Human Development established each year by the UNDP shows that poverty has worsened in a world that, overall, has become wealthier. The 200 wealthiest individuals have an income of 500 US dollars per second, while 1.3 billion people live on less than one dollar per day (UNDP, 1999). Indigence, lost dignity, multiple insecurities, the absence of control over one's own present, and thus the absence of a future: Such is the situation of a considerable proportion of humanity. This situation cannot continue very long without serious geopolitical consequences.

Since Stockholm, the interactions between poverty and the environment have been the subject of attentive study. While analyses diverge, with some holding the poorest peoples responsible for environmental deterioration and others seeing the poor as the victims of that same deterioration, all agree on the reality of these interactions.

At a Summit being held in a country ravaged by AIDS, on a continent undermined by poverty and conflicts of access to resources, an absence of binding commitment by the wealthy nations side by side with the poor countries would have considerable political cost less than one year after the events of September 11, 2001.

For these reasons, the Summit cannot avoid placing social development at the centre of the discussions. The fear that it will go no farther than what was done in Copenhagen in 1995 and the discouraging results of the preparatory conferences, like the one in Monterrey in 2002, lead some to feel that the objective of the Johannesburg Summit should be the preparation of a "Rio +12" which will make binding decisions.

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For ample, continuously updated information on sustainable development and the international conventions: http://www.iisd.ca, the Web site of the International Institute for Sustainable Development, in Winnipeg (Canada).

Managing plant genetic resources: from an empirical approach to international institutionalisation.

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An empirical and volontarist approach to managing and preserving plant genetic resources. Without going all the way back to prehistory, we can say that until the 1970s the management of plant genetic resources was basically the empirical approach employed by those using this diversity, and farmers in particular. At the same time, the European colonial powers created phytogenetic collections *ex situ* as early as the 17th century, in the form of "botanical gardens" with the varied plant species that explorers brought back from all over the world. At the start of the 20th century the work of Russian botanist Nikolai Vavilov was to have an important effect on the management and preservation of plant genetic resources. Vavilov wrote that research into plants and the replacement of natural populations by modern cultivars could have a negative effect on genetic diversity. However, he also wrote, "*it is precisely this genetic diversity that may be called upon to provide the solid base needed to create new varieties and breeds of organisms on which the existence of humanity itself depends.*" He therefore collected the seeds from various cultivars around the world and organized them into a collection. In the 1920s his collection of phytogenetic material at Saint Petersburg in Russia consisted of 250,000 samples, but it was not until the 1950s that efforts were made to establish collections of agricultural genetic material. Their role was to bring together the genes of certain cultivated species in order to facilitate their use in research. Thus, the IRRI[1] was created in 1960 as the result of a joint effort by the Philippine government and the Ford and Rockefeller foundations. These foundations financed four collections of genetic resources that in due course became International Centres for Agricultural Research (ICARS), but this action was not part of a worldwide co-ordinated programme to manage plant genetic resources.

Growing awareness of the importance of establishing programmes to manage and conserve plant genetic resources on an international and global level. At least three factors contributed to this international awareness: at the end of the 1960s, as a result of the "green revolution," it was publicly admitted that the genetic diversity of third world countries had been eroded and that there were inherent risks in this erosion. As early as 1967, at the joint conference of the FAO and the International Biological Programme, the participants agreed on the importance of building up large collections and gave priority to natural populations in danger of disappearing.

Genetic vulnerability (e.g. the problem of rotting maize in the South of the United States in 1970) favoured the formation of a consensus in favour of a co-ordinated collection and conservation programme aimed at making sure the raw material essential to plant improvements did not get lost. An American commission of investigation revealed the narrowness of the genetic base used in the main plants cultivated.

In 1972 the Club of Rome in its "Limits to Growth" report did not directly tackle issues linked to management of agricultural genetic resources. However, the United Nations Stockholm Conference on the environment – organized in response to the Club of Rome scenarios – refers to the management of genetic resources in recommendation 39. This recommendation asks countries to reach an agreement on an international programme to protect the world's genetic resources.

Against this background it was up to the CGIAR (Consultative Group on International Agricultural Research), to implement the programme to conserve and manage plant genetic resources. Created in 1971 with its headquarters at the World Bank, it boasted thirteen centres operational in 2001 and more than 400,0000 samples preserved. This has been achieved by, on the one hand, managing the four pre-existing ICARS (including IRRI and ICARDA[2]) and on the other, extending the fields of activity covered, with the creation of new centres (CIMMYT[3] and ICARDA, for example, being established in 1972). In 1974 the CGIAR set up a new co-ordinating organization, the International Board for Plant Genetic Resources (IBPGR) with its headquarters at FAO offices in Rome. The IBPGR did not create its own gene banks, but simply designated the existing structures as "reference collections" for the phytogenetic material collected. In the middle of the 80s, the IBPGR's network consisted of about 600 scientists and 150 collections of basic genetic material in some forty seed banks. However, although a lot of these activities are taking place in industrialized countries, a large proportion of gene banks in developing countries are CGIAR centres and not national collections managed by a country. In this

1 International Rice Research Institute
2 International Centre for Agricultural Research in Dry Areas
3 International Maize and Wheat Improvement Centre

context, various authors have pointed out that some industrialized countries, which have relatively low natural phytogenetic diversity, are as rich in terms of their collections of genetic material as third world countries. New issues are therefore being taken on board in relation to collections of plant genetic resources, particularly by developing countries.

Growing awareness of the importance of access to and use of collections of genetic resources: are intellectual property rights for seeds compatible with the notion of a "humanity's common heritage" for plant genetic resources? From the end of the seventies, several countries voiced concerns at the difficulties of accessing genetic resources originally obtained by prospecting in developing countries, but now located in ICAR collections or in collections in industrialised countries. Similarly, IBPGR collecting activities are another source of conflict. The IBPGR was commissioned to co-ordinate and finance sample collecting activities in countries, particularly in developing countries. However, the priorities for collecting are very close to those of industrialised countries because they relate essentially to the major cereal cultures, and cultures considered to be important on an international scale, although the part played by the ICARS and developing countries is still significant. Finally, given that genetic resources are considered to be "humanity's common heritage," with access depending on the sovereignty of states, they ought to be freely accessible to all, without any restrictions. This has led to the private use of the genetic resources contained in these collections, not only as a vector for diversity but also as a vector for particular characteristics (yield, resistance, etc.). For user countries, this has resulted in – through the commercialisation of seeds protected by intellectual property rights (plant variety certificate or patent) – the development of private profits and an increase in social well-being, without compensation (either through technology transfer or money payment) to the countries of origin of the resources. Against this background of conflict, negotiations on the FAO's international commitment on phytogenetic resources began in 1983. The FAO acts to preserve free access to phytogenetic resources, access to genetic diversity being of prime importance in order to limit the risk of eroding agricultural production and to ensure the development of seeds. This entails preserving the notion of "humanity's common heritage" for genetic resources. The FAO also strives for the implementation of financing mechanisms to compensate the countries of origin of these resources, in the form of technology and monetary transfers. These are distributed via an international fund fed by voluntary payments from countries and private enterprise, in return for using the phytogenetic resources preserved in international collections and reference collections. Administration of this fund remains centralised at the FAO. In 1989 the FAO revised its proposals because of the lack of success of its 1983 programme due, partially, to the poor level of voluntary contributions to the fund and partially to the increasingly urgent demands of developing countries. The FAO defined the "right of farmers," which is the stage prior to the notion of national sovereignty, because it recognises the work of domesticating and improving local varieties carried out by successive generations of farmers. This can be remunerated by a a sort of tax, (a user's fee), or by a mandatory international fund based on a percentage of a macro-economic indicator. Such a system could have worked if certain countries, particularly the United States, had not favoured a policy of protecting innovations in biotechnologies by means of patents, while still demanding access – whether free or paid – to plant genetic resources, without any technology transfer, or licensing from patents. Southern hemisphere countries considered this position to be unacceptable and asserted their right to national sovereignty over genetic resources. This has brought us closer to a private sector approach, with bilateral negotiations for access to genetic resources, royalty payments, technology transfers and dependence licences on patents.

Growing awareness of the importance of genes, from the 1992 Rio convention to the FAO 2002 international commitment: conditions of access to plant genetic resources and sharing of the advantages. The 1992 Rio Convention on Biological Diversity (CBD) recognised the sovereignty of States over their resources and, simultaneously, their responsibility to manage and conserve them. Signatory states also recognised the need for a fair and equitable sharing of the advantages linked to the use of genetic resources. In the context of international negotiations on biodiversity, thought must be given to how this convention might be implemented (by both Northern and Southern hemisphere countries) and the different economic and legal tools that can be applied. The CBD favours a position that equates to pseudo-free access, which is facilitated by bilateral agreements with transfers of benefits and technologies, and close to the RGV model for private management. In order to reach this level of interaction, each state must define national legislation for access to genetic resources, specifically the implementation of contracts, the best known being Material Transfer Agreements, which are applied either in a firm-to-state relationship (or firm-to-local community, or collection of genetic resources) or in a firm-to-firm relationship. Thus, in the case of FAO multilateral exchange agreements (International Commitment 2001), MTA-type contracts limit the risk of an innovator preventing access to a resource without the agreement of its initial holder. These contracts can also help ensure either that no property rights are taken out on innovations derived from a collection or, where authorisation to take out intellectual property rights is granted, to make sure that the advantages are shared (results of research, transfer of innovation, technological transfer and/or royalty payments) for innovations resulting from the use of material or genetic information contained within it. In relation to plant protection, it is worth noting that although the United States uses mainly patents, the European Union proposes plant certification (PC) and/or patents with mandatory dependence licences designed to maintain free access to biological diversity while still ensuring the protection of the innovation variety. In this context the FAO has pursued its attempts to guarantee special status for agricultural genetic resources, leading to the signing of the International Commitment in November 2001. The International Commitment is a multilateral agreement that ensures access to the genetic resources of signatory countries without exclusion. This is achieved by means of contracts that stipulate the compensation that must be paid to an international fund for developing countries, depending to an extent on the innovation, but more importantly, on the intellectual property rights taken out for the innovation. Protection by PC, which ensures free access to the genetic resource for innovations that are not "essentially derived from" a resource, requires no contribution. There may, however, be a contribution of a voluntary nature where a patent is involved, and access may be blocked to certain resources. It is worth bearing in mind that although the International Commitment is a step toward generalised remunerated free access, it is limited to a list of species. Other species not on the list must be managed by the CBD.

Internet Sites.

http://www.cdb.org Official site of the Convention on Biodiversity
http://ww.fao.org Official site of the FAO.
http://www.brg.org French Bureau for Genetic Resources.
http://www.cgiar.org Consultative Group on International Agricultural Research. Provides access to the sites of all International Centres.
http://www.cnrs.fr Centre National de la Recherche Scientifique.
http://www.cirad.fr Centre de Coopération en Recherche Agronomique pour le Développement.
http://www.inra.fr Institut National de la Recherche Agronomique.
http://www.dainet.de/genres/vir/history/vavilov.htm The extraordinary biography of Nicolai Vavilov.

Biodiversity: heritage under threat, ruthlessly pursued resources and the very essence of life.

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From the diversity of life to the concept of biodiversity.

It is a well known fact that life takes many different forms. When cavemen painted bison, lions, boar and antelope they were already demonstrating – among other things – their knowledge of a diversified living world.

Since then, naturalists, palaeontologists and systematists, and later ecologists and geneticists, have long commented on the diversity of life, the richness of living and extinct species, the genetic variability within populations of the same species and the diversity of ecological functions and ecosystems.

Thus, since it first appeared 3.8 billion years ago in the waters of planet Earth, in the form of molecules and then protocells capable of reproducing themselves, life has continuously extended its diversity through transforming itself. When new species come into being, others disappear: like the individuals who make them up, species are mortal, but their lifespan is usually counted in millions of years (from 1 million for vertebrates to ten million for invertebrates). We know that the planet has survived several major natural disasters – massive volcanic eruptions, asteroid impacts, etc. – and that these events have led to what we call major extinction crises. For example, as a result of the turmoil that followed the impact of an asteroid 65 million years ago (the scar is still visible in the form of the immense Chicxulub crater in Yucatan), and the eruption of the Deccan Traps in India, the dinosaurs that "dominated" the Earth at the time were wiped out. They gave way to the mammals, which then diversified on a prodigious scale, giving rise to a succession of adaptive radiations... and the appearance of man!

In short, life is a phenomenon that has lasted for nearly 4 billion years. It has never ceased changing due – to a greater or lesser extent – to its environment. In order to adapt, life has used its intrinsic capacity for diversification, which is what has enabled it to succeed: what finer example could we have of sustainable development? But also what a lesson: to survive in a changing world, it is essential to diversify, and transform!

Today the Earth is home to more than ten million species – estimations vary between 10 and 30 million – but the number of known species, i.e. species described and named, does not exceed 1.7 million. Known, is something of an overstatement, since for the overwhelming majority of these species we are almost totally ignorant of their biology, their functional characteristics, their role in the planetary ecosystem and their possible uses for man.

Thus, 250,000 plant species have been identified (there may be 280,000). From ten to 50,000 of these species are considered to be edible to man, but he consumes only between 150 and 200. Nine species (wheat, rice, maize, barley, millet, potato, sweet potato, sugar cane and soya) that have been domesticated for thousands of years contribute more than 75% of the vegetal calories and proteins that feed humanity, and just three (wheat, rice and maize) account for more than 60%. Whereas the traditional Chinese pharmacopeia lists nearly 5,000 plant species, the pharmaceutical industry has explored the medical potential of scarcely a thousand of them.

Are bare numbers sufficient to enable us to appreciate the diversity of life, its significance, even its *raison d'être*? Or does our fascination with numbers and quantification distract us from the crucial point: the virtue of diversity itself, the vital value of the existence of differences? The enumeration of the diversity of life is inadequate to translate what the concept of biodiversity gives us, a concept that literally came into being at the United Nations Rio de Janeiro Conference on Development and the Environment in June 1992. The word itself was coined in 1985 by Walter G. Rosen while working in a scientific workshop in the build-up to the Rio conference. But it was Edward O. Wilson who launched the word into the scientific community with his work entitled *Biodiversity*. A work that resulted from the same workshop, four full years before its worldwide success at Rio.

The diversity of life is a fact. I would like to limit use of this new word *biodiversity* – which on a superficial level appears to convey the same meaning – to the concept that was developed behind the scences at Rio de Janeiro and which resulted in the Convention on Biological Diversity. Refering to the diversity of life in this context means something different from what the systematist, the geneticist or the ecologist usually means in his own specialised world. It does means all that, but it also means more. And it is therefore different.

The concept of biodiversity introduces two epistemological breaks with the familiar observation of the diversity of life.

The first remains within the field of natural sciences and highlights the interdependence that exists between the three major elements of diversity in life, traditionally studied separately by specialists who are inclined to ignore each other. The elements I refer to are genetic variability, the diversity of species and functional or ecological diversity. And the specialists are geneticists, systematists and ecologists. In short, it is the very idea of diversity that is most important.

The second epistemological break – and in my eyes the more significant of the two – takes us out of the field of natural sciences: the concept of biodiversity is not purely the property of biologists. This break places the diversity of life at the very heart of the issues, concerns and conflicts of interest that appeared at Rio. It explains how the application of an international convention ratified by 182 countries and the European Union – a convention whose aims included organizing the development of knowledge, the protection and sustainable use of the diversity of life and a fair distribution of the advantages that arise from it – is now unavoidable for the governments of the world (even those, like the United States, that refused to sign).

These considerations place us firmly in a different conceptual universe from that of the biologists, who focus on the diversity of life, its states, mechanisms and role in the way ecosystems work.

Human activities and extinction crisis: growing awareness.
Between Stockholm 1972 and Rio 1992 a profound change began that should culminate in Johannesburg 2002: we have moved gradually from concerns that centred mainly on preservation of the environment (Stockholm) to awareness at a global level of the great interdependence between saving the environment and the diversity of life on the one hand, and continued social and economic development on the other (Rio). In Johannesburg, the emphasis should be placed on the conditions for the sustainable development we have talked about since Rio and issues regarding biodiversity should be taken into account against this perspective. This will making a definitive break between the preservationism of a nature that is foreign to man – typical of post-war conservation movements (that created reserves, bans and fences) – and participative management of biodiversity and landscapes where it is deployed, as advocated at Rio by the Global Biodiversity Strategy (1992).

But first we should return to what has been called the sixth mass extinction crisis and our species' responsibility in the matter.

With the ecological and economic success of the human race, we entered the sixth extinction crisis. The five previous crises were the consequences of geological (volcanic eruptions) or astronomic (falling meteors) catastrophes, generally followed and amplified by climatic and therefore ecological changes. The present crisis stands out as being the work of man, but also because it is taking place on a much more restricted time scale and in a geographical area that is increasingly monopolised by man and his activities. It threatens the very foundations of the sustainable development of human societies.

The prehistoric colonisation of the islands of the Pacific and Indian oceans one to two thousand years ago by man with his cortege of associated species: rats, cats, dogs, goats, pigs, is certainly the cause of the extinction of about one quarter of the avian fauna of the world and, more generally, many large species, birds, mammals and reptiles. Before the arrival of the Europeans, the Maoris destroyed the moas, immense ostriches that were endemic to New Zealand. In this respect the case of Madagascar is particularly eloquent[Encart 1].

Estimated extinction rates are fairly precise for the best know taxonomic and most accessible groups: vertebrates and higher plants. Apart from that, we can only hazard extrapolations, based on the relationship that is well known to ecologists and bio-geographers between the specific richness S and the area of the habitat A ($S = kA^z$) and which enables us, for example, to predict an extinction rate from simple deforestation figures[Encart 2].

Since the year 1600, 484 vertebrate species and 654 plant species have disappeared from the planet. This is without any doubt an underestimation because the available information for tropical regions is incomplete.

Based on a diagnosis of the state of natural plant and vertebrate populations and their milieus, the IUCN has established a list of species that are threatened with extinction. The list contains 3632 plant species and 523 vertebrate species.

Most authors suggest an extinction rate that is between 1,000 and 10,000 times greater than the natural rate. Although the main cause lies in the demographic, economic and technological expansion of man, it is compounded by three secondary or resulting causes: destruction, alteration or fragmentation of milieus, the increasing introduction of invasive species[Encart 3] and over exploitation (hunting, fishing, harvesting).

Encart 1. Man and the extinction of species on Madagascar.

Madagascar is a large island of 594,180 km² that is renowned for the high endemism of its fauna and flora. When Portuguese explorers arrived there in about 1500 they found a people that had lived there for nearly two thousand years, having originally come from Indonesia, with a few stops along the way in India and the east coast of East Africa. These Madagascans had built up a society that was based on breeding bovines and pigs, as well as fishing and agriculture.

At a distance of 400 km from the African continent, from which it has been separated for 200 million years, Madagascar was never home to the ostriches, baboons, zebras or lions that are a great tourist attraction in the large reserves of East Africa. However, it did have its own ecological equivalents of these great carnivores and herbivores, though these are now known to us only through their skeletons.

These large species were unable to resist the effects of man and his domesticated animals. They were either their direct victims or were unable to support the ecological transformations that resulted from their expansion. Half a dozen species of large non-flying birds measuring up to three metres in height and weighing 500 kg thus became extinct. A profusion of bones and eggs (the size of a football) of this Elephant Bird or Aepyornis can be found on the beaches of Madagascar. Six genera of lemur, all large and diurnal (one the equivalent to the gorilla) figure among the list of extinct species, along with two turtles, whose shells measured up to a metre in length, and a large carnivore, a sort of giant mongoose. Madagascar is one of the great centres of biodiversity, especially rich in endemic species and particularly threatened by the current extinction crisis that is arousing so much interest today.

Encart 2. Worrying deforestation rates.

The loss of natural habitats is one of the most serious threats to biodiversity and the destruction of tropical forests has become synonymous with a loss of biodiversity. (The recent sixth Conference of Parties at The Hague in Holland was particularly concerned about this issue). Humid tropical forests cover 7% of the terrestrial surface and are thought to be home to 50% of terrestrial species. Based on temperature regimes and precipitation, the original extent of humid tropical forests has been estimated at 16 million km^2. Thanks to a combination of observation on the ground and interpolations from satellite images we can evaluate the current surface area of tropical forests and annual deforestation rates.

Conversion rates from natural habitats to agricultural land for the decade 1980-1990.

Conversions to cultivation/plantations		Conversions to pasture land	
Paraguay	71.2 %	Ecuador	61.5 %
Nigeria	32.0	Costa Rica	34.1
Mongolia	31.9	Thailand	32.1
Brazil	22.7	Philippines	26.2
Ivory Coast	22.4	Paraguay	26.0
Uganda	21.4	Vietnam	14.0
Thailand	17.1	Nicaragua	11.8

However, these estimations of deforestation rates continue to be contested because they depend on definitions and pre-suppositions that are used both to quantify the original extent of the forest and the nature of the forest strips converted to other uses.

On a planetary scale the first cause of the destruction of tropical forests is the development of cultivation and plantations (45,000 km2/year). The same area is destroyed by commercial exploitation of wood. To this we must add 25,000 km2 degraded in the production of heating wood, mainly for the needs of villages and to cook food. Lastly, 20,000 km2 are cleared annually for purposes of animal husbandry and to provide pastureland.

The relative importance of these activities varies according to the world region considered, wood exploitation predominating in tropical Asia, animal husbandry in Latin America and firewood gathering and animal husbandry in tropical Africa.

The effects of this fragmentation of the forest milieu on the erosion of biodiversity have yet to be analysed.

We must also add a fourth derived cause: cascading extinction. When one key-species disappears, it takes with it a whole series of other species that were dependant on it (the disappearance of a plant can lead to the extinction of all associated insects; the disappearance of an insect can wipe out the plants that it pollinated).

But apart from these ecological causes of extinction, it is clear that the leading cause is the growth of the human population and its needs for natural resources.

In this context we can note some amplifying factors: the increasing weight of an economic system that is unable to take into account the environment, renewal of resources and the interests of future generations. The globalisation of the economy and the consequent reduction in the range of products coming from agriculture, forestry or fishing; the predominance of legislative and institutional systems that favour non-sustainable exploitation of resources; the insufficient nature of our knowledge and the absence of its application.

Encart 3. Introduced species and extinction.

For some twenty years the island of Guam in the Marianne Archipelago between Japan and New Guinea has been affected by the collapse of its avian fauna. Of the 18 indigenous species, seven are today considered to be extinct and four others have become so rare that their disappearance seems to be inevitable. This decline, which has no equivalent in any of the other islands in the archipelago, is attributed to the introduction and expansion of the brown tree snake, Boiga irregularis. It is a voracious predator for perched and nesting birds, as well as for their eggs and offspring. Moreover, because it also feeds on small mammals and lizards (the latter are particularly abundant), it can reach high densities while exterminating its most vulnerable preys.

On the island of Santa Catalina off the Californian coast, 48 local plant species have been eliminated mainly through overgrazing by goats and other herbivorous mammals that have been introduced.

In Madagascar, where the ichthyofauna is highly endemic, with 14 of its 25 genera unknown elsewhere, a recent inventory of fresh water zones was unable to find five of them. Introduced fish dominate all these aquatic milieux. The combination of the degradation of natural milieus and the introduction of exotic fish seems to lead the native ichthyofauna to complete extinction.

And there is the case of Lake Victoria that is known for its 350 endemic species of fish. Today many of them are rare or extinct. Apart from the introduction of the Nile perch in 1960, other factors have a role to play in this large-scale process of extinction, among them pollution through fertilisers and other pollutants and the proliferation of the resulting algae and anoxia.

One of the messages coming from the Rio planetary summit is that if we do not begin to take measures now to protect milieux and species, we shall be compromising the chances of sustainable development for ourselves and for future generations.

Priority action must focus on: improving fundamental knowledge and distributing it; developing strategies for conserving and maintaining sustainable use of the planet's resources; the implementation of procedures to favour a fair distribution of the advantages derived from biodiversity. These are the three objectives underlined by the Convention on Biological Biodiversity.

The protection and sustainable use of biodiversity must become integral parts of economic development. The adoption of an ecological framework, in the broad sense of the term, must make it possible to bind preservation of resources to development, thus breaking away from the erroneous models whereby some claim that protection of biodiversity and the biosphere will necessarily hinder development, whereas others allege that development will inevitably deplete resources and degrade ecological services [Fig.1].

We can thus change from a situation of non-sustainable development to the situation of sustainable development that all nations recommend. But let us review the major stages in the history of protecting nature in order to have a better understanding of the evolution of the ideas taking shape; ideas which the Johannesburg conference should contribute to accelerating and implementing.

In relation to the emergence of agriculture some ten thousand years ago, the desire to protect nature is relatively recent. If we adopt as a criterion the creation of protected zones, reserves and natural parks, we find the first signs appearing toward the end of the 19th century with the creation, in the United States in 1872 of the first national park in the world, the Yellowstone[1] National Park. However, it was not until the first half of the 20th century that the movement took root: the first natural parks in Europe were created by Sweden in 1909, followed by Switzerland (1915) and Great Britain (1949).

In France the reaction was slower, with the exception of the National Society for the Acclimatization and Protection of Nature (Société Nationale d'Acclimatation et de Protection de la Nature), a private scientific and philanthropic association that created the Camargue zoological and botanical reserve in 1928. It was not until 1960 that a first law relating to national parks was voted in, followed by the creation of the first national park, the Valoise, in 1963.

1 We can, however, trace the origin of conservationist practices further back to philosophical and religious beliefs that accorded a sacred value to exceptional landscapes, to animals or to life itself.

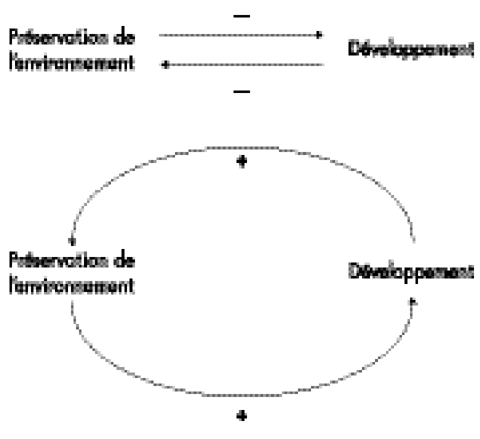
The International Union for the Protection of Nature was created in 1948. Its transformation, eight years later, into the International Union for the Conservation of Nature and Natural Resources (IUCN) gave formal recognition to the idea that the preservation of nature should form part of a much broader perspective relating to the judicious use of nature and its fruits for the benefit of man.

But the publication in 1992 of the *World Strategy for Conservation* was a landmark that stressed the need to preserve ecological processes, while still paying attention to the demands of development.

The Global Biodiversity Strategy.
In 1992 the Global Biodiversity Strategy – a guide to studying, preserving and using the resources and biological wealth of the planet in a way that is both sustainable and equitable – was published under the aegis of the World Resources Institute, the World Conservation Union and the United Nations Programme for the Environment.

The preface, which is signed by the directors of these three organisations, points out that "*development has to be both people-centered and conservation-based: Unless we protect the structure, functions, and diversity of the world's natural systems*

Figure 1. From the traditional vision of the environment/development relationship (top) to the ecological vision (bottom), which constitutes the key model for sustainable development.



– on which our species and all others depend – development will undermine itself and fail. Unless we use Earth's resources sustainably and prudently, we deny people their future. Development must not come at the expense of other groups or later generations nor threaten other species' survival."

The major leap imposed by this text, in relation to the dominant philosophy in circles dedicated to the protection of nature before Rio, is the insistence on the fact that conservation of biodiversity is not simply a question of protecting wild species in nature reserves but that it also – and principally – consists in saving the great ecosystems of the planet, perceived as the very basis and support for our development.

Of course the same idea was already at the origin of the concept of a biosphere reserve[Encart 4] and Unesco's Mab (Man And Biosphere) programme clearly fitted into a perspective of ecodevelopment as soon as it was launched in 1971. For various reasons that it would take too long to analyse here, and because it is in the nature of things human that it takes time to implement cultural and practical evolutions into reality, the idea needed to be relaunched by the Gbs. This venture was also based on greater knowledge and greater awareness.

Encart 4. Biosphere Reserves.

In 1974 a workgroup from Unesco's "Man And Biosphere" programme (initiated in 1971) launched the idea of the biosphere reserve. The originality of this concept, compared with the traditional perception of reserves and the philosophy on protecting nature that prevailed at that time, was that it simultaneously took into account the objectives of both conservation and development. Traditional reserves are defined in relation to nature; biosphere reserves begin with a series of questions and reflections on the relationships between human societies and their natural environment. They were designed to respond to one of the most essential questions being asked today: how can we reconcile conservation of biodiversity and biological resources with their sustainable use?

The reserves of the biosphere are protected areas that have been set apart by States, which then submit them for Unesco approval to be included in the world network of biosphere reserves.

Each biosphere reserve is destined to fulfil three fundamental functions that are complementary and interactive[Fig.2]:

1 a conservation function, in order to ensure the protection of the countryside, ecosystems, species and their intrinsic genetic variability;

2 a development function, in order to encourage a local economy that is sustainable from an ecological, sociological and cultural point of view;

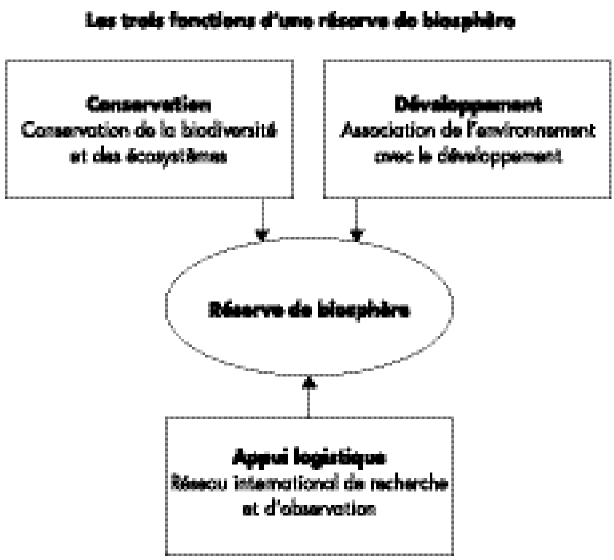
3 a logistical function, for research, on-going supervision, education and training

with regard to conservation and sustainable development on a local, regional and planetary level. These areas comprise – around a central completely protected zone – buffer zones where non-destructive activities may be carried out and transition zones where sustainable economic activities that are compatible with the environment may be set up.

They resolutely bring together in the main ecosystems of the planet both conservation, which is their ultimate goal, and sustainable development. They also constitute a world network for research and ecological supervision and contribute to developing awareness, education and training with regard to environmental problems.

Unesco has approved the creation of 409 biosphere reserves in 94 countries. There are ten in France: Camargue, Cévennes, Tuamotu (French Polynesia), the Fango Valley (Corsica), the Guadeloupe archipelago, the Mer d'Iroise, the Mont Ventoux, the Pays de Fontainebleau, the Luberon and the Northern Vosges.

Figure 2. Every biosphere reserve is supposed to fulfil three complementary functions that are mutually supportive: conservation, development and logistical support for research and education.



Moreover, this post-Rio dynamism has contributed to relaunching the world mechanism for biosphere reserves, in the context of the "Seville Strategy," put together at the end of a conference of experts organised there by Unesco in March 1995 (see Biosphere Reserves. The Seville Strategy and the statutory framework of the World Network, 1996). One of the salient points of this document is the new role attributed to biosphere reserves in the implementation of the results and recommendations of the United Nations Conference on Environment and Development at Rio, and particularly the Convention on Biological Diversity.

This dynamism reflects a global increase in activity among those involved in conservation, nature and resources management. It has also influenced NGOs that – as we have seen – have succeeded in making an impression since Rio, as well as the relevant scientific community itself.

It is worth saying a few words about this scientific activity. The groundwork was prepared backstage at Rio and was meant to pave the way for Unesco, the International Union of Biological Sciences and Scope to launch a broad international programme called *Diversitas*.

National scientific bodies did not accept the *Diversitas* programme without some difficulty, but it eventually gave rise to great dynamism that has produced concrete results in the form of national and regional programmes for biodiversity and a new strategic plan that clearly defines three priority fields:

1 Understanding, guaranteeing supervision of and predicting changes in biodiversity;
2 Evaluating the impact of these changes in terms of the ecosystems and how they function, as well as in terms of people, their health and that of their domestic species;
3 Developing the sciences involved in conservation and biodiversity and its sustainable use, as well as the necessary measures and practices.

Here again, this follow the progression of ideas toward approaches that suit a culture of sustainable development. A progression that better integrates various areas and directions of knowledge that were previously separate or simply operating side by side.

Thus, the epistemological revolution seems to be complete. The revolution implicit in moving from an enraptured description of the diversity of life, to the development of an awareness of the complex dynamics wherein human societies, diversity of species and the ecological context interact with and overlap each other – what I have suggested should be the meaning of the word "biodiversity" when used as a concept. Johannesburg should be the international stage for its implementation within the framework of a planet-wide project for sustainable development.

Biodiversity as a resource: the major issues.

Before looking – in the spirit of the times – at the interest in terms of resources for man that biodiversity represents, it would seem useful to examine the *raison d'être* of this diversity for the living world itself: animal, plant, micro-organism and man.

Intraspecific genetic diversity is the ultimate basis of evolution. The adaptation of wild or domestic (or cultivated) populations to local conditions depends on this. The history of agriculture has amply demonstrated this: genetic diversity ensures adaptation to a changing world, and thereby guarantees the future. It is this potential that enabled the improvement of animal and plant breeds for the greater benefit of human populations. Even today, an estimated 50% of production increases come from the exploitation of this wild genetic heritage.

The relationship between biodiversity and the way ecosystems function is less well established. As early as the 1950s, ecologists were defending the hypothesis that the diversity of species could affect how ecosystems work in three ways:

1 greater diversity should increase resistance to invasions by other species;
2 it should reduce the severity of attacks on plants by pathogenic agents;
3 it should translate into greater richness in the upper trophic levels.

Stimulated by post-Rio debate, recent experiments support this analysis and the more general hypothesis whereby the diversity of species gives ecosystems a greater capacity to resist disruption and to restore balance after it has occurred (resilience).

In other words, it seems that the diversity of species gives ecological communities the capacity to resist their enemies and to adapt to disruption and changes to their environment.

Thus, the loss of diversity of genes within a species, species within ecosystems and ecosystems in a region, indicates drastic reductions in the goods and services produced by the ecosystems of the planet, following disruption to the environment,.

In a word, biodiversity ensures adaptation to a changing world, a guarantee of *sustainable development*.

An economic approach to biodiversity.

In order to be fully accepted, it is not enough that conservation biology develop rigorous knowledge of the dynamics of biodiversity and propose ecologically effective strategies for its preservation.

It must also develop these strategies in such a manner as to render them compatible with the economic development of the populations destined to implement them. *Conservation must become a politically and socially acceptable target.*

This supposes an economic, as well as an ethical and philosophical evaluation of biodiversity. In fact, trying to evaluate the biological resources and ecological services provided by biodiversity in monetary terms does not allow us to avoid questioning *its value for human societies*.

Any economic evaluation of biodiversity faces three types of difficulty:

1 a large proportion of biodiversity, along with its precise roles and functions, is unknown to us;

2 there is no universal and homogeneous indicator for this biodiversity that would be capable of integrating genes, species and ecosystems;

3 the usual economic tools are not really compatible with the ecological representation of the world that is required in order to take account of the dynamics of biodiversity. These include – in particular – a timescale and direct and indirect hierarchies of interaction, far removed from the usual concerns of the market economy.

Under these conditions, what type of economics must we develop in order to analyse these problems?

We can try to evaluate in monetary terms the genetic resources, species taken separately, even ecosystems, by measuring the economic utility of each of these elements of man's natural heritage, while bearing in mind that the problem is a veritable scientific enigma that can only partially be solved.

More often than not, these resources do not have a market value and their economic evaluation can only be indirect. The value indicator then used is its induced wealth, in other words, the wealth created by economic activities that can be developed around the resources considered.

Thus, although it is impossible *a priori* to set a real economic value on wild plants, we can, however, make realistic estimations in certain specific cases. Here are two examples of plants related to cultivated species:

1 a wild strain of wheat in Turkey provided resistance genes that were incorporated into several varieties of commercial wheat, thus creating an estimated profit of 50 million dollars a year for the United States alone;

2 the resistance gene for yellow dwarf virus supplied by an Ethiopian barley now protects the Californian barley harvest from this fatal disease, the equivalent of an income of 160 million dollars per year.

More generally, according to United States Department of Agriculture estimates, the genetic resources (related wild plants and cultivars) used to improve plants, yield an annual increase in agricultural productivity in the region of one billion dollars. Moreover, by avoiding famines and malnutrition, the world contribution of wild relatives of cultivated plants represents an estimated indirect benefit of several billion dollars a year.

Economists tackling the problem of evaluating biological diversity defined a framework of values adapted to this particular purpose.

They distinguished four categories of value
1 *usage values*, which suppose *consumption* of the resource in one form or another;
2 *option values*, linked to the possible future *exploitation* of the resources;
3 *existence values*, linked to the *satisfaction or well being* procured by the existence of biodiversity;
4 *ecological values*, linked to the *interdependence between organisms* and *smooth operating* of natural systems.

Usage values, which are close to the traditional economic universe because they are the same as those of consumer society, are by far the easiest to assess. Most authors distinguish three sub-sets inside each category:
1 *direct consumption* values, when the products are used without any transformation, as in fishing, hunting and gathering;
2 *productive* values, coming from using the resources in production cycles, as in the case of forest harvesting, extracting substances with medical virtues, improving plants and variety production;
3 *recreational* values, which suppose a subjective use of the resource without real consumption, as in the case of hiking or a photo safari.

Some of the values defined above are difficult to appreciate in monetary terms. How can we assess the value of the gorilla or the white whale? What value do we accord to a landscape? The pleasure of coming across a deer, a fox or a boar in the course of a forest ramble.

Economists studying the environment have developed a method, called contingent evaluation, which they try to apply to all cases where a direct economic evaluation is impossible. Based on surveys, it consists of estimating how much potential "consumers" would be willing to pay: how much would they be willing to pay to protect the African elephant, to preserve or restore a given landscape?

This approach has given rise to profound scepticism. Of course it comes up with figures, but what are they worth? What do they mean?

At the end of the day, it seems to be preferable to adopt a more pragmatic and less ambitious approach, even if that means using purely qualitative criteria.

In the meantime, we can already consider the current value of world markets relative to the goods and services provided by a few major activities linked to biodiversity, such as forestry (85 million dollars a year), the pharmaceutical market linked to plants (200 million dollars a year) or tourism (about 2.5 billion dollars a year).

Biodiversity, a source of medication.

For a very long time mankind relied exclusively on natural medication extracted from plants, animals or minerals to treat illness.

Thus, primitive populations discovered that the bark of quinquina treated intermittent fever, that hunger could be appeased by chewing coca leaves, that gravid animals aborted after consuming seeds contaminated with ergot of rye, or that the latex from unripe poppy capsules eased pain.

"Natural" medicine is very old and still very widespread. The *Pen ts'ao*, by the Chinese herbalist Shen Nung, dates back to 2800 BC: it lists 366 medicinal plants, including *Hephedra*, which is well known today because one of its alkaloid, hephedrine, is used in ophthalmology.

Rather more recently, Dioscorides described more than 600 therapeutic plants in his *De Materia Medica* (in the year 78 our era), among which we find aloe, ergot and opium.

Finally, we mustn't forget Theophrastus Von Hohenheim, better known as Paracelsus (1490-1541) who was responsible for the birth of medical chemistry.

In the 19th century the development of organic chemistry in Europe made it possible to analyse the active components of medicinal plants, and the modern pharmaceutical industry came into being. Today, an estimated 40% of medicines contain an active ingredient extracted from a natural substance, a plant in two thirds of cases.

Table 1. Principal plants and their active products used for medical purposes

Species	**Compound**	**Usage**
Belladonna	Atropine	Anticholinergenic
Camelia	Caffeine	Stimulator of nerve centres
Camphor tree	Camphor	Vasodilator
Coca	Cocaine	Anaesthetic
Poppy	Codeine	Analgesic, antitussive
Morphine	Analgesic,	
Colchicum autumnale	Colchicine	Antitumor agent
Digitalis	Digitalin	Cardiotonic
Rauwolfia	L. Dopa	Antiparkinsonian
Menthe	Menthol	Vasodilator
Chincona tree	Quinine	Antimalarial, antipyretic
Reserpine	Hypotensor	
Datura	Scopolamine	Sedative
Nux vomica	Strychnine	Stimulant for the central nervous system
Thyme	Thymol	Antifungal

Table 1 provides some examples of pharmaceutical compounds of major importance that were obtained from higher plants.

The WHO estimated that 80% of the population of the planet regularly has recourse to traditional medicine based on plants. Traditional Chinese medicine currently uses more than 5,000 plants, one thousand of them on a regular basis.

In the United States and Western Europe an estimated 25% of medical prescriptions contain ingredients extracted from higher plants. Francesca Grifo of the American Museum of Natural History has shown that 118 of the 150 most frequently prescribed medicines in the United States were originally derived from living organisms, 74% plants, 18% fungi, 5% bacteria and 3% from *Bothrops* (a venomous snake) alone. Nine of the top ten are based on natural products coming from plants.

The situation is undoubtedly the same elsewhere, or indeed even more marked by the use of products extracted from nature. Many medicines widely used in Europe are not for sale in the United States. For example, a derivative of gingko leaves is considered to be very widely used by Europeans over the age of 45. Various compounds derived from distilling the leaves of this tree have the property of facilitating cerebral circulation and are thought to reduce the risk of Alzheimer's disease. It is interesting to reflect that this species escaped total extinction in nature thanks to the Chinese monks who long maintained them in the gardens of their monasteries.

Another example is a product extracted from mistletoe, which doubles the life expectancy of women suffering from breast cancer.

And of course there is the case of *Aconitum napellu*, one of the most poisonous European angiosperms (flowering plants). It contains between 0.4 and 0.8% of aconitine in its dry matter and a whole series of other alkaloids (aconine, napelline). Aconitine is a powerful poison: three or four milligrams is enough to kill a human by paralysing the nervous system, a fact that was well known to the Gauls and Germans who applied *Aconit* sap to the points of their arrows in order to inflict mortal wounds.

Used in the right doses these same alkaloids extracted from leaf or root powder are used to treat bronchitis, rheumatism and trigeminal neuralgia.

In the domain of anticancer therapy, the search for active substances of vegetal origin led to the discovery of a new class of molecule, the taxoids – taxol and taxotere. Taxol is a molecule that is extracted from the bark of the Pacific yew tree and is used to treat breast cancer. It was discovered in the United States and its antitumoral action was identified in 1979. To extract taxol it was necessary to fell trees with a very slow growth rate (one hundred-year-old tree provides only one gram of taxol, half the quantity required to treat one person for one year). Thus semisynthetic taxol produced in laboratories had to be used instead.

More recently researchers at the CNRS Institut de Chimie des Substances Naturelles at Gif-sur-Yvette succeeded in synthesising taxol from a precursor present in the leaves of the European yew. This has the advantage of constituting a renewable source because the leaves can be picked without having to fell the tree. Moreover, this research facilitated the discovery, among the intermediate synthetics, of taxotere, which is more active than taxol.

Having said this, the proportion of plant species that have been explored for possible medicinal properties remains astonishingly low: barely 1100 species out of 365,000 known species (including algae)!

How can we estimate the market potential represented by tropical or other forests in terms of discovering new medicines?

To date, the proportion of studied plants yielding a major medical substance is one out of 125. The corresponding market in the United States is at least 200 million dollars a year. If we suppose that one species of tree currently disappears per day, we can then estimate the loss of potential medicines at three or four per year, a cost of about 600 million dollars.

Pharmaceutical companies continue to largely ignore this source of medicine, preferring to test synthetic molecules at random, although the chances of discovering a major new molecule are 1 for every 10,000 tested. Companies have much more difficulty patenting natural products than those they make synthetically. The potential profits from marketing natural products are therefore significantly lower, not to mention problems with customs and importation rights.

The marine world has long remained unexplored from this point of view. The study of biological molecules of marine origin only really began in the 1950s. The description of some three to four thousand new substances, synthesised by marine organisms, algae, invertebrates or micro-organisms, has enabled us to classify nearly 500 new active substances: anti-tumorals, anti-virals, immuno-modulators, antibiotics, anti-fungals, etc.

At present, three medicines of marine origin are commercially available: one antibiotic (cephalosporin), one antiviral (vidarabine) and one antitumoral (cytarabin).

Finally, carefully selected genetic mutations may transform plants into medicine factories. Neuroleptic colza is a good example. Colza is a crucifer that is the result of natural hybridization between cabbage and field mustard. Its domestication centres were located in the overlap zones of diversity centres for field mustard (Eurasia) and cabbage (Western Europe and North West Africa). It is cultivated for its seed, which is rich in oil and proteins. Through genetic engineering man has created a producer of neuroleptics. This discovery by the Belgian company Plant Genetic System (PGS), with a seed harvest of 30 quintals/hectare, produces 3 kg/hectare of this therapeutic molecule.

Biodiversity and human food.

It is quite surprising to realise that human civilisation uses an extremely restricted number of species in agriculture and animal husbandry, most of them domesticated in the Neolithic era: a few hundred plants and less than a hundred animals. The majority of agricultural production comes from about twenty plants. For several millennia successive generations have sought to improve these strains without trying to take advantage of the rest of the fauna and flora.

Almost all contemporary agronomic research – whose aim is to increase production – relates to improving the cultivars of the 20 main plant species that account for 80% of world harvests. Three of them, wheat, maize and rice, account for nearly half [Tab. 2].

This is all the more paradoxical because more than 3000 wild plant species are known to be edible! Worse, in the course of the last few centuries, the production of species known and cultivated by aboriginal populations has reduced as a consequence of acculturation phenomena caused by colonisation.

One of the best-known cases is that of amaranth (three species of the *Amaranthus* genus), the seeds of which were consumed by the Aztecs before the Spaniards forbade them to cultivate it when they colonised Mexico. Similarly, a plant from the high plateaux of the Andes, peppergrass (*Lepidum meyenii*), with roots like those of the black radish and rich in sucrose and starch, which was cultivated by the Incas of Peru and Bolivia, is in danger of extinction because it now covers only about ten hectares.

Of the wild plants that constitute serious potential candidates for a large-scale food crop, the domestication of several of them would enable a spectacular growth in plant production in tropical countries.

This is the case, for example, of the New Guinea winged bean (*Psophocarpus tetragonolobus*), all of whose above-ground parts – leaves, pods and seeds, are edible and which can grow up to 50 cm a day!

A tree in the lowlands of Amazonia, *Mauritia flexuosa*, known to the Amerindians as the "tree of life," is an excellent candidate for large-scale cultivation because not only its fruit, but also its shoots and pith are edible.

An important source of natural food, proteins in particular, is provided by fishing activities and, to a much lesser degree, aquaculture. An estimated 40% of the protein needs of the poorest two thirds of the world population come from fish.

However, the exploitation of this resource has increased fivefold since 1950, going from 20 million tonnes a year to more than 100 million tonnes at the end of the eighties – the greatest share by far coming from the oceans. This considerable increase in the pressure exerted on marine resources since 1950 results from the extension of fishing activities toward zones that were scarcely exploited in earlier years (e.g. the tropical seas) and to species and fish sizes that were previously neglected. This over-exploitation is now translating into stagnation, followed by a decline in catches – resulting in ever more intensive and less profitable fishing.

Table 2. The main food plants in the world.

Species or group of species	Production en 1990 (millions of tons)	% of total	accumulated %
wheat	595	15,5	
rice	519	13,5	
maize	475	12,4	
			41,4
potato	270	7,0	
barley	180	4,7	
manioc	158	4,1	
sweet potato	132	3,4	
soya	108	2,8	
sugarcane	95	2,5	
			65,9
banana and plantain	71	1,8	
tomato	69	1,8	
grape	60	1,6	
sorghum	58	1,5	
orange	52	1,4	
oats	44	1,1	
coconut	42	1,1	
cabbage	42	1,1	
apple	40	1,0	
rye	37	1,0	
			73,9
Total (including other plants)			
	3 839		100,0

From an ecological vision of the world to the implementation of sustainable development on a planetary scale.

The renewal of the ideas and approaches that have gradually developed from the scientific, economic and social dynamics born from the effort to implement the Convention on Biological Diversity, are opening real prospects for sustainable development on all scales from local to regional and global.

The broader ecological vision that came into being at Rio and that made the diversity of life an *environmental concept* now enables us to tackle the problems linking environmental preservation to the objectives of viable development of human societies, both North and South – for today's generations and those of tomorrow. In this context, the concept of biodiversity in its full ecological dimension appears to be decisive:

1 because it forces us to reinsert man, *Homo sapiens*, into the dynamics of the diversification of life that has never stopped for 3.8 billion years;

2 because it leads us to reconsider and to deepen the relationship between the diversity of life, how ecosystems work and the performance of human societies in terms of development.

In order to provide a better grasp of this "double jointedness," I can only return to the admittedly debatable[2] concept of *ecological services* as outlined in figure 3.

However debatable its anthropocentric construction, the concept of ecological services opens new perspectives for ecology – which in this context is doing no more than returning to its original concerns (see Deléage, 1997: *Histoire de l'écologie, une science de l'homme et de la nature*).

In fact, this is where ecology rediscovers her older sister – economics – after being totally ignored throughout the 20th century.

We are now witnessing the flowering of a new discipline, ecological economics, which will have a key role to play in establishing the basis for sustainable development.

Simultaneously, against the background of the Conferences of Parties (COPS) that have been held every two years since Rio, political initiatives have been taken to implement the major recommendations of the Convention on Biological Diversity (CBD). Thus, governments have developed the Global Taxonomy Initiative and announced the guidelines for a programme to fight against invasive species. Since 1994 the Global Environment Facility – a CBD financing mechanism – has allocated 3.86 billion dollars to developing countries for biodiversity purposes. Despite these efforts and actions, it must nevertheless be said that the CBD lacks clear objectives and deadlines and it is therefore difficult to assess its

2 Debatable because it is based on the simplistic and misleading duality of man/nature and because it implies that nature supplies services for man, whereas in fact it is a simple "function."

effectiveness (Kate, 2002). In Europe certain directives adopted by the European Union, such as the "habitat"Encart 5 directive, give the member states joint targets that should make it possible to make significant progress.

What are the ecological services mentioned in figure 3? They comprise very varied ecological processes, such as the recycling of organic waste, the water cycle, climate regulation, the renewal of soil fertility, water purification and the pollination of plantations and orchards, as well as wild flowers. We only become aware of their reality and their economic importance when they have become damaged and we have to spend money on restoring them.

Let's look at two examples, one local, the other on a planetary scale.

In the North East of the United States the water coming from springs in the Catskills had long been bottled and sold throughout the region, particularly in New York. A few years ago as a result of changes in land use in the whole catchment area that serves New York, excessive fertilizers and pesticides became too strong for the ecological service which had purified the water of the Catskill Mountains free of charge. The quality of the water dropped below the standards set by the National Agency for the Protection of the Environment. The city of New York thus proceeded to estimate

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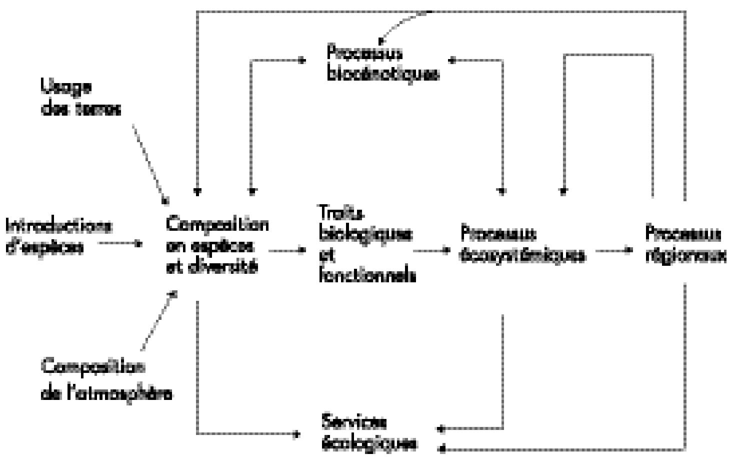
Figure 3. Relations between the diversity of life, ecosystemic processes, ecological services and factors for change linked to human activities. Biological resources and ecological services are one of the essential bases for the development of human societies which, if badly conducted, could have a negative effect on them.



Encart 5. Natura 2000. Contracts to act.

More often than not, preserving natural habitats, flora and fauna, means supporting the human practices (agriculture and forestry for instance) which, over time, have fashioned the biological diversity of territories. It is essential to maintain this biodiversity in order

to promote sustainable and controlled development, particularly in rural zones.

By adopting two directives ("birds" in 1979 and "habitats" in 1992), the European Union gave its member states a joint target to protect species and their rare or threatened natural habitats in Europe, in accordance with simple principles:

– the constitution of a European network of sites called Natura 2000;
– that management of these sites should take economic, social and cultural requirements into account.

In 2001 France completed the transposition of these two directives into its legislation. It opted for a judicial mechanism based on voluntary work and the accountability of those in charge of managing and maintaining natural environments.

Three essential choices were made:

1 to act in a transparent and concerted fashion, at all stages of operations, and specifically via the pilot committee set up for each site;

2 to develop contractual management based on the initiative and participation of the owners and managers of the territories;

3 to integrate the environment in action relating to managing and enhancing the rural area.

At present the "targets documents" defining management directions and appropriate measures are being drafted for each site with a view to promoting local participation.

2002 will be an essential stage in the concrete implementation of site management. Owners, farmers, foresters, hunters, associations and local communities will be able to enjoy the benefits of paid Natura 2000 contracts for work and services rendered to the community.

Thus, Natura 2000, with its considerable financial resources, should assert itself as a real tool for the development of regions, guaranteeing the conservation of flora, fauna and natural habitats. (According to a memo from the Ministry for Environment and Land Use) the cost of processing and purifying the water: 6 to 8 billion dollars in investments, to which must be added the annual operation and maintenance costs estimated at 300 million dollars. Local representatives then asked for an evaluation of the cost of measures to restore the integrity of the natural purification services of the catchment area. Estimated at 1 billion dollars, infinitely cheaper than the water treatment plant, these measures were adopted by the city of New York.

The second example comes from Robert Costanza, one of the founders of ecological economics. In 1997 *Nature* magazine published a much-debated article by him and his team in which they tried to evaluate all the services rendered to humanity by the ecosystems of the planet. Their approach was to evaluate, not the ecosystems themselves, but the variation in well-being resulting from a variation in the service rendered, in accordance with the principles of economic theory. The methods used were based very largely on the populations in question accepting to pay. The calculation came up with a mean annual figure of 33 billion dollars (33×10^{12}), nearly twice the total GNP for all the countries on the planet. Whatever the fragility of such an estimation, it has the double merit of drawing attention to the unsuspected value of the services provide by the ecosystems of the globe and opening a field of research without which the implementation of all the sustainable development that everyone is demanding will be nothing more than a pious hope.

Thus, in spite of first impressions, we have made a lot of progress since Rio. Let us hope that Johannesburg will enable us to embark on a new stage that – this time – will be decisive!

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Fisheries, Marine Resources and Conservation: toward a renewal of the concept of sustainable development in the marine world?

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The development of human activities linked to the exploitation of marine resources is facing major scientific challenges in terms of sustainability: overexploitation of resources, erosion of marine biodiversity in the broad sense of the term and integrating growing multi-discipline scientific knowledge into concrete management action. These challenges, linked to the sustainable exploitation of resources and conservation of both species and the ecosystems in which they evolve, clearly do not lend themselves to a simple unified approach in terms of management.

Surprises from a life-size research experience. Planned experimentation on exploited marine ecosystems is not feasible in the scientific sense of the term, because of the absence of controls over the vast scales of time and space involved. Knowledge is acquired by analysing the consequences of our actions i.e. exploitation, which has only been intensive for less than a century. Quantification by scientists of possible fishery samples dates from the 1950s and recent calculations have only slightly modified these estimates: we can potentially take from 80 to 100 million tonnes of fish annually from the oceans of the world. At the present moment, fishing hauls have levelled out at this value. However, it seems that this level is not ecologically viable. The report on the worldwide state of marine resources published by the FAO comments on the growing number of overexploited stocks which, in the year 2000, represented close to two thirds of the stocks exploited. In 1995 scientists thought that the stocks that had diminished as a result of overexploitation would rapidly be replenished by putting a stop to fishing activities. Surprisingly, several studies show that most stocks of marine fish are only slightly resilient even in the absence of any exploitation. One reason for this lack of resilience seems to reside in the interaction between the pressure of intense fishing and natural variations in abundance caused by climatic forcing on different levels. On a grand spatial scale recent studies have confirmed the impact of oceanic phenomena such as El Niño on ecosystems on the scale of the Pacific Ocean, massively modifying the abundance and availability of exploited resources. Over a longer timescale, palaeo-ecological research confirms the existence of large fluctuations over periods ranging from a few decades to a century. On finer spatio-temporal scales we can see, for example, that national stocks such as South African anchovies, present inter-annual recruitment variations of a factor of twenty in the space of four years, in spite of moderate exploitation. Scientific research has enabled quantification and interpretation of these changes, which have often been unexpected and sometimes even surprising.

Evolution of observation means and analysis. The community of fishery researchers quickly grasped the importance of routinely collecting data on the capture, fishing efforts and biology for exploited species, which enabled detailed analysis of the mono-specific dynamics of populations. Although catch management continues to be based essentially on this type of conventional data, via traditional models of population dynamics, their limits have become apparent with the development of modern observation techniques. Methodological progress has been made since the end of the seventies in the fields of submarine observation (hydro-acoustic, video, acoustic marking), remote oceanographic detection, computer technology and digital modelling tools. This progress has enabled us to obtain a more in-depth view, with much higher resolution in terms of both time and space. These new databases and new techniques for linking knowledge (modelling, Sig) have opened up prospects for scientific fishing management based on ecosystem considerations (Fig. 1) – a prospect that should result in practical applications. On the other hand, the international scientific community has developed an awareness of the necessity of developing and standardising knowledge bases (fishBase, fishstat, etc.), biological (Census of Marine Life) and environmental (Coads, etc.) observatories, as well as analytical tools (Ecopath, Ecosim, Climprod, etc.). We are witnessing an increase in international co-operation in terms of resource management both from a point of view of sharing methodologies (international symposiums) and producing recommendations with regard to management by international commissions and organisations, with growing involvement of NGOs.

Sustainability and the many issues involved. Our perception of the sustainability of marine resource exploitation has evolved considerably over the last two centuries. Until the beginning of the 20th century, these resources were considered to be practically inexhaustible. The first half of the last century saw the rapid development of industrial exploitation and scientists interpreted the great variability of resources essentially as the result of environmental forces. From 1950-1975, however, optimal sustainability criteria were defined solely as a function of the intensity of fishing activity (maximum balanced catches defined and calculated into global quotas, with checks on overall activity and/or mesh size). As a result of the repeated failure of this approach to conventional management (depletion of many stocks managed on a scientific basis), fishery scientists lost much of their credibility. The next period was characterised by many attempts to broaden the management criteria to include environmental and socio-economic aspects, attempts that remained largely unsuccessful despite the long-term potential of this approach. The viability of certain fishing fleets was nevertheless maintained by prospecting for new resources and in new geographical zones. As a reaction to this internationalisation of fishing, shoreline countries made an historical step by claiming their rights to resources situated within an exclusive economic zone up to 200 nautical miles from their coasts. This tendency to claim resources spread to many countries, especially during the nineties, through the establishment of transferable individual quotas. This was accompanied by growing public and official awareness of the necessity of protecting the marine environment and resources, which was further reinforced by the activism of ecological scientific associations. This resulted specifically in the establishment of more and more marine reserves that enabled geographical control over access to resources. Moreover, another type of control increasingly came to be exercised on the market through certification of sea products (eco-labelling), as a result of pressure from multinationals associated with NGOs. A major influence in recent years has been the growing awareness of the scale of what is at stake and recognition that the scientific knowledge required to ensure exploitation and conservation of the ecosystems is incomplete. As a result of the 1992 Rio de Janeiro conference and the adoption of Agenda 21, the precautionary principle was proposed by the FAO in 1994 for sustainable development of fishing and translated in 1995 into the drawing up of the code of conduct for responsible fishing. This code encapsulates a global consensus for development that is increasingly based on an ecosystemic approach and new methods of control aimed at improving the well being of current human generations without sacrificing that of future generations. Lastly, concepts from terrestrial ecology – such as the setting up of reserves, publication of lists of endangered species and protection and restoration of habitats – and the role of environmentalists in the eyes of the general public, have led to a broadening of the issues at stake for sustainable exploitation.

In 2001 the FAO Reykjavik declaration outlined an attempt to reconcile the different exploitation issues with those of conserving marine ecosystems, based on the precautionary approach. It recommended deeper studies aimed at understanding the way ecosystems work (trophic networks, the role of the habitat, biotic and abiotic factors affecting the stability and resilience of ecosystems) while encouraging responsible management of catches, particularly via the setting up of mechanisms designed to cut excessive fishing back to sustainable levels. The co-viability of exploitation systems and the natural ecosystems on which they depend is an emerging theme in which the concept of sustainability is taking on a new dimension.

One of the major issues for fisheries and their future will therefore be inseparably linked to our ability to harmonise conservation objectives with the exploitation of renewable marine resources. The difficulty lies in distinguishing between natural variations in marine ecosystems controlled by their own internal dynamics and climatic variations, and the effects of anthropogenic activities on these same ecosystems. The absence of reference points in these permanently evolving ecosystems makes it difficult to reconcile sustainable exploitation of a few species and the preservation of the whole ecosystem in all its diversity. Comparative and historic approaches may provide some answers. However, the definition of a set of ecosystem indicators enabling us to identify ecological, environmental and socio-economic dynamics now constitutes a step toward quantifying the many and evolving states of ecosystems. Research must play an important role in defining such indicators, their validity and frame of application. These indicators should facilitate better accounting of the multiplicity of issues and ensure the co-viability of fisheries and marine ecosystems.

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Desertification and its relationship to the environment and development: a problem that affects us all.

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Introduction.

There is a wide variety of terms used to describe desertification and its expansion across geographical space which no doubt stems from attempts to attract increased resources to combat the phenomenon. Unfortunately, by extending the concept, its meaning has been weakened, resulting in the opposite of what was intended. A clear notion of desertification is essential so that it may be applied diagnostically and operationally as a value.

Monitoring and assessment of desertification both have dual objectives. Firstly they measure and evaluate the degree of land degradation in order to diagnose the seriousness of the problem. And secondly they measure the impact of action undertaken. They rely on in-depth knowledge of the mechanisms and processes involved, and on the development of specific tools, such as indicators and observatories.

Desertification is both an environmental and developmental problem. It affects local environments and populations' ways of life. Its effects, however, have more global ramifications concerning biodiversity, climatic change and water resources. The degradation of terrain is directly linked to human activity and constitutes both one of the consequences of poor development and a major obstacle to the sustained development of dryland zones. Beyond the application of appropriate techniques, efforts to combat desertification should be accompanied by measures to stimulate economic and social change and should also be an integral part of development programs.

The United Nations Convention to combat desertification indeed expresses a change of direction in this respect. Its founding objective is to encourage governments to undertake commitments at State level or in terms of aid to development so as to define legislative and statutory frameworks that will enable populations to plan and manage their own natural resources. Where the convention has been less effective, is in the setting up of specific development tools such as funding mechanisms or tools that effectively incorporate science and technology into their processes. It has nevertheless lead to real progress, particularly concerning the mobilisation of human resources. Its future and its implementation will depend on the parties involved and their ability to find swift partnership solutions.

The notion of desertification.

From the origins of the term to international awareness.

In the accepted meaning and dictionary definition of the term, desertification involves the transformation of a region into desert. The primary meaning of "desert" is an area devoid of human presence. Today, by extension, the term has taken on a climatic and biological dimension encompassing regions with scarce or irregular rainfall or those with sparse or reduced vegetation. Various different definitions of desertification have been proposed over time, in particular in the last twenty years. The abundance of definitions possibly conceals the impreciseness of the concept while different scientific or political communities have brought different acceptances and interests to the term.

In 1927, describing the impoverishment and deterioration of the southern Tunisian forests, in a paper entitled "Les forêts du Sahara," Louis Lavauden seems to have been the first to have given the term "desertification" a scientific meaning. He attributes an anthropogenic origin to the phenomenon: "In the whole of the zone in question, desertification, if I may so say, is a purely artificial phenomenon. It is a purely man-made occurrence. It is also a relatively recent event and could be combated and eradicated." Fairfield Osborn, in 1948, in his work *Our Plundered Planet* denounces the deterioration of the planet's natural resources through human action as the most important problem in the world concerning the future of man. Observing the deterioration in vegetation and soil in the sub-humid north of Central Africa, Aubreville wrote in 1949: "What we are seeing are actual deserts emerging before our eyes, in countries where the annual rainfall is 700 to 1500mm of rain."

In the fifties, the Unesco arid zone research program brought developments from the scientific community and our knowledge about ecology to bear on such environments. However, the connections between human activity and the dynamics of regions remained practically unexamined. The serious drought that affected the Sahel in the seventies, along with famine, social crises and influxes of refugees, called international attention to the environmental crisis in hand and the problems of the development of dryland zones in a dramatic way.

The United Nations organised a conference on the Human Environment in 1972. The government and international communities formed an inter-state committee to control drought in the Sahel (the Cilss). The United Nations Sahel Office (the Unso) was also created within the Pnud. The United Nations General Assembly decided to hold a conference on desertification in Nairobi in 1977, the Uncod (United Nations Conference on Desertification). The conference proposed the following definition of the term: "Desertification means the reduction or destruction of the biological potential of a region and may eventually lead to the emergence of desert conditions. It is one aspect of the general degradation of ecosystems." It laid down a plan of action to combat desertification (the Padc) with 28 recommendations detailing courses of action to be undertaken. It entrusted the implementation and the follow-up of the plan to the "United Nations Environment Program" (Unep). There then followed a phase of international research initiatives and the setting up of international loans and intervention schemes, particularly concerning reforestation.

During this period, the term "desertification" was at the centre of much debate and controversy and it is worth remembering a few points emerging from it: land degradation became distinguishable from drought, a term that designated the consequences of a more or less prolonged deficit in water. Drought was seen as a factor that made desertification worse. The use of the term desertification in the expression "desertification of rural areas" seemed to derive from the idea of an area becoming "deserted," that is to say, uninhabited. In this case, desertion would be more appropriate

Le Houérou, based his work on land research studies and, in 1968, created the term "desertisation." The term, with its scientific content, was meant to be more specific but was not retained by the international community. In 1991, the Unep formed an ad hoc group to provide a "global evaluation of desertification – conditions and methods." According to the proposed definition, desertification was "land degradation in arid, semi-arid and sub-humid zones resulting primarily from human activity. It involves a certain number of processes which lead to the impoverishment of soil quality and vegetation where human activity is the main factor." The definition recognises humankind's own detrimental impact as the primary cause of desertification. Included in the notion of land degradation are declining harvests, reduction in vegetation cover, the way that physical mechanisms harm the surface of the ground, the reduction in quantity and quality of water resources, and the deterioration of soil quality. The definition featured a geographical dimension – desertification concerned land without water or areas corresponding to arid, semi-arid and sub-humid dryland zones. This refers to the definition of bioclimatic zones based on the value of the P/Etp ratio (the relation between total annual rainfall and the annual value of potential evapo-transpiration). Dryland zones under consideration thus corresponded to a ratio of $0.05 < P/Etp < 0.65$ (Unep, 1992, in Le Houérou, 1995). Highly arid zones ($P/Etp < 0.05$) were not taken into account as they were already considered to be desert.

Following requests by the countries affected, desertification was put at the top of the agenda at the United Nations Conference on Environment and Development in Rio in 1992 (Unced). The international community recognized that desertification was a global environmental problem which required a worldwide response. The Conference asked the United Nations Assembly to instigate an intergovernmental negotiation committee to draw up a Convention to combat desertification. In accordance with the established schedule, the committee completed negotiations and the United Nations Convention to combat desertification was adopted in Paris on 17 June 1994. It was ratified in 1996 by more than 50 countries and came into effect in December of the same year. The definition of desertification retained at international level – and first stated in chapter XII of Agenda 21 reads: "Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities." (Article 1). This definition is the result of a political compromise between the various parties and, although it retains the same geographical dimensions, it differs in significant ways to the preceding definition, in particular as far as highlighting causal factors is concerned. It effectively reduces the previous emphasis on human agency as central to the process of degradation.

Beyond words, concepts and clarity.

The term "desertification" has been the subject of much discussion and even controversy, in the course of which it has been defined in many different ways. It is however crucial to be clear about the notion and give its content both diagnostic and operational dimensions. According to Glantz and Orlovsky (1983), there were nearly 100 definitions in circulation in the eighties. Katyal and Vlek, in a recent study (2000), collated criteria included in definitions by different authors so as to highlight areas of agreement and disagreement. They observe that desert expansion theory, defended in particular by Lamprey (1975), which evaluated the advance of the Sahara at 5.5 km a year, has been rejected by the scientific community. Various studies have conclusively shown that deserts were not showing significant advance (Warren and Agnew, 1988). Instead, recent studies based on spatial observation show that desert frontiers either advance or recede according to the rainfall of a given year (Tucker et al., 1991). Likewise, a consensus has been reached to the effect that land desertification concerns dryland zones, i.e. arid, semi-arid and dry sub-humid zones that correspond to a ratio of $0.05 < P/Etp < 0.65$ (UNEP, 1992). Hyper-arid zones ($P/Etp < 0.05$) are not taken into account. Likewise, the land degradation in humid zones, often linked to deforestation, is considered separately.

Among the differences of opinion, there are several major points to remember, even if our knowledge today enables us to provide certain nuances:

1 Does the term desertification describe a process or the condition of an area?

2 Is desertification a reversible or irreversible phenomenon?

3 What are the respective roles of human agency and climatic conditions in desertification?

For certain authors (Rapp, 1974; Ahmed and Kassas, 1987; Mainguet, 1994; etc) "desertification" corresponds to the state of an environment that manifests desert-like conditions, in the final stages of land degradation. Others (Rozanov, 1982; Dregne and Chou, 1993; etc) consider that the term "desertification" describes processes of degradation to soil quality and vegetation, processes that can be either reversible or not, and that bring about a gradual loss in productivity. These two points of view are significant in two respects, firstly in the evaluation of the extent of the problem. Effectively, the zones affected by desert conditions represent only a small part of arid zones in general, whereas vast spaces are affected by the degradation of natural resources. Secondly, differences in opinion here influence strategies and whether priority should be given to restoration of damaged zones or to eliminating causes and implementing preventative measures. Land degradation is a major problem for the environment and in the development of dryland zones. It is from this viewpoint that international authorities (Unep, Unced) have retained the term "desertification" to refer to land degradation in dryland zones. This definition does not quantify the degree of land degradation that should characterise desertification. Some authors such as Katyal and Vlek (2000) suggest that areas affected by productivity losses of more than 15% be considered to be in the process of desertification, but provide no means to measure this.

Land degradation covers a wide variety of processes, implying various degrees of seriousness. Many authors associate desertification with criteria governing irreversible degradation (Le Houérou, 1968, 1992; Rozanov, 1982; Mainguet, 1995). When talking of desertification, the term "irreversible" is used when vegetation and soil have no chance of returning to their original state despite the total or almost total protection of an area for the duration of one generation, or twenty-five years (Floret and Pontanier, 1982). According to Warren and Agnew (1988), land degradation includes desertification, which is an extreme manifestation of it. Desertification, limited to only arid zones, is considered as the final stage of degradation of natural and exploited ecosystems. According to Le Floc'h (1996), The notion of an "irreversibility threshold" enables differentiation between these two notions. Desertification associated with a total loss of productivity and resilience is not a sudden phenomenon. On the contrary, it appears as an evolutionary process, marked, of course, by different thresholds. The gradual insidious process of land degradation leads to irreversible desertification. If, on the scientific level, it is wise to fix evolutionary and irreversibility thresholds within the process, on the applied level, land degradation is certainly a more common occurrence and constitutes a greater, more serious threat to the maintenance of land use and its ecological functions. However, were the concept of desertification to include the notion of irreversibility as the ultimate stage in a series of processes leading to a definitively sterile environment, in our current technological and economic context it would be rarely employable. According to Dregne (1983), only 0.2 % of the terrain of our planet would be affected. Any evaluation of the affected zones should include notions of the different degrees of degradation, even when the process is reversible.

Generally, all authors are in agreement that desertification is mainly caused by human intervention. Land degradation occurs when natural balances or dynamics are altered by human agency through over-exploitation of resources. Human actions are largely voluntary; sometimes they are linked to ignorance, but often they are determined by increases in demand in contexts where technology has evolved insufficiently and rules governing access to resources are absent. If human agency is undeniable and widely demonstrated, climatic conditions also have an impact and their respective roles are discussed extensively. Droughts, in particular in the Sahel, have shown up the desertification of these zones. Reduced rainfall, or its wider variability, has increased natural resources' vulnerability to degradation and it is less easy for ecological and social systems to resist. However, it has been observed that the impact of such droughts is weak or negligible where human or animal impact is low or non-existent (Le Houérou, 1993). Indeed, the vegetation and soil of arid regions have been able to adapt to recurrent drought conditions over the past centuries and millennia, acquiring an ability to recover their characteristics if disturbed (what is known as "resilience"). According to Le Floc'h (1996), the most serious ecological problems stem from the behaviour of populations or actions carried out during climatically favourable periods and their consequences only appear afterwards, when degradation has lead to a loss of resilience and recovery capabilities following disturbances. Drought in this instance can reveal existing degradation. All authors concur that a rise in drought phenomena does not cause desertification but is an important factor concerning the enhancement of anthropogenic effects on land degradation in dry-land areas.

The causes and processes of land degradation.
The notion of "land" refers to the natural components of cultivated or non-cultivated ecosystems. It includes various elements – the earth, the water, vegetation, fauna, physiography and microclimate – that may be described in terms of biophysical characteristics or attributes. Land serves various purposes for man – for agriculture, forestry, pasture, and as a support for infrastructures. Land also plays a regulating role in ecological and environmental terms. Land degradation means the loss of certain inherent properties or the reduction of their capacity to fulfil essential biological, ecological, economic or social functions. Such degradation is associated with the degradation of their constituents or of their functional links.

Human activities are determined by social context and by economic and institutional environment. They are translated into concrete actions on the environment via practices that modify biophysical processes and ecological characteristics. The growth in populations' needs and the absence or obsolescence of rules governing access to resources leads to an increase in pressure on resources and to badly adapted and harmful practices. Such practices – like overgrazing, extensive clearing and deforestation – have an effect on vegetative cover and soil. They modify the biophysical functioning processes of agronomic and ecological systems leading to a series of repercussions that may engender a spiral of degradation. The halting or modification of such practices produces different evolutionary trajectories and possible recovery if irreversibility thresholds have not been reached.

In general, degradation starts with an alteration of vegetation, modification of flora constituents, and species most sought after or used become rarer or disappear. Then, or simultaneously, vegetative cover becomes thinner and the production of biomass diminishes. Capacities for reproduction and regeneration of vegetation reduce further. Soil loses protection from vegetation and is open to the mechanical action of rainfall which causes a change in the state of its surface. The biomass reduces and thins out leading to progressive loss of organic matter, one of the determining constituent elements of soil properties. Structural stability and porosity decrease, while

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Conceptual framework of the causes of desertification and land degradation.

Signs

Destruction of plant cover, lowering in land productivity, erosion of the soil and transformation to sand.

Immediate causes

Overgrazing, inappropriate cultivation, excessive extraction

Underlying causes

Increase of human pressure, poorly adapted techniques and management methods, drought and climatic accidents, ecosystem fragility.

Fundamental causes

Demographic increase, poorly adapted control of access to resources, economic crises, poverty, institutional frameworks and development decisions openness to erosion increases leading to progressive destruction of the ground. The consequences on fertility – lowering of exchange capacity and of available elements – and on hydric elements – increase in runoff, lowering of supplies of water available to plants, modification of the hydric regime and exchanges with the atmosphere, and aridification – are highly significant. These consequences will have an effect on vegetation and production. Degradation starts a downward spiral and without intervention will lead to irreversible desertification.

Desertification and land degradation described here in general terms result from interactive and complex processes, driven by a number of factors that work on different scales in both time and space. If desertification is indeed a global phenomenon affecting dryland zones in general, on a local scale situations and developments are diverse and correspond to original combinations of factors. This means that in order to take action against desertification, there is a need for reliable data governing the state of the local environment, which incorporates and identifies the respective interests of the different types of actor in the zone.

The result of land degradation is the progressive loss of vegetation and soil productivity in dryland zones, leading to a weakening of productive capacities and abilities to sustain the populations living there. It means that ecological systems, as well as alternative practices, have little possibility to develop. In advanced stages of degradation, land becomes unfertile, whole zones stripped of plant life and their populations abandon them. Beyond consequences on a local scale, desertification may have more far-reaching effects, with serious economic and environmental consequences. The erosion of soil and shifting sands means sand is introduced into neighbouring areas, infrastructures, sometimes even towns. The degradation of water reservoirs in areas of relief leads to problems of water level, flooding and damming. Finally, the destruction of living conditions and of populations' resources accelerates and aggravates migratory problems. Desertification constitutes the main obstacle to sustainable development in dryland zones.

Assessment and monitoring of desertification.

The extension and increase in cases of land degradation coupled with concerns voiced by both those countries concerned and the international community have created the need to perfect evaluation and surveillance tools. The establishment of categories and rates of land degradation (Warren and Agnew, 1988), however, presents a certain number of problems concerning:

1 the nature of the criteria to be retained to measure the state of degradation;

2 the evaluation of resilience and the soil's recovery capacities;

3 how to incorporate fluctuations between years and variability;
4 the availability of necessary data;

the relation between data and the criteria implemented and the capacities for the maintenance of local land use systems. In the authors' minds, criteria used to evaluate tendencies of land degradation and desertification should be clear, relevant and specific, both in terms of environment and scale, which supposes prior knowledge of fundamental processes.

The objectives pursued in desertification assessment-monitoring are twofold – firstly to evaluate and measure the state of land degradation so as to diagnose the seriousness of the problem, to characterise its scope and detect changes and evolution. Secondly, to gauge the performance of countermeasures and action undertaken as well as the effects of national political decisions in this domain. The need for evaluation and monitoring is expressed in the desertification convention which obliges countries to report advances in countermeasure application. There are a number of articles that deal with data collection and the establishment of indicators.

Several sources provide data about desertification tendencies, ranging from global surveys and analyses of satellite data to studies of local level environmental change. Global data about desertification has emerged from two main sources: firstly, from the Global Assessment of Soil Degradation (Glasod), carried out at the University of Wageningen for the Fao. Data is presented to a scale of 1/10 000 000th. Secondly from the International Centre for Arid and Semi-Arid Land studies (Icasals) of the Texas Tech. University; this data refers to soil degradation in zones suffering from degradation of vegetation. Generally, figures supplied by Icasals are much higher than those from Glasod. The estimation of the percentage of arid land on the planet suffering from desertification varies from between 19.5 % (Glasod) to 69.5 % (Icasals) depending on the sources. The Unep itself recognises that the data used to establish an Atlas of desertification, published in 1992, was incomplete and imprecise. Whilst it did not deny the importance of the problem, it concluded that more detailed and better quality information was required urgently.

Furthermore there are detailed case studies that have enabled us to come to a good understanding of environmental change and the way populations react in a given place. Such local-level studies, often carried out over a number of years, demonstrate the resilience of grazing and farming systems to large-scale variations of rainfall (Toulmin, 1993). This research presents a very different picture to research on a more global scale. The main problems here arise from using studies of a limited number of sites to draw more general conclusions about whole regions and from reconciling often contradictory results obtained at a local level with those obtained at a global level.

What means and methods do researchers have available to evaluate and monitor the progress of desertification?

Desertification and land degradation result from mechanisms and processes that are both complex and interactive and that depend on a whole range of factors effective at different times and places in different ways. Monitoring them requires details of the biophysical and socio-economic conditions of environments undergoing such phenomena but also an understanding of the mechanisms and processes resulting from these conditions. Furthermore, monitoring requires the establishment of basic parameters in order to define effectively the conditions of the environment and their dynamic relationship in space and time. Then, the interactions between those factors inducing desertification-related processes need to be analysed and modelled. Without going into every aspect with its own research concern, we will briefly touch on three: indicators, observatories and monitoring from space.

Indicators.

Indicators are traditionally used in evaluation, monitoring, and forecasting because they translate processes, situations and their evolution in a summarised form. As with many other terms, "indicator" has a very broad use and it is worth reminding ourselves of several definitions.

Definition of terms

Indicator

Parameter or value calculated on the basis of other parameters, giving indications about or describing the state of a phenomenon in the environment or in a particular geographical area, and whose scope is broader than the information directly linked to the value of a normal parameter.

Index

Group of weighted or aggregated parameters or indicators describing a particular situation.

Parameter

Measured or observed characteristic or property.

Benchmark

A benchmark is a norm in relation to which indicators or indices can be compared with a view to determining trends.

Indicators have, according to the OCDE (1993), two main functions:

1 to reduce the number of measurements and parameters that would normally be needed for the precise assessment of a situation.

2 to simplify the process of communicating results of measurements to users.

Their aim is to condense a large amount of information into a few understandable measurements, then to help us decide what action to undertake. To do this, indicators have to be correlated to aims and objectives and expressed in terms compatible with these aims and objectives. A good indicator should be relevant to the problem in hand, based on reliable data and analysis, and respond to user needs. It should be sufficiently sensitive to indicate changes early on. (Rubio and Bochet, 1998).

In the context of the Convention, different types of indicators should be taken into account – on the one hand, indicators concerning the implementation of the Convention's plans and actions at national and regional levels. These are termed "implementation indicators." On the other hand, there are indicators governing the impact of action undertaken to combat desertification.

The United Nations Commission for Sustainable Development (CSD), in association with SCOPE and the UNDP/UNSO, OCDE and the FAO have established a working program to define sustainable development indicators (SCOPE, 1995; CSD, 1996). Indicators governing desertification or land degradation are included in this program. Several international workshops have been organized leading to the adoption of the "Pressure – State – Response" (PSR) scheme to provide a logical framework for the organisation of indicators. This relies on the notion of causality – human activity places pressure on the environment and changes its state as well as that of natural resources. Society responds to these changes by adopting corrective measures. One advantage of the PSR framework is to highlight the relations between human activity and the environment; however, it tends to suggest such relations are linear, whereas, in reality, they are much more complex.

Numerous organisations have developed studies and research programs about indicators (SSO, 1996, 2001). However, it is currently noticeable that, where a number of research studies have dealt with indicator application at different levels, few indicators have actually been tested or calculated and even fewer are effectively operational. Affected countries find it impossible to include the indicators they need in their reports. At the present time, this is a major omission. One of our priorities is to develop the use of existing indicators and to test them in comparative situations.

Observatories.
The development of methods governing both assessment and monitoring of the environment and the impact of countermeasures against land degradation relies on effective long-term monitoring networks which employ compatible data collection and transfer techniques. The idea of such observatories is to collect necessary data based on similar foundations and to follow how processes evolve over time while enabling the definition of reference situations. They enable the development and testing of indicators and tools that assist in decision-making and which incorporate these indicators. They also constitute privileged sites of research into the study of mechanisms and processes as well as on the factors determining evolutions.

The Sahara and Sahel Observatory has implemented a Long-Term Ecological Monitoring Observatories Network (Roselt) for the zone around the Sahara (Sso, 1995). This measure was taken in consultation with African countries and is destined for their use to assure long-term monitoring of desertification and to develop associated research techniques. It is made up of a network of observatories connected at the regional level of the Sso geographical zone on the African continent. The Roselt project was built according to a bottom-up approach, starting proposals from nations of suitable sites and research and monitoring teams. Appraisal and designation was then carried out, leading to the selection of 23 observatories under the Roselt umbrella. A restricted number of 12 pilot sites were selected for the first phase of the project. The project received the financial backing of several sponsors including the French Global Environment Facility, The French Cooperation and the Swiss Cooperation.

The Roselt strategy stands out as a an essential contribution to the understanding of environmental phenomena and their relevance to the problematic relations among global changes, sustainable development and measures to combat desertification. Roselt is a tool for both research and development in three ways:

It contributes to the improvement in the potential of our basic knowledge about the functioning and long-term evolution of ecological and agro-ecological systems and about the co-viability of ecological and socio-economic systems, assuring the scientific and statistical monitoring of the environment to enable characterization of causes and effects of degradation of areas, on the one hand, and to better understand the mechanisms that lead to these phenomena, on the other.

It assists in the application of knowledge, by classifying it, processing data and making it available, as well as by elaborating indicators and results at different local, national and regional levels. The results obtained about the state of the environment, its evolution and its relation with social and economic movements will go on to be applied as tools for the establishment of sustainable development and environmental protection plans and strategies to support development programs and decision-making. They could possibly enable elaboration of plausible evolutionary scenarios.

It assures the learning, demonstration and study of environmental questions and their inclusion in developmental politics and programs as well as in the combat against desertification.

Tools to monitor from space.

Mapping and monitoring of degradation spread over the earth's surface constitute two key sources of knowledge about the phenomenon of desertification. They are indispensable to the instigation of combat plans and sustainable programs employing natural resources in arid zones and in particular in the Mediterranean.

There has been much study in the field about the processes of degradation and the dynamics of ecosystems and it is difficult to draw general conclusions from results obtained on a larger or even regional scales with any degree of certainty. Detailed information about the current state of plant life and soil on a regional scale is often not available. Precision field studies are irreplaceable but do not allow for detailed regional cartography due to their high cost, their lack of sufficient standardisation and because of difficulty accessing certain areas. Remote sensing from satellites is one source of alternative information. However, radiometric data collected does not correspond directly to the data that is required and has to be interpreted to obtain information (Bonn and Escadafal, 1996).

Thus, studies of South Tunisia and the desert fringe of the Nile (VSD, 1993-1996) within the framework of the "Desertification Watch with Satellites" project (the VSD project), financed by the European Union for its "Avicenne" program, set out to measure changes in the surface properties of arid environments studied by satellite and to integrate additional data into this information so as to obtain an effective instrument for monitoring. The research clearly demonstrated the feasibility of monitoring desertification by satellite. Results obtained showed in particular that some parameters (colour and composition of soil, its texture, and degree of vegetative cover), indicators of the state of desertification and its evolution, could be obtained from space by satellite. The colour and shine of surfaces recorded by satellite image represent, for example, a good indicator of the drift of shifting sands. On the whole, the VSD program has highlighted that satellite techniques, combined with a good knowledge of the terrain under study, enable the detection of both the progression of degradation over arid zones and its restoration through the positive effects of countermeasures and protection.

Beyond such advances, it appeared that the diversity of methods used to monitor arid environments made it difficult to compare conclusions drawn from one area to the next, or even from one team of researchers to the next. This recognition highlighted the need to lend a regional dimension to the fine-tuning of monitoring tools. Several programs have been developed, particularly with European Union assistance. In the Mediterranean zone, we will cite the following projects: Medalus (Mediterranean Desertification and Land Use, coordinated by King's College, University of London), Demon (Satellite-based Desertification Monitoring in the Mediterranean Basin, coordinated by the University of Trier in Germany, for the northern bank of the Mediterranean), and the Cameleo project (Changes in Arid Mediterranean Ecosystems on the Long-Term and Earth Observation, coordinated by the Joint Research Centre in Ispra, Italy, for North Africa). Their scientific method is based on results collected by their different partners. Their task consists of identifying indicators of local ecological changes on the ground (whether deteriorated, stable or restored), determining those factors that are detectable from space, seeking out the most suitable high resolution satellite data (while preparing for future data collection), fine-tuning processing algorithms and result presentation methods. Finally, the creation of models of observed changes means that plausible evolutionary scenarios may be put forward.

Desertification of the environment from local to global scales. Land degradation and climatic change.

There is a constant debate questioning how desertification interacts with climatic change. The terms are both complex and controversial. The difficulty here arises from the fact that our knowledge about the processes of land degradation and about mechanisms of climatic change are still very incomplete. The debate may be summed up by four essential questions about which we only possess fragmentary information.

1 Have recent regional climatic fluctuations increased desertification? Following a period of prolonged drought in Sahelian Africa, it was observed that the reduced rainfall and its greater variability increased the vulnerability of natural resources to degradation. But it was also observed that the impact of such drought was weak or negligible where human and animal impact was weak or non-existent. For all those researching this question, the intensification of drought phenomena is not at the origin of desertification but constitutes an important factor in the increase of anthropogenic effects on land degradation in dryland zones.

2 Are global climatic changes and subsequent global warming responsible for periods of increased drought? And with what consequences for desertification?

Since the end of the 19th century, the planet has been affected by large scale warming which has lead to an overall increase in air temperature of 0.5°C. This warming is however not the same in both hemispheres and it varies with latitude (Janicot, 1996). Scenarios based on global circulation models all anticipate a general increase in annual temperature, without being specific about seasonal variations. They are not in agreement however over possible rainfall changes in subtropical and tropical latitudes.

In the case of Western Sahelian Africa, climatologists increasingly believe that there is actually a link between global temperature changes and rainfall. Their conclusions are based on the effect that higher temperatures would have on the surface water of the South Atlantic and the consequent impact on Sahel rains. However, if surface water temperature increases are caused by global warming, we cannot dismiss the hypothesis that there are long-term cyclical changes to ocean temperature that have no relation to global warming and about which we know very little. At present, the intergovernmental think tank monitoring climatic evolution believes that continued global warming will lead to higher temperatures, lower humidity in the Sahel, increased variability of rainfall and storms of higher intensity.

To sum up, and despite existing uncertainties, it seems that foreseeable global climatic changes should take the form, in subtropical dryland zones, of an increase in arid conditions, which would increase populations' pressure on resources and land degradation.

3 Has land degradation, in return, had an effect on the local or regional climate?

On the local level, there have been hypotheses suggested concerning the mechanisms connecting local rainfall to variations in the nature of the surface of the soil. Such interaction is said to be related to an increase in albedo from the surface and thus to a reduction of both the energy available to the soil and the quantity of humidity present. The validity of this hypothesis seems to be contested, in particular due to divergences between the scales of modifications observed and those necessary to produce models of phenomena.

Among the experiments and measurements that have been made, results for the Sahel, for example, have shown that the land-atmosphere feedback effects do exist but remain weak compared to those effects produced by ocean surface temperature variations. It may be said that the desertification process is not the main cause of drought in the Sahel, but it might have contributed to enhancing the significance and persistence of the observed pluviometric deficit (Janicot, 1996).

Climatologists are highly cautious about the existence of strong feedback between land degradation and the evolution of the local climate. Any effect of this type would be minor and mainly dominated by the possible effects of global climatic change in these regions.

4 Does the degradation of arid land have an effect on global climate? Newly emerging documentation and models of the impact of changes on the Earth's atmosphere caused by human activity in dryland zones in global energy terms have met with a certain degree of success despite the complexity of the processes at stake (GEF, 1995). General global atmospheric energy balance might be influenced by any one of the following: changes in albedo ratios; soil humidity and water presence changes; changes in surface texture; dust emission and variations in carbon emission or absorption.

Each factor's influence varies according to the zones concerned – arid, semi-arid etc. In very arid zones, the albedo modification would be the dominant factor relating to the evolution of soil surface constituents. Wind erosion produces considerable dust emission, which, once in the atmosphere, produces a change in radiative balance.

In less arid regions, where soil humidity is higher, zones affected by desertification more often demonstrate an increase in temperatures linked to the reduction of evapotranspiration. This phenomenon has also been noticed during prolonged drought.

On the issue of carbon emission or retention, energy consumption levels remain very low in the zones concerned and they contribute little in this respect to CO_2 emissions. A reduction to ecological systems and agricultural and grazing zones in the region would lead to an increase in emission and to a reduction in retention capacities. The periodic burning of grassy areas in semi-arid or sub-humid dryland zones contributes considerably to the emission of CO_2 and particles. However, where human pressure on the environment is moderate and the balance between cultivated and fallow land maintained, carbon emissions are compensated for by absorption in biomass production and the net contribution is weak. However, where human pressure is augmented, with excess land stripping, a reduction in plant cover and of the biomass, the net contribution increases with land degradation.

Generally, an increase in plant cover, particularly ligneous vegetation, has a significant effect particularly for carbon absorption and the prevention of land degradation. Recent studies seem to show that in dryland zones, soil plays a significant role in carbon absorption and that the control of degradation and soil loss may be important in combating global warming. However, this point is far from being recognised as fact by all experts and more precise research on the carbon cycle appears necessary.

It is probable that land degradation in dryland zones does contribute to climatic changes on a global scale. However, the relative importance of this contribution is not known. If it was recognised and verified that land degradation in dryland zones has an influence on global climate, then combating desertification would take on increased importance for the international community and notably in developing countries.

Land degradation and biodiversity.
To this day, arid lands have not enjoyed the attention needed to address questions of the preservation, conservation and economic development of their biodiversity in national and international strategies. This is particularly the case in Africa around the Sahara.

Arid conditions have increased and developed in these zones over a period of time and been allied to long-term anthropogenic pressures. This has lead to processes of adaptation and evolution that result from the existence of original genetic lineages and the presence of a whole range of focal points assisting adaptation and evolution. Many arid zone species have ecophysiological and genetic properties that help them adapt to drought conditions, assisted by the diversity of their habitat ecosystems. This makes these zones precious resource centres for the future. Studying the role of biodiversity in the way ecosystems function has shown (Di Castri and Younés, 1990) that higher ecosystem biological diversity leads to better uses of non-biotic resources and to greater stability when faced with habitual or catastrophic variations to the environment. Biodiversity plays an important role in the resilience of ecosystems by reinforcing their capacity for recuperation after disturbance.

The fact that agricultural practices date back a long way in these zones has meant that local populations have appropriated significant supplies of traditional varieties of cultivated plants and breeds or populations of domesticated animals that are well adapted to their surroundings. Some varieties are known to possess genetic characteristics that could be useful throughout the world in improvement programs.

For example, recent studies have shown how important traditional varieties of millet and related wild species in the Sahelian zone are as genetic resources. Likewise, there are several field species cultivated around the world, such as *Cenchrus ciliaris*, which also originated from these zones. Furthermore, these areas constitute a sources of genetic diversity for future species improvement, and the importance of biological diversity within them should be extended to other biological groups, such as micro-organisms. A recent programme has been studying the diversity of rhizobia with a view to using them to restore degraded lands in the north and south Sahara.

Biodiversity is mainly lost through desertification and through changes to modes of land use and its cover in dryland zones, due to over-exploitation of populations and the destruction of habitats. The inter-relatedness of land degradation prevention, sustainable rural development and biodiversity conservation should engender a form of co-ordination and synergy among specific sponsor-led and State-level programmes.

When land supporting biological diversity degrades, it affects the flora of the area and certain species that make up the pharmacopoeia and traditional farming systems become rarer, and even disappear. It also affects wild and even domesticated fauna so that effective management and conservation of breeds can no longer be guaranteed. Previously permanent water sources become intermittent, upsetting the biotopes of numerous species. Migratory birds, part of the world's heritage, find their habitats increasingly precarious in the remaining humid zones of dry areas.

For a long time, the protection of biodiversity has been maintained by creating national parks and designating protected areas. The developers of such parks have generally considered human activity as predatory. Faced with an increase in pressure on resources, these "sanctuaries" have become of major significance to farmers, hunters, and pastoralists – in land ownership and forestry terms, with their availability of species that have disappeared from cultivated zones. The majority of players involved (States, NGOs development and nature conservation groups, and farming organisations) today recognise the necessity to associate biological diversity conservation strategies with the economic development of its potential in different communities. Likewise, beyond the general need to conserve protected areas, international authorities recognize how important biodiversity protection is in exploited areas and ecosystem preservation programs.

Given the role that biological diversity plays in ecosystem resilience and the fact that ecosystems will have to adapt to probable, if not foreseeable, climatic modifications, preservation of local biodiversity and the encouragement of floristic adaptation to drier or more humid conditions is doubtless one of the major goals at stake to promote future evolutions. From this point of view, maintaining ligneous reserves that are sufficiently dense and ecosystems that are sufficiently diverse to encourage the conservation of high levels of biodiversity in situ, represents another major goal.

In the area of genetic resources for farming, there is a combination of factors at stake – availabilities of local varieties that are well adapted to agro-climatic conditions and of species that may represent new opportunities for economic development in local as well as international markets. The conservation of species and genes in situ is a crucial factor in particularly because ex situ gene banks are very costly and are difficult to maintain for long periods. Such conservation also implies, however, acknowledging the important role that farmers and communities fulfil as major players in species preservation.

Biodiversity must be considered not only as part of humanity's global heritage but also as a potential basis for local development that links in well with current practices in a way populations can understand. This means that the study, economic development and conservation of biodiversity are not limited to a handful of particularly rich zones but spread around regions. By studying and monitoring biodiversity, we should be able to extract the correct samples from their original biological dry-land lineage. This work will enable us to draw up lists and maps of taxons present and to establish a critical evaluation of their vulnerability in this respect. The study of populations' activities as they relate to biological diversity should enable us to draw up principles for economic development and for its use within viable long-term development frameworks.

Land degradation and water resources.

In dryland zones, water resources are closely dependent on climatic conditions, but also on plant cover, land use and soil condition. These different elements will be modified by the process of desertification. Although the effect of desertification on local climate still remains a matter for debate, most authors (Thornes and Burke, 1999) do consider that there is an effect that results in an increase in the persistence of drought phenomena.

Changes in plant cover, soil surface degradation, and changes to the physical properties of soils, due to the disappearance of organic matter, will lead, on a local scale, to changes in the components of the water cycle and the hydric balance: lower infiltration, an increase in immediate runoff, and a reduction in evapotranspiration. The latter will lead to a change in surface energy balance and to an increase in temperature. Higher rates of immediate runoff will lead to soil erosion, thus, to the reduction of its capacity to absorb water to support vegetation. All of which leads to an increase in aridity in both the climatic sense (through increases in temperature and persistence of drought incidents) and the edaphic sense, leading to the degradation of water supplies in the soil (Floret and Pontanier, 1982; Grouzis et al., 1992).

As concerns water reservoirs in areas of relief, the same phenomena (plant cover and infiltration reduction, immediate runoff, and soil erosion) will have repercussions on hydrological systems and drainage. The reduction of infiltration and of deep drainage will lead to a lowering of the phreatic table resulting in the reduction of river drainage in terms of flow as well as duration. The distribution of water reserves to supply populations will be drastically reduced over time. Meanwhile, runoff and rapid drainage will lead to water loss beyond the zone in question and to flooding, creating major, and even dramatic, consequences for infrastructures and further flood problems downstream.

The erosion of soil from water reservoirs in areas of relief, and rapid drainage associated with it will also shift considerable quantities of sediment. Some authors (Thornes and Burke, 1999) cite figures of 20 to 200 tons per hectare and per year in the Mediterranean zone. The transportation of such sediment will have important consequences on the stability of riverbeds downstream, on sedimentation and on damming, but also on the silting up of estuaries and deposits at sea.

Not only does water constitute the essential base of agricultural production and economic development in dryland zones, but it is also one of its major environmental constituents, which has a significant impact on the health and living conditions of populations. The direct and indirect effects of desertification are to increase the rarity of available hydric resources in affected areas. This brings with it harmful consequences for adjacent zones, including international waters.

Desertification and development.

Natural resources: public interest and basis for development. Environmental preoccupations are taking an increasingly important place in public opinion and in social demands, particularly in northern countries. The "productivist" discourse of the sixties has disappeared, sometimes replaced by a "conservationist" one opposing development and environment. Southern countries have problems accepting the rhetoric of the privileged and the efforts that are demanded of them. The World Bank and international organisations underline the synergy and not the competition between the environment and development ("Economic development and rational management of the economy are complementary aspects of the same programme – without good environmental protection, there can be no viable development; without development, there can be no worthwhile environmental protection," The World Bank, 1992). A southern point of view on the environment, however, is considered as the key to sustainable development and its integration into development plans. Its emergence is often held back due to the urgent measures required to respond to immediate problems. Analysis shows that in the south, development and environment are closely interdependent. The reasons for this are threefold:

1 Firstly, natural resources constitute the basis of productivity of ecological systems and habitats. In developing countries, exploitation of renewable natural resources contributes, in a determining way, to the satisfaction of the essential needs of a large part of the population. For food, health and daily life, humankind exploits a wide variety of living

natural resources. National economies are largely based on these resources, which contribute moreover, directly or indirectly, to the majority of a country's exports. Thus according to the World Bank, in the majority of African countries, the share of agriculture and the exploitation of renewable natural resources in the gross domestic product in 1992 was higher than 30%. The abundance and renewal of natural resources are controlled by fluctuations in the environment. Their future depends on the use to which societies put them and how exploitation techniques are controlled, as well as the way they are distributed and appropriated.

2 Human activities linked to development have important repercussions on the environment and ecosystems. During the period 1960-1990, it has been estimated globally that a third of the rise in farming production was due to increases in farming areas. The increase was down to farming marginal, fragile, barely productive lands to the detriment of natural ecosystems. Such farming, in the absence of adapted management methods, encouraged the degradation of land. It is estimated that globally 1,960 million hectares of land, or 17% of the farmable surface of the earth, have deteriorated due to human agency since 1945 (Gcrai, 1994). The continued and rapid increase of the population and of urbanisation leads to increasing and diversified demands in food requiring a considerable increase of production and in the efficiency of distribution networks. In 1950 in Africa, alongside his own consumption, a farmer had to feed 0.18 non-farming inhabitants. The ratio rose to 0.45 in 1980 and will reach 1.21 in 2010 (Cce, 1984). The quantity of food products the farmer puts on the market will have multiplied by 7. Often, satisfaction of short-term urgent needs, associated with unforeseen climatic, demographic and economic crises, leads to harmful practices, setting in motion desertification processes. Access and management control mechanisms for natural resources implemented by traditional societies then become obsolete under the pressure of demand. In various places there has been a saturation of available agricultural space, resulting in particular in a reduction in the time land is left fallow and a break with balanced rhythms (Floret et al., 1992). In the future, production increases should therefore be carried out essentially on already farmed land and not by increasing surface areas.

Tropical and Mediterranean zones are typically rural societies under social and demographic transformation, with fragile ecological systems of little resilience. They survive with high drought constraints and have coped with strong anthropogenic disturbances (such as desertification, aridification, deforestation, etc) for decades. The potential of these areas is reduced more quickly and the speed of recovery is slower than in climatic zones that are less restricted. Generally, what we see is an increase in aridity of edaphic origin, a reduction in water efficiency throughout an ecological system as well as profound changes to plant cover and landscapes that affect the system's productivity and its populations' living conditions. The irrigation of land, particularly in arid and semi-arid zones frequently leads to salinisation problems which tend to sterilize land and lead to the abandon of its irrigated perimeters. The size of the areas concerned (50 % salinised land in Iraq, 30 to 40 % in Egypt, 35 % in Pakistan; Barrow, 1994) attests to the seriousness of the problem, which is made even more acute because planning is costly and irrigable land has limits to how far it can extend.

3 Finally, pressure on resources and environment depends on the functioning of social systems. Rural development cannot be reduced to processes of technical or economic evolution; it is a dynamic and based on social construction shaped by multiple actors and determining factors. This social dynamic conditions what values areas take on through use of their ecosystem's natural resources, agricultural production systems and other diverse rural activities. Rural areas and natural resources are crucial to different groups within a population, or for different populations, for their material and social reproduction as well as that of their existence. The way in which human societies manage space and resources is strongly marked by cultural constraints which underlie their perception of the environment, and their capacities to evolve and appropriate new technologies. For a society to protect its environment it has to be economically possible and its environment has to be part of its reference system. Although there is no one-to-one relationship, poverty, and the short-term survival strategies it imposes, constitutes one of the most important causes for "mining" style exploitation of resources and the degradation of environments.
The destruction of natural resources and loss of land productivity constitutes a major obstacle to development in these countries which may lead to major catastrophes that are difficult to reverse – such as famine, land abandon, large scale migration (refugees from the environment). It is estimated that there are currently 25 million refugees, that is to say, 58% of the world's total refugees, who are migrant due to environmental catastrophe (International Federation of Red Cross and Red Crescent Societies, World Disaster Report, 1999).

Desertification and poverty.

The reduction of poverty is one of the major directions of intervention in developing countries. Debates and decisions around the subject of poverty reduction, in the field of public aid to development and that of multilateral institutions, reflect the evolution of certain currents of economic thought (the works of Amartya Sen, in particular). Economic growth can only play a role in reducing poverty if it is integrated into an environment enabling

the poor to benefit from economic opportunities that are generated.
The analysis of the concept of poverty leads to a frame of reference which distinguishes monetary poverty – relating to income, from poverty in living conditions and poverty of capacities. The idea of monetary poverty is interlinked with of standard of living and results from a lack of resources leading to insufficient consumption. Poverty in living conditions implies the impossibility of accessing collective services enabling satisfaction of fundamental needs such as health, education, etc. Poverty of capacities refers to a lack of means to bring out the best of ones individual capacities, to seize the opportunities that present themselves, and have one's opinions heard.

Numerous authors underline the strong link between desertification and poverty. According to Ph. Dobie (2001), the proportion of poor people among populations is noticeably higher in dryland zones, especially among rural populations. This situation increases yet further as a function of land degradation because of the reduction in productivity, the precariousness of living conditions and difficulty of access to resources and opportunities. Decision-makers are highly reticent about investing in arid zones with low potential. This absence of investment contributes to the marginalisation of these zones. When unfavourable agro-climatic conditions are combined with an absence of infrastructure and access to markets, as well as poorly-adapted production techniques and an underfed and undereducated population, most such zones are excluded from development.

As a result of a lack of capital and of economic opportunities, poor populations are lead to exploit their limited resources in a way that satisfies their immediate needs, even if this short-term exploitation compromises the long-term survival of these resources and reinforces their vulnerability over time (Smith and Koala, 1999). Where poverty engenders land degradation, desertification is in turn a major contributing factor to poverty.

Action to combat poverty takes place in three major directions – creating economic opportunities, supporting and strengthening aptitudes and institutions that work closest to populations (the concept of "empowerment"), and assisting populations themselves, particularly the poorest sections, to reduce their vulnerability. This action also coincides with measures to combat desertification, which aim to diversify activities and revenues to reduce the pressure on resources, develop capacities, decentralise resource management, secure access to resources, reduce populations' vulnerability faced with unforeseen climatic events, etc. Ph. Dobie (2001) underlines the necessity for public investment in arid zones to combat desertification and to promote sustainable development. Examples, in particular that of the district of Machacos in Kenya, seem to show that there may exist significant returns on investment in these zones. At State level, it is a good idea to show how national action programs to combat desertification (Nap) should be associated with intervention in other directions – in particular strategies to reduce poverty (Psrp). This requires, among other things, that action to combat desertification is not only directed towards aspects of resource protection and conservation, but also that they aim to develop productivity in these zones and diversify opportunities in a modern economic framework.

Combating desertification and promoting sustainable development. Desertification and land degradation in dryland zones results essentially from human activity. It is rare that man degrades the resources and the land he exploits intentionally. At every latitude, humankind has managed to create systems adapted to the most difficult of conditions. However, it should be emphasised that development in arid zones is seldom continuous (Mainguet, 1995). More than in other ecosystems, it is characterised by progress and regression. The fight against desertification and land degradation is part of a global approach to environmental and development problems. The viability of action undertaken to combat land degradation is often determined by the increase and diversification of resources enabling an increase in the standard of living of populations. An effective strategy that aims to reduce or halt land degradation should take into account sustainable development criteria.

Development of viable long-term farming strategies in tropical countries need to meet four major challenges. The first is that of satisfying the food needs of populations with high rates of increase and that are becoming increasingly urbanised. The second involves the preservation of natural resources and the environment. The third concerns world economic competition which forces agricultural producers in developing countries to take on producers from other regions of the world even in their own market places. The final challenge consists of redistributing wealth more equitably, without excluding important sections of societies from development (Cornet and Hainnaux, 1995). Ecological or environmental viability cannot be understood from a purely conservationist point of view. It is a question of preserving the environment and resources so as to preserve the productive capacity of environments in a natural or human way. Sachs (1992) highlights the necessity of extending the productivity of natural systems by intensifying and diversifying the way different ecosystems' potential resources are used, while establishing methods of management and technology that reduce any negative impact on their functioning to a minimum.

Sustainable development, in the context of desertification, means above all halting the processes of degradation and stabilising the equilibrium between resources and exploitation, while re-establishing viable social and political frameworks for natural resource management. Because of demographic growth, methods of land use that are traditionally extensive have major negative impacts on plant cover and soil. More intense farming and breeding, plus taking the fragility of the area into account are thus indispensable to limit stripping away of vegetation cover, overgrazing and deforestation – all of which propagate desertification.

This intensification does not contradict the objectives of ecosystem conservation and world environmental preservation. In fact, it should enable the limitation of anthropogenic pressure over reduced areas, thus encouraging the conservation of biotopes.

The convention on desertification, called for by the poorest countries – in particular those on the African continent – is doubtless the environmental agreement that most closely links the environment and development (L. Tubiana, 1999).

Combating desertification.

Appropriate techniques for economic and institutional changes.

Techniques of combating desertification have been the subject of much research. There is unfortunately no ready-made scientific solution to control desertification and nobody is in a position to provide a simple response. There are however a number of partial solutions that have been tried and tested for particular conditions in particular regions. Solutions are specific to each place and each situation. Literature on the subject today is abundant and various technical solutions exist for most problems encountered. The quantity of resources to be marshalled to implement technical solutions varies as a function of the state of degradation of the area.

Solutions to combat desertification are based on controlling causes of land degradation. As desertification is above all the result of human agency, it has become apparent that attention should be paid to the three main areas of activity in which it appears: grazing zones, farming in pluvial areas, and irrigated zones. This distinction mirrors the way countermeasures operate, in that the causes and types of desertification – and consequently the methods for combating it – are largely specific to these three fields.
Generally, techniques and methods to combat desertification may be divided into four categories corresponding to a variety of complementary strategies:
Corrective methods aiming to halt a phenomenon and to reverse existing degradation. We may cite here dune fixation, combating shifting sands, anti-erosion, and water and soil conservation techniques, reforestation, as well as techniques of ecosystem rehabilitation (Pontanier et al., 1995).
Techniques enabling the better exploitation of resources, so as to increase

productivity and improve regeneration. These correspond to formulating improved and adapted practices for agriculture, breeding, the use of the biomass and soil.

The finalizing of integrated management resource models. This relates to the resolution of conflicts, the creation of negotiation and decision-making locations and the establishment of rules governing management and access to resources.

The implementation of institutional and political mechanisms suitable for economic development and the preservation of natural resources. Among them the establishment of legislation and regulations, the implementation of economic and financial incentives, the development of infrastructures, and the reinforcement of human resources.

Countermeasure techniques and methods should be adapted to the particular conditions of the zones concerned. In a study for the French Development Agency on the subject, Jouve et al. (2001) put forward three major demands:

1 That techniques should be contextualised, that is to say that the conditions in which countermeasure techniques are implemented should be taken into account so as to select the most relevant. Three main types of condition should be taken into consideration when justifying choices: the agro-ecological context, defining the biophysical characteristics of environments, production systems and agrarian dynamics.

2 The involvement of the various actors engaged in the struggle against desertification, which is one of the essential conditions of the sustainability and success of action undertaken.

3 The existence of an adapted institutional framework.

What projects respond to populations' needs?

Numerous projects to combat desertification have been undertaken in the last twenty years, representing a considerable investments both financially and in terms of the mobilisation of human resources. However, the results of these efforts have generally been unsatisfactory and many projects have not reached their goal. It is generally admitted (Warren and Agnew, 1988; Rochette, 1989; Chambers, 1990) that the causes of low efficiency or project failure have been:

1 The fact that the problem of desertification has not been considered in the global context of the socio-economic development of countries involved and that the countermeasures taken have not been integrated into rural development programs.

2 An often-erroneous approach to problem-solving based on a mis-recognition of processes and inadequate diagnoses.

3 The fact that action was taken with little reference to populations' needs, their priorities or their savoir-faire.

4 Weak overall effectiveness of aid programs, linked to poor co-ordination between agencies and insufficient decentralisation at national level.

Via the new perspectives set in place and by breadth of experience, we may attempt to define a certain number of desirable general criteria for projects to combat land degradation in dry-land areas: The approach should be integrated, combining the prevention and combat of land degradation with development programs and environmental strategies defined at national level; this approach should be directed towards local populations and communities as a priority.

The essential aim of projects is to bring solutions to populations' problems, within a framework of real involvement, enabling them to increase their resources and to manage them over the long term (assuring rights and income for poor populations).

Projects should be based on solid scientific knowledge of processes and causes, and on precise local diagnoses. They should bring significant contributions to resolving problems of land degradation in dryland zones or rehabilitation of already degraded zones while ensuring adoption of durable resource management systems. In this domain, projects should be innovative and results should be reproducible.

Projects should adopt a flexible learning approach, allowing for changes of direction if necessary. Projects should be long-term and include several phases.

Effective coordination should be established between intervening parties based on quality, commitment and continuity of the workforce.

Monitoring and evaluation mechanisms should be implemented, based on agreed repayment schedules and quantifiable objectives and measurement parameters, while encouraging the development of the countries' institutional capacities.

The United Nations Convention.

The United Nations Convention to combat desertification aims to guarantee a long-term commitment to the parties concerned through a legally-binding document. Its aim is to combat desertification and to alleviate the effects of drought on seriously affected countries, those in Africa in particular, through measures that take effect at every level. This process should be supported by cooperation and partnership arrangements internationally, within the framework of an integrated approach that is compatible with that of the Action 21 program. The underlying aim should to institute sustainable development in the affected zones. The convention includes a main text with forty articles and four appendices relative to it regional level implementation: Africa (Appendix I), Latin America and the Caribbean (Appendix II), Asia (Appendix III) and the northern Mediterranean (Appendix IV). A fifth Appendix concerning the membership of the convention of central and eastern European countries is on the way to being created. France is unaffected and is not involved in Appendix IV. However, it has an observational role and assists in some collective actions.

For its implementation, the Convention set up a number of bodies. The Secretariat, the permanent executive office, is based in Bonn. It takes care of promotion of the convention, the organisation of meetings, the sending of reports and the co-ordination of other publications. It is also in charge of liaison with other organisations or conventions. The Conference of Participating Countries (CDP) is at the head of the convention, and is the governing and decision-making body. It is organised by the Secretariat and brings together all signatory countries. International organisations and non-signatory countries are also present as observers. Decisions are taken by consensus. Instead of creating a new fund to combat desertification, the convention has underlined the necessity to improve management and to mobilise and co-ordinate existing funds, by creating a Global Mechanism. The Conference of Participating Countries has made it responsible for identifying existing financial resources. It will mobilise and channel financial resources from bilateral and multilateral organisations on all levels allowing it to draw up and execute projects and programs. Another subsidiary body of the convention is the Committee on Science and Technology (CST), made up of representatives of the States. It meets at the same time as the Conference of Participating Countries and deals with scientific aspects, concerning co-operation and the transfer of technologies.

Interdependent and innovative approaches.

The United Nations Convention to combat desertification recognises the global scale of the problem. It also underlines that efforts to counteract desertification should be accompanied by measures aiming to encourage economic and social change and be conceived to remedy the causes of desertification. In other words, efforts should be an integral part of the development process (World Bank, 1998). The convention's approach is based on obligations and on the principle of solidarity between countries affected and developed countries. It obliges countries concerned to accord priority to the combat against desertification and against effects of drought, to attack the underlying causes of desertification, in particular the socio-economic factors, and to collaborate in this direction with the populations concerned. At the same time, developed countries make a commitment to actively supporting these efforts and to supplying significant aid to this end.

A number of guiding principles result from the convention, which should underpin the application strategies implemented:

The fight against desertification and land degradation is part of a more global approach to environmental and development problems. An effective strategy aiming to reduce or halt land degradation should take into account the criteria for sustainable development: environmental integrity, economic efficiency and social equity.

A participatory approach is essential in the definition of strategies, action plans and countermeasures. The participation of affected communities seems to be a precondition to the success of any preventative action or countermeasure. Participatory approaches have greater chances of sustained success, as much in terms of project planning at a local level, as in policy ideas at the national level.

By laying emphasis on the participation of local actors in development and decentralisation of the decision-making process, the convention advocates a new role for the State. The new perspectives laid down by the convention are leading to evolutions in the role of the State. This new role is to be found in particular in the co-ordination of international initiatives and the setting up of adequate legislative and regulative frameworks, enabling the development of national consultation mechanisms and capacity building in local communities for self-management of their natural resources in the framework of a development program that is more sustainable.

Science and technology constitute essential tools in the struggle against desertification. The causes and effects of desertification are far from clear and it is advisable to strengthen international co-operation as concerns research and scientific monitoring. Science and technology must be deeply involved if we hope to respond to populations' real needs.

A strategy to prevent and fight against desertification should be based on the implementation of concrete projects, capable of bringing suitable solutions to major problems encountered locally.

The implementation of the convention fundamentally depends on National Action Plans (Nap), the establishment and drawing up of which is the responsibility of the countries involved. The convention asks affected countries to establish national action programs to produce an inventory of their situation and suggest a strategy of countermeasures. These Nap should be elaborated according to a participatory process involving the State, local groups, basic communities and farmers, from conception through to execution of the program.

Congenital abnormalities and difficulties

The Convention to combat desertification managed to undertake a change of direction but it has been less effective in setting up specific tools. Without major economic impetus and dealing with environmental subjects that only interest the poorer countries of the planet, it has had difficulty mobilising the international community (Tubiana, 1999).

Difficulties encountered concern budgetary matters. The Convention to combat desertification does not have a special fund for operations. Action plans may be financed via the World Environment Fund, but only in relation to actions concerning other conventions, such as biodiversity, climatic change etc. Current negotiations, should, eventually, enable direct financing from this fund. One promising finance ally is via specific operations for financing development projects. The Global Mechanism should play a facilitating role for project finance, but has had much difficulty in finding a place in bilateral and multilateral funding and in specifying fields of activity.

The Secretariat's operating budget and that of the convention's various bodies also constitutes a bone of contention between northern and southern countries. The Secretariat itself is considered as excessive by some countries. The complex mechanism of United Nations organisations leads to a proliferation of meetings and other workshops with results that do not match up to human and material commitments. A great many people make their living from such procedures, above and beyond concern for the populations affected. Unlike other post-Rio conventions, the Convention to combat desertification is not based on a strong stand from the scientific community. Neither does it have the backing of the scientific community. The CST, a subsidiary body of the Convention, brings together representatives of countries and – as a result of the number of members and the way it is organised – it is rather inefficient, contributing little to implementation of the Convention.

A certain number of crucial questions concerning the Convention's functioning, (in particular implementation procedures, the operational strategy of the Global Mechanism, and improvement of the CST's work), constantly lead to tense debate where little is achieved but a widening of the gap between developed and developing countries. A climate of mistrust is not conducive to the creation of long lasting partnerships, and the convention could be in danger of losing its legitimacy if these questions are not resolved to the satisfaction of all parties involved.

Real advances.

The Convention to combat desertification is doubtless the one environmental convention that deals with both environment and development in closest proximity. It advocates the necessity of a synergy between economic policy, development plans and national programmes for environmental preservation in clear terms. It has been able to put forward a change in approach and has a fundamental objective to encourage governments to make commitments in terms of state policy or as aid development programmes, and to define legislative and regulatory programs enabling populations to organise themselves to manage their own natural resources.

The preparation of national action programmes has constituted a major exercise of resource mobilisation and awareness in the affected countries. Their establishment is on the way to completion, particularly in Africa. Even if results remain disappointing in terms of diagnostics of the situation and of definitions of combat strategies, production of the programmes has led to real participatory processes, which have encouraged different sections of the population to speak out, expressing their views and their needs. They have been important exercises in the management and mobilisation of resources, ranging from the empowerment of local actors to promoting awareness in public opinion via a revision of legislative and institutional frameworks. In many cases, their production mobilised enormous resources and significantly raised expectations. The NAP processes have up till now had an unexpected reach and impact, particularly as concerns the democratisation of relations between actors of civil society and their public powers.

Now projects and programs have to be implemented and the combat against desertification has to be integrated into the management of natural resources and the environment. One question, that of financing the combat against desertification is one that is becoming increasingly pressing. But there are others: Will developing countries be in a position to respond to the calls of developing countries? Will the Global Mechanism manage to mobilise a sufficiently large offer to respond to demand? And will the convention whither and become an organisation that is outdated and inefficient, or will it really become the partnership tool that it should indeed be?

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Climate Change.

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Since it was formed in the solar system some four and a half billion years ago, the Earth has evolved continuously through different geological eras. This evolution, which concerned every aspect of our planet – continents, oceans, biosphere, etc – led, via a series of successive changes, to the appearance of life, thus distinguishing the Earth from the other planets in the solar system. Until the beginning of the 20th century these changes were brought about by natural phenomena linked mainly to variations in the orbit and inclination of the Earth in its course around the Sun. But the demographic explosion, the development of industrial and agricultural activities and the multiplication of available forms of transport led, in the course of the last century to profound changes in our environment that affect the whole of the planet.

Planet Earth is characterised by the presence of several compartments, all of which condition the balance of life: continents, oceans, terrestrial and marine biosphere and atmosphere. The atmosphere, which can be identified by the presence of clouds and the blue colour linked to the diffusion of sunlight, is an extremely thin envelope with a vertical extension of no more than a few tens of kilometres. It is therefore particularly fragile, especially since its chemical composition reflects to a large degree the natural and anthropogenic emissions on the surface of the Earth. Thus, apart from nitrogen, which represents 4/5 of the total, the presence of oxygen, the other major element in this atmosphere, is a direct result of the balance between photosynthesis and respiration. The presence of water in its different forms is another essential characteristic of the balance of planet Earth: liquid in the oceans, liquid or solid in the clouds and in the form of vapour in the atmosphere, where it represents only a very small percentage of total abundance, a few percent in humid zones and less than one thousandth in dry zones.

But other gases also exist in the terrestrial atmosphere in relatively small quantities, gases such as carbon dioxide (365 millionths or parts per million – ppm), methane (1.8 ppm), nitrous oxide (0.31 ppm) and ozone (0.05 ppm close to the surface and 4 to 6 ppm in the stratosphere at altitudes of 20 to 40 km), all of which play a fundamental role in the energy balance of the Earth, and thus in the balance of life. On the one hand, they filter the incident solar rays – this is mainly the role of the ozone in the terrestrial stratosphere which prevents ultraviolet solar rays capable of destroying the constituent molecules of living matter from reaching the earth – and, on the other, they absorb some of the rays emitted by the surface of the Earth in the infrared wavelength range and partially reflect them back to the same surface. They thus contribute to increasing the thermal energy and help maintain the mean temperature of the planet as we know it today at 15° C. If this natural greenhouse effect did not exist, the temperature of the Earth would be –18° C and liquid water would be unable to remain on the surface. In all likelihood, this is what happened on Mars, which is more distant from the sun and thus colder. On the Earth, 2/3 of this greenhouse effect is due to water vapour and 1/3 to carbon dioxide. It is therefore important to remember that neither molecular oxygen nor molecular nitrogen, the most abundant constituents of the atmosphere, plays a role in this mechanism, in so far as their molecular structures do not provide them with absorption properties in the infrared wavelength range. Finally, other greenhouse effect gases, such as CFCs, used mainly in cooling industries and accused of destroying stratospheric ozone, are a recent addition to all of these components which are naturally present in our atmosphere.

The dynamic balance of planet Earth modified by human activities. In order to have a better understanding of the disturbance to the energy balance of the Earth that has been attributed to human activities it is interesting to review the history of our planet, particularly over the last 400,000 years, a period for which we have precise data concerning climate balances. This data comes from archives in the form of the polar icecaps, particularly those that have accumulated at the centre of the Antarctic continent where their thickness can be several kilometres.

In the course of the crystallisation process whereby ice is formed, small bubbles of air are imprisoned and they provide evidence of the composition of the atmosphere at the time of their formation. By extracting core samples of ice more than 3 kilometres long, which approximately equates to the thickness of the icecap on the Antarctic continent, palaeo-climatologists can now reconstitute the variations in temperature and the concentration of minority constituents in the atmosphere over the last few hundred thousand years.

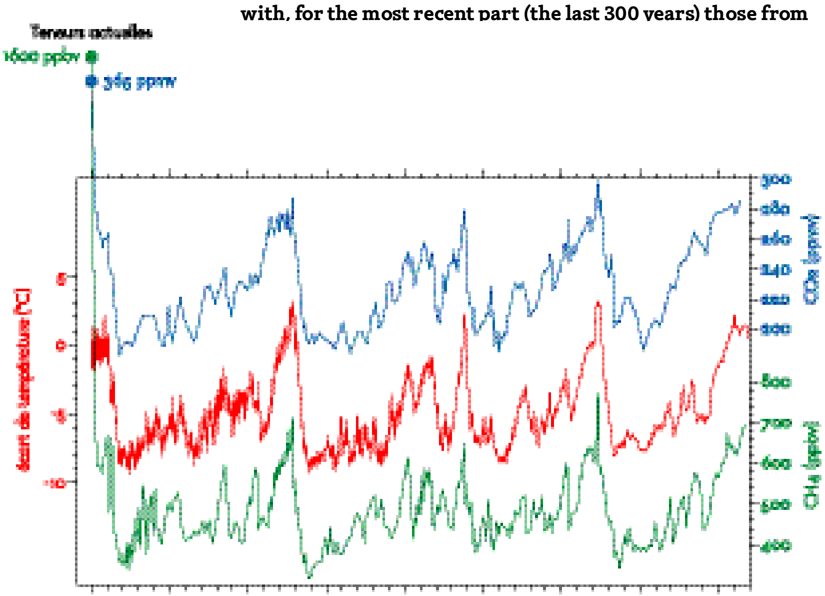
An analysis of this data from the past shows that the climate of the Earth responds to variations in the solar energy reaching its surface. This energy is subjected to oscillations that are linked to the cosmic parameters for the orbit and position of the earth in its course around the Sun. They are characterised by recurrent periods close to 20,000, 40,000 and 100,000 years and appear as alternate cold periods – the ice ages – and climatic optima during the interglacial periods. Temperature variations reflect these oscillations and we can thus go back through time from the present interglacial period to an ice age 20,000 years ago. Then we find new interglacial ages 120,000, 240,000 and 330,000 years ago, separated by ice ages during which the mean temperatures were as much as 5 to 6° C colder. The surface of the Earth was profoundly modified during these periods, particularly in regions of high and mid latitude in the Northern hemisphere where a gigantic icecap appeared. Liquid water accumulated in these icecaps and the mean level of the seas was 100 metres lower than it is today. With regard to the atmosphere, the proportions of carbon dioxide and methane contained in the glacial archives show that the quantities of these gases in the atmosphere also varies with climate oscillations Fig.1. Quantities are lower during the glacial periods, with values of 200 ppm for carbon dioxide and 0.4 ppm for methane. But we can also observe that the proportion of carbon dioxide never exceeded 300 ppm over the last 400,000 years and that the proportion of methane never exceeded 0.8 ppm.

However, over a little more than the last two centuries the concentration of greenhouse gases other than water vapour increased rapidly in the atmosphere in response to human activities. The proportion of carbon dioxide, now at 365 ppm, increased by 30% and three quarters of this was caused by the use of fossil fuels. The proportion of methane more than doubled over the last 300 years to reach 1.8 ppm, essentially because of intensified agriculture, which by using nitrogen fertilizers, is also partly responsible for the increase of nearly 20% in nitrous oxide (0.31 ppm). The evolution in the proportion of carbon dioxide over the last 30,000 years perfectly illustrates the scale, and most of all the rapidity of this upheaval. Whereas the change in proportion from 200 ppm observed during the last ice age to the interglacial value of 280 ppm took a few thousand years, the disturbance caused by human activities since the start of the 19th century, (which is of a similar order of magnitude), took place in less than 200 years. We are therefore talking about an extremely rapid variation in terms of natural evolutionsFig.1, which confirms that human activities greatly modify the proportions of carbon dioxide and other greenhouse effect gases in the atmosphere.

Beyond the concentration of these different gases in the atmosphere, we must also take into account their capacity to absorb infrared rays and to reflect them back to the Earth's surface. However, this capacity depends on the structure of the molecules. Thus, if we put the same quantity of methane and carbon dioxide into the atmosphere, the warming power of the methane will be 56 times greater than that of the CO_2. In the case of nitrous oxide, there is a factor of 280. For ozone in the low atmosphere it is 1200. Other greenhouse gases, such as CFCs, which have been accused of destroying stratospheric ozone and which were mainly used in cooling industries, have, for an equal mass, a warming power of between 5000 and 10,000 times greater than carbon dioxide. Fortunately, they have a much lower concentration in the atmosphere, in the order of 0.004 ppm. When we consider the global effect of the different constituents, we notice that they all play a significant role in the additional greenhouse effect (which we shall also refer to hereafter as "radiative forcing"). The mean usable energy for warming the lower layers of the atmosphere, which was close to 240 Wm^{-2}, has increased by 2.43 Wm^{-2} since 1750 i.e. about 1%. While carbon dioxide accounts for 60% of this increase, the relative shares for methane, CFCs and nitrous oxide are, respectively, 20%, 14% and 6%. However, another variable plays an important role in any comparison of the different greenhouse gases. And that is the time they remain in the atmosphere before disappearing or being exchanged with other compartments of the environment. It is easy to see that the longer a gas remains in the atmosphere, the more it will be able to exert its warming power. Carbon dioxide remains in the atmosphere for a mean period of between one and two centuries. Its impact on the environment will therefore be greater than that of methane, which has a lifespan of only 10 years. However, action to reduce concentrations will be more effective on methane in the short term. This can represent an advantage for the implementation of strategies to reduce greenhouse gases.

The case of ozone, which is not taken into account in the above evaluation, is particularly interesting. On the one hand, the introduction by man of CFCs caused a reduction in the quantity of ozone in the stratosphere

Figure 1. Variations in concentrations of carbon dioxide (upper line) and methane (lower line) over the last 420,000 years. These two curves combine the measures carried out at Lgge Grenoble on bubbles extracted from a Vostok Antarctica ice core with, for the most recent part (the last 300 years) those from



and thus a diminution, estimated at 0.15 Wm^{-2} between 1979 and 2000, of the associated greenhouse effect. Because ozone is a very reactive gas that we cannot find in the glacial archives, it is impossible to offer an estimate that goes further back into the past. On the other hand, the variations in ozone in the troposphere, which have been monitored for about a century and a half through analysis of relative concentrations of ozone in the air close to the surface of the Earth, illustrate the link between climate change and air quality. They are based on chemical measures which show that in the years 1880-1900 the proportions of ozone did not exceed 10 to 15 billionths (ppb), whether in sites close to cities like the Montsouris park in Paris or in remote stations far removed from all sources of pollution, like the Pic du Midi at an altitude of 3000 metres. Today, the proportions for this site are in the order of 50 ppb. They therefore indicate an increase with a factor close to 4 in the course of the 20th century, which can be directly linked to human activities. In fact, ozone is not a constituent that comes out of the chimneys of factories or the exhaust pipes of cars. It is formed in the atmosphere by a chemical transformation in the presence of sun rays that provide the energy necessary for the reactions, based on various precursors, volatile organic compounds and hydrocarbons, with nitrogen oxides as catalysts. Moreover, this process of formation is extremely sensitive to the presence of nitrogen oxides because only a few hundred billionths of these compounds are required to trigger the oxidising processes that lead to the formation of ozone.
The usual sites of this formation are large agglomerations and industrial zones where this mixture of nitrogen oxides exists, linked to the process of combustion and transport, and hydrocarbons. The ozone and its precursors are also transported, on regional and continental scales, far from pollution zones and thus contribute to the observed global increase. This increase is estimated at 36% since 1750 and it is considered to contribute to increasing the additional greenhouse effect in a significant manner (0.35 Wm^{-2}). However, because ozone has a lifespan of a few weeks in the lower atmosphere, the observed proportions reflect the distribution of sources, unlike other gases such as carbon dioxide or methane, which have time to spread and mix all over the planet.

Human activities and climate warming: growing awareness.

As early as the 19th century, the Swedish scientist Svante Arrhenius drew attention to the fact that man was modifying the carbon dioxide composition of the atmosphere by using coal. Based on a relatively simple calculation, he estimated that our planet should warm up by 5° C by the end of the 20th century. But it was not until the 1970s that scientists focused on the problem of the potential effect of human activities on the climate.

Modellers were the first to become aware of this. The years after the Second World War saw the appearance of the first computers, although these were still quite rudimentary. Weather forecasting was one of the fields explored by means of models based on systems of physical equations that enabled us to describe the movement of the atmosphere and the water cycle from evaporation at the surface of the oceans to the formation of precipitation. Developed with a view to applications in meteorology, a science concerned with predicting disturbances whose individual evolution can only be followed over a few days, these models were then used on climatic scales of a month and longer. In this case, forecasts focused on mean values and no longer on following up individual disturbances. The first experiments, conducted in the sixties, enabled us to verify that the models were capable of simulating the major characteristics of the climate.

But climatologists very quickly took an interest in the capacity of these models to give an account of climates other than the ones in which we live today. Experiments conducted in the course of the seventies examined the consequences of doubling the proportion of carbon dioxide. They confirmed that such a modification would result in significant warming. These results were taken seriously and prompted scientific meetings and reports by experts; including one published by the NSF in 1979 with very well documented conclusions. But it was during the following decade that awareness really began to develop, not only in the scientific community but well beyond it, as the magnitude of the consequences of this climate change, both economically and ecologically, began to be defined.

In scientific terms, the results of climate models accumulated. Of course they differed from one model to another. For example, the warming predicted by four different models (three American and one English) in the event of an instantaneous doubling of the proportion of carbon dioxide varied between 1.5 and 4.5° C. This amplitude with a factor of 3 in the value of what climatologists called "climate sensitivity," resulted essentially from the way in which the formation of clouds is treated. Because of their optical properties, they both absorb and reflect solar rays. Moreover, they are affected differently depending on whether they are "high clouds" or "low clouds." Because of this complexity, it is difficult to take the behaviour of cloud systems into account in models and there is always a major source of uncertainty in predicting future climates. But beyond these uncertainties, all models – and this affirmation still remains practically certain now that the number of simulations has been multiplied by a factor close to 10 – predict a warming. Moreover, this warming is systematically greater than the one – a little more than 1° C – obtained from doubling the proportion of carbon dioxide, which corresponds to a radiative forcing of 4 Wm^{-2}, in the absence of any climate feedback. There are therefore amplifying mechanisms that very demonstrably dominate the climate's response in the case of an increase in the greenhouse effect. Thus, a warming of the atmosphere will, within a certain period of time, be transmitted to the surface layers of the ocean. This will lead to greater evaporation, which increases exponentially in function of the temperature and therefore an increase in the quantity of water vapour present in the atmosphere. And because water vapour is itself a "greenhouse gas," the radiative forcing is amplified. The reduction in sea ice, which is highly reflective of solar rays, in response to this progressive warming of the ocean, constitutes a second amplification factor (it is then replaced by a much more absorbent ocean surface). Against this, none of the compensating mechanisms we can mention seems to be effective.

The majority of the scientific community was quickly convinced of the scale of the problem and the necessity of analysing every aspect of it. The first results obtained from Vostok Antarctic ice, suggesting that the climate is an amplifying system also contributed to the growing awareness. It was further strengthened by the fact that mean temperatures measured on the surface of the Earth in the 1980s showed a clear increase. The community then drew the necessary conclusions. As early as 1979 the World Meteorological Organization (WMO) set up a research programme called the World Climate Programme (WCP). Aware of the strong interactions that exist between climate and environment, the ICSU (International Council for Science) launched an ambitious programme called the International Geosphere-Biosphere Programme (IGBP). The WCP and the IGBP are two of the four components of what is now known as the Global Change programme (the other two components are devoted to biodiversity and the human dimension in climate change). Thanks to these international initiatives, which received strong support from research organizations in many countries, understanding of the complex mechanisms governing climate evolution has progressed greatly over the last twenty years.

Aware that this was a problem they could not afford to ignore, governments wasted no time in providing support. Signed in Montreal in 1987, the protocol banning the production of compounds contributing to the destruction of the ozone layer constituted a first example of what can be done in terms of the global environment. With hindsight, the decisions taken here have proven to be judicious and, thanks to them, we may hope for a slowing down in the reduction of the ozone layer in the decades to come, followed by a reversal of the process. The scientific consensus that rapidly came to be established, the clearly identified consequences and the restricted number of producers, greatly facilitated the signing and implementation of this protocol. But although it presents many similarities, the response to the case of stratospheric ozone cannot be easily extrapolated to the problem of climate change, which is a much more complex question. Evidence for the existence of a link between human activities and climate warming is solely based on predictions from models which we know to be fairly rudimentary, and the consequences of this warming are not clearly identified. Moreover, although measures must be taken to reduce the use of fossil fuels, it will be difficult to have these measures accepted because the notions of economic development and individual comfort are so strongly linked to energy consumption. The first stage is therefore to establish a diagnosis.

To this end, the Intergovernmental Panel on Climate Change (Ipcc) was created in 1988 under the joint auspices of the Wmo and the United Nations Environment Programme (Unep). The problem was now being addressed on a more political level and was one of the central subjects at the Rio Earth Summit in 1992, during which the United Nations Framework Convention on Climate Change (Unfccc) was discussed before being ratified in 1994. In response to the very well documented arguments of the scientists presented in the form of Ipcc work, governments were quick to take the problem seriously. They agreed to set up what came to be called a Conference of the Parties (Cop) which, from Rio de Janeiro (Cop1) to Kyoto in 1997 (Cop3) and Marrakech in 2001 (Cop7), laid down a set of rules to limit man-made emissions of greenhouse gases, to which the Johannesburg summit may give their first concrete form.

From Rio to Marrakech: the trail of IPCC reports.

From the very beginning the Ipcc took an interest in three distinct questions: group I dealt with the scientific aspects of climate change. The other two tackled, respectively, the impact of climate change and analysis of the measures for adapting to and assessing it (group II) and studying the socio-economic aspects (group III). To date, three complete reports have been published, the first in 1990, the second in 1996 and the third in 2001. Each individual report is divided into chapters, the first draft of which is produced by a team of ten researchers from different countries. In order to accomplish this task, each author solicits contributions from researchers involved in the field in question. Based on these very bulky reports (nearly a thousand pages), fifty-page summaries are drafted, then the "decision-makers' summaries," which are much shorter and much more accessible. All this is completed by an overview report. Once each of these documents has been drafted, the scientific community (acting as proof-reader) gives its opinions, as do representatives from government bodies. The drafting and proofreading process always takes more than two years, in order to be able to offer governments a text that has the support of the scientific community.

The figure of 3000 people, mentioned for the second report, includes authors (around one hundred), contributors (a few hundred) and proofreaders. Comments from various sources (the scientific community, government bodies, but also NGOs) are taken into account by the authors and the texts are amended accordingly. If the authors feel that a comment is invalid, which sometimes happens, they must give the reason or reasons why they chose not to take it into account.

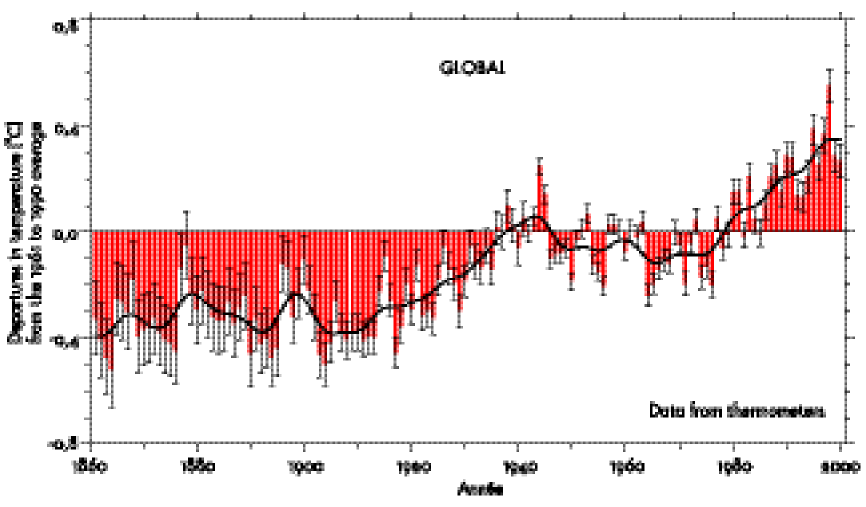
Then comes the last stage before publication, that of approval by the member governments of the IPCC (over one hundred countries). The "decision-makers' summaries" are discussed line by line by the delegates from the different countries and approved, after possible modifications in the course of meetings that NGO representatives may attend as observers. Consensus is the rule and it is sometimes very difficult to reach, in spite of the efforts of the IPCC operators and the authors who are present at this final meeting, whose common goal is to reach a solution that is acceptable to all and which is a true reflection of all the reports. The content of the reports is not rediscussed, but the content of the extended summaries is also submitted for approval and great attention is paid to the coherence between the different stages of the reports. Here we shall be looking essentially at the conclusions of group I, which deals with the science of climate change. We shall sum up its work in a series of four conclusions.

The first two are the subject of a consensus that was developed in the course of the three IPCC reports. One, which we have already largely covered, states that human activities modify the proportion of greenhouse gases in the atmosphere. The other, which we have already mentioned, relates to the warming observed in the course of the 20th century [Fig.2]. Already visible at the time of the first IPCC report, the available record up to 2001 now gives a clearer picture. Warming has accelerated in the course of recent years. 1998 was the hottest year since 1880 and, if we look for the ten hottest years, they are concentrated in the last two decades. And it is this chart taken as a whole, which enables experts to conclude that our climate has warmed a little more than a half-degree (0.6 with a margin of error of 0.2°) since the end of the last century. This warming took place in two stages: the first between 1910 and 1945, the second after 1976. Certain aspects – quality and geographical coverage of the oldest data, corrections to be made in oceanic temperatures measured by merchant ships, bias from urbanisation for stations which, originally in the country, have progressively become part of an urban milieu – have been the subject of many discussions. These points have been taken into account independently by different teams and the graphs obtained are quite similar.

It is also worth noting the debate that is raised when we compare, for the period covered, the temperatures measured at the surface of the planet and those obtained from sounding balloons and satellite observations. The temperature of the atmosphere observed since 1979 by the last two methods increases three times more slowly than the surface temperature and it is difficult to say whether this is a real phenomenon or whether this difference is linked to the fact that the period of comparison is relatively short. On the other hand, many observations corroborate this warming indirectly: the extent of Alpine glaciers is diminishing almost universally (exceptions can be explained either by the modification of atmospheric circulation or by an increase in precipitation), the snow coverage and the thickness of sea ice are decreasing in many regions, lakes and rivers spend less time frozen, the ocean is warming on the surface, the sea level rose about ten centimetres in the course of the 20th century, and there is more water vapour in the atmosphere. In spite of some shady zones, there is a general consensus: the climate is warming.

The third conclusion relates to a point that is certainly important for scientists, but which also turns out to be the key question for the decision-maker: is the warming we are experiencing all over the planet linked to

Figure 2. Variation in the mean temperature of the planet since 1861 (adapted from Ipcc 2001 report).

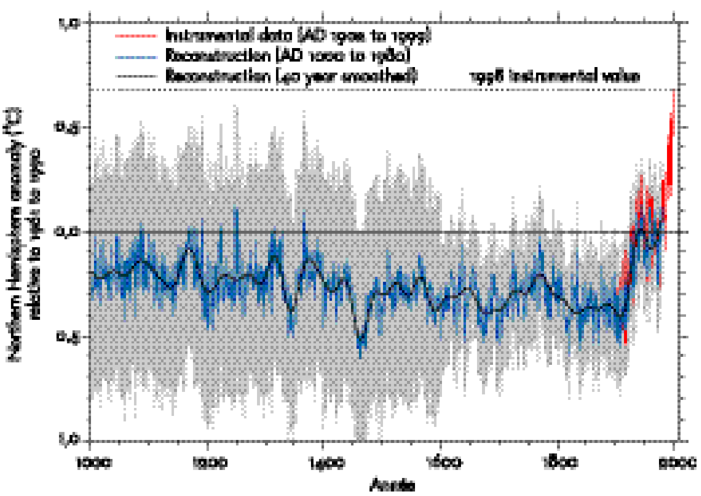


the proven increase in the greenhouse effect. Without going back to great ice ages, all we have to do is look at the recent past to see that without any intervention on the part of man, the climate can change in ways that are every bit as remarkable as those in the 20th century. For the period we call the Little Ice Age, between the middle of the 15th and the end of the 19th century, there can be no doubt. Based on many testimonies, such as the advance of the Alpine glaciers or the paintings of the Flemish masters with their harsh winters depicting streams and rivers covered with ice. During this cold period, which reached its climax between 1550 and 1700, the temperature was, at least in Western Europe, at least one degree colder than in our 20th century. Conversely, the beginning of the last millennium – a period when the South of Greenland was hospitable territory – was relatively hotter. It is difficult under these conditions to state certainly that the warming we are experiencing today is linked to the increased greenhouse effect caused by human activities. The greenhouse effect is increasing and the climate is getting warmer, but is there a cause and effect relationship? To this question the first IPCC report responds that "the magnitude of the observed warming is roughly consistent with the predictions of the climate models, but it is also comparable to the natural variability of the climate. The observed warming could therefore be due to this natural variability." Ten years ago at the Rio summit the scientists' response was: "we don't know." But it has changed considerably thanks to a new set of scientific results that enabled the IPCC experts to indicate in the 1995 report that "the balance of evidence suggests that there is a discernible human influence on global climate."

This statement represents a first obstacle removed. Up until that point, taking account of the increase in the greenhouse effect since the beginning of the industrial era, climate change models predicted a warming in the region of 1° C. This is double the observed change, estimated at between 0.3 and 0.6° C. But these predictions did not take into account all aspects linked to human activity. For example, they ignored the effect of the cooling caused by the presence of micro-particles in suspension in the air. These micro-particles are produced from sulphur compounds that are partially produced by the use of fossil fuels, making the atmosphere slightly less transparent and absorbing a small amount of the energy that comes to us from the sun – something in the region of 0.5 Wm^{-2}. This fact is sufficient to counteract a part of the warming caused by the increased greenhouse effect and reduce the difference between predictions and observations. What is more convincing for the specialist is the revelation of a whole series of indices, all of which indicate that the observed warming is in all probability not solely due to natural causes. These indices are based on geographic, seasonal and vertical comparisons of warming, for which the predicted and observed characteristics concur all the better because the models take the role of the greenhouse effect and that of aerosols into account, and not simply the natural causes of climate variability such as volcanic eruptions, which can cause noticeable cooling – but only for a short time – or small fluctuations in solar activity. Moreover, the fact of taking sulphur aerosols into effect offers a plausible explanation for the fact that the temperature warms more at night than during the day because their cooling effect comes into play only on the visible part of rays – therefore during the day. When taken individually, none of these elements constitutes proof in itself, but their convergence has led scientists to suggest that the action of man is already perceptible. This is an important conclusion, which effectively played a key role in negotiating the Kyoto protocol. The fact of suggesting, even cautiously, that human activities are beginning to have an influence on climate, puts climate change at the centre of the problems that our society will have to face up to in relation to the environment and gives it a decidedly socio-economic dimension.

The diagnosis was refined between the IPCC reports of 1996 and 2001. First of all, the climate continued to warm and – added to this – we had better knowledge of climate variations over the course of the last century. Dating

Figure 3. Estimated mean temperature in the Northern hemisphere during the last millennium. This figure combines the estimate resulting from the combination of different indicators (information deduced from analysis of tree growth rings, coral, ice cores and historical archives) with thermometric measurements for the most recent part (since 1861). The grey shading indicates the estimation.



back to 1995, this knowledge became more concrete with the publication of a graph of climate variation throughout the last millennium, a curve that was based on the joint efforts of palaeoclimatologists who reconstructed different climatic series based on complementary approaches, and statisticians who combined them and extracted a mean value from them. This figure is still very largely speculative[Fig.3] but it nevertheless leaves little doubt: recent warming diverges from natural variability.

Climate models, which have made great progress, confirm this diagnosis. Long simulations show that the warming of the last hundred years cannot in all likelihood be due solely to natural causes. In particular, the marked warming of the last fifty years cannot be explained except by taking the increased greenhouse effect into account. Hence the conclusion: "There are new and very strong indications that a considerable part of the observed warming of the last fifty years can be attributed to human activities." From "perhaps" in 1995, we arrive at "probably" in 2001. The sceptics' camp is shrinking and this conclusion, approved by group I at the time of The Hague conference and ratified in the summary report before the Marrakech conference, pushed the scientific debate into the background. In the mind of the decision-makers, the questioning, followed by the doubt about the effect of man's action on the climate, have changed into a near-certainty.

From our point of view some questions still remain, such as those linked to the possible influence of changes in solar activity. We will need at least another ten years to be able to change this "probably" into a certainty. But one extremely important point is that the response to this question in no way influences the scale of the warming that awaits us in the course of this century and beyond. Even if the influence of the additional greenhouse effect was permanently masked by the natural variability of the climate, the predicted increase is so great (an extra 4 to 8 Wm^{-2}) that significant warming between now and the end of the century can be predicted without any doubt. That is the fourth conclusion of the IPCC report, which also indicates that there are many uncertainties associated with predicting future climate changes. Before looking at these, we shall look in greater detail at the ways in which man modifies and will continue to modify the composition of the atmosphere.

The greenhouse effect and human activities: a review of the situation and future development.

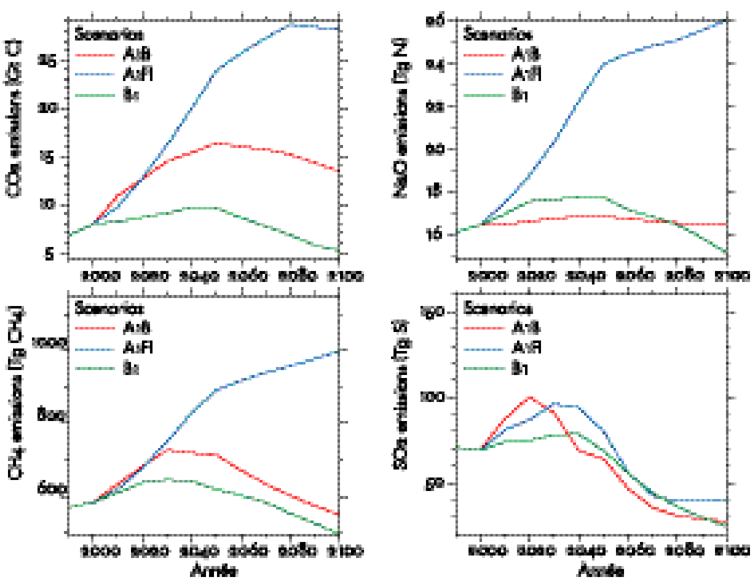
Without wishing to neglect the importance of the other greenhouse effect gases, we shall be focussing our attention on carbon dioxide, not only because its contribution to the additional greenhouse effect is by far the greatest (60%), but also because of the very long time it stays in the atmosphere. This implies that in order to be able to control the evolution of this additional greenhouse effect, it is essential to monitor carbon dioxide emissions. With regard to controlling levels, the UNFCCC stipulates that "the objective is to stabilize concentrations of greenhouse gases in the atmosphere at a level that does not pose any dangerous anthropogenic threats to the climate system. This level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable sustainable economic development."

The increase in the proportion of carbon dioxide in the atmosphere is only the reflection of a much more important disturbance that affects the whole way that planet Earth functions. Carbon is contained in every compartment of the terrestrial environment: atmosphere, ocean, biosphere, internal Earth. In the atmosphere we find it essentially in the form of carbon dioxide. On the continents we find it deep in fossil fuels, and on the surface in the vegetation and organic matter of the soils. In the ocean it exists mainly in the form of carbonates, particularly in the main carbon pool that is the deep ocean. All of these compartments are in equilibrium with each other thanks to a permanent flux of exchanges, such as respiration and photosynthesis between the atmosphere and the biosphere, gas exchanges between the atmosphere and the oceans, or the assimilation of carbon by micro-organisms in the ocean. This complex system is balanced over a scale of millennia. Naturally, during the transition from a glacial era to an interglacial period, the exchanges between the compartments of the terrestrial environment become modified and the system loses its equilibrium for a few centuries, or even a few millennia. Today, man is taking his turn to induce such an imbalance through additional emission sources that he has contributed to creating: combustion of fossil fuels (coal, oil, natural gas), emissions due to agricultural practices, and deforestation, which continues to diminish the capacity of vegetation to trap the carbon dioxide contained in the atmosphere. Of course this disturbance caused by human activities remains relatively small in terms of exchange flows because it corresponds to an annual emission of 7 billion tonnes (GtC) of carbon into the atmosphere, the majority of which (6 GtC) is linked to the combustion of fossil fuels. Natural exchange flows are in equilibrium with tens of billions of tonnes. But this amplitude is sufficient to modify the atmospheric concentrations and – most of all – its rapidity is worrying. Even if some is absorbed by the oceans (2,008 GtC), another portion by vegetation and soils (1,919 GtC), there is an average of 3 GtC of carbon accumulating in the atmosphere every year.

What about the future? When it comes to emissions, we turn to the economists, whom the IPCC has asked to come up with different scenarios that take into account all emissions of greenhouse gases but also sulphur compounds which, as we have seen, have a negative radiative effect. These scenarios, forty in number, are constructed, taking into account different possibilities in terms of future demographic and economic developments and technological progress that we may reasonably expect to make. We shall not describe them in detail but – and this is no surprise – the scenario with the highest emissions is associated with rapid economic development and massive use of fossil fuels, whereas the lowest emissions correspond to a services and information economy with optimal research into clean techniques and energy efficiency. In the maximum scenario[Fig.4] the annual emissions of carbon dioxide (a little less than 30 GtC) quadruple their present level (7 GtC) toward the end of the century whereas with the minimum scenario, they grow slightly and then return to a level of 5 GtC. Emissions of other gases, methane and nitrous oxide, are also greater in the maximum scenario whereas those of sulphur compounds diminish in almost all scenarios due to the efforts already made over several years to reduce the causes of this pollution.

The next stage consists of moving from emissions to concentrations in the atmosphere, using biogeochemical models. For carbon dioxide, the models take into account the ocean and biosphere sinks and their evolution, because

Figure 4. Emissions of carbon dioxide, methane, nitrous oxide and sulphur dioxide for three of the scenarios recently proposed by the Ipcc for the period 1990-2100.



once in the ocean, carbon remains there for about a thousand years whereas its storage in vegetation is very transitory (a few decades). Here again, there are no surprises: the greater the emissions, the more the concentrations are high. The maximum scenario would lead us toward the end of the century with concentrations close to 1000 ppm for carbon dioxide (a threefold increase), 3 ppm for methane (doubling) and 0.45 ppm for nitrous oxide (150%). Translated into terms of radiative forcing, this means an increase of 8 Wm^{-2}. But even the minimum scenario, where the mean emissions of carbon dioxide in the 21st century are close to their present level, has alarming consequences with, in 2100, a concentration of more than 500 ppm and, taking all compounds into account, an extra radiative forcing of 3 Wm^{-2}.

It is therefore not enough to maintain carbon dioxide emissions at a constant level in order for its concentration to stabilise, whereas for emissions of gases with a low lifespan, like methane, stabilisation of their concentration in the atmosphere occurs within a few decades. Here we touch an essential point that explains why scientists consider that the Kyoto protocol, which stipulates a slight reduction in carbon dioxide emissions, is only a first stage, especially with developing countries being considered as an exception. Having said this, and we will come back to it in greater detail at the end of this article, it is an indispensable first step, an essential stage in order to be able to set up more stringent rules at a later date. And even if the rules dictated by Kyoto have been relaxed in the course of the successive Cops, if the United States, the principal source of carbon dioxide, now refuses all constraints, the agreement ratified at Marrakech represents a bright hope which, if approved at Johannesburg, will be hailed as a promising step forward.

But much remains to be done in order to one day reach the target of stabilisation aimed at by the Unfccc. To convince us, let us consult not the economists but specialists on the carbon cycle. In order for the concentration of carbon dioxide to stabilise, emissions must be counterbalanced by the oceanic and biospheric sinks, as confirmed by the models. Whatever the concentration aimed at, at a given time in the future the annual emissions must go back down below their present value in order to reach 2 to 3 GtC, or even lower. If we settle for stabilisation at 1000 ppm, which climatologists regard as completely unreasonable, emissions must never exceed 15 GtC and then return below their present level in two centuries. To stabilise at 550 ppm, double the pre-industrial concentration, would require that emissions be below 12 GtC in 2040 and that they drop to their present level toward 2100 and to about 2 GtC at the end of the 22nd century. But if we set ourselves a more reasonable target of 450 ppm, emissions will have to start diminishing as early as 2020 in order to reach their present level in 2050 and less than 3 GtC at the end of the century. Of course an increase in the concentration of carbon dioxide favours photosynthesis with, thrown into the bargain, the hope of a greater and greater biosphere sink. But other effects (increased decomposition of organic matter in the soil, different distribution of species, etc.) cancel out the extra absorption resulting from greater growth in vegetation. They even go much farther and we may worry that the vegetation might turn from being a carbon dioxide sink into a source... The accumulated absorption capacity of the ocean and the biosphere may very well diminish as of the middle of the 21st century. Between the 30 GtC of the maximum scenario, where no effort is made to limit the greenhouse effect, and the undoubtedly desirable one of stabilisation at a concentration not too far removed from the current value, results in a difference of a factor of 10. The gap is immense...

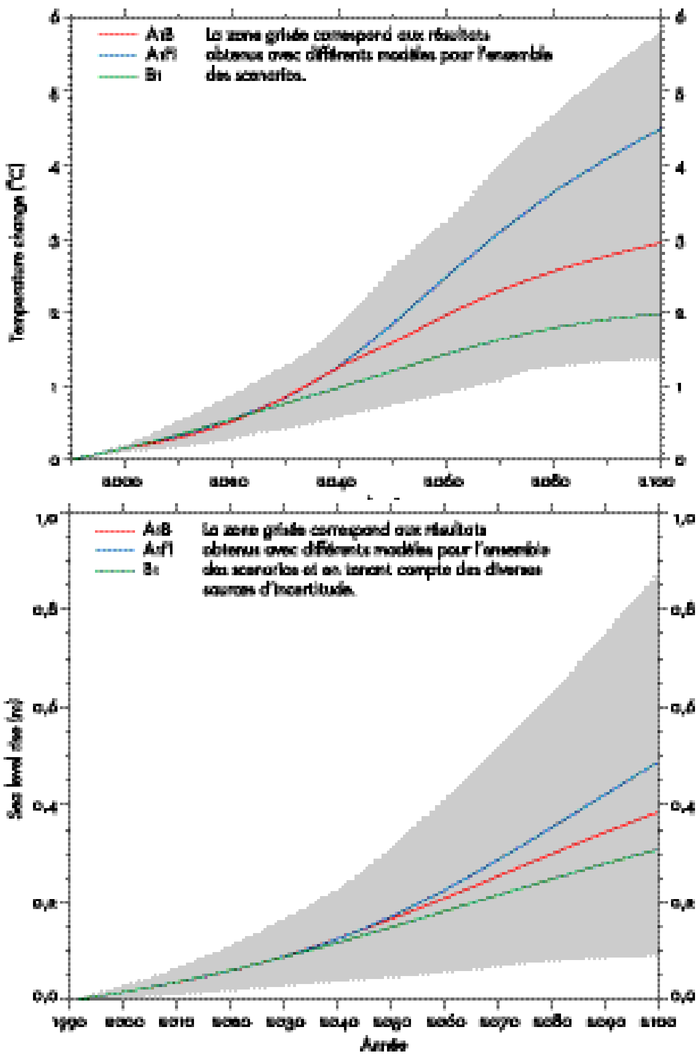
Today the majority of carbon dioxide emissions come from the use of fossil fuels, which corresponds to about 6 billion tonnes of carbon being emitted every year. In order to stabilise atmospheric concentrations we would have to reduce emissions by more than 40%. Hence the magnitude of the problem, because the means of energy production are thus directly called into question. 40% of these are in fact based on oil, 20% on gas and 25% on coal. It is interesting at this point to reflect on an equitable distribution of the 2 to 3 billion tonnes to which we would have to return in order to stabilise the concentration of carbon dioxide gas in the atmosphere. For a population of 6 billion inhabitants, each inhabitant of the Earth would have 500 kg of fossil fuel per year. This figure represent about 10% of the current emissions of an American, 15% of those of a German, 25% of those of a French person, but 120% of those of an Indian and 200% of those of an inhabitant of some of the sub-Saharan countries of Africa. It is also interesting to note that this ceiling is achieved by a single Paris – New York return flight or the use of 2 tonnes of concrete. The effort necessary in order to stabilise concentrations of greenhouse gas is therefore enormous and also completely at odds with a vision of development founded on the idea of always consuming more. Given the current inequalities and the necessity of developing emerging countries, the way out consists in all likelihood of enabling India and China to develop without increasing their emissions of greenhouse gas in the future but also considerably reducing the emissions of rich countries at the same time.

Moreover, as we have seen, the problem is not only quantitative, as the time variable also comes into play in the level of stabilisation, particularly with regard to the time constants imposed – in the case of carbon dioxide – by exchanges with the oceans and the biosphere. Thus, decisions made in the next 15 or 20 years will decide whether the course for the 21st century and beyond is one of reason or catastrophe.

What future for the climates of the Earth?

Although the study of current and past climates combines observations and digital simulations, predictions for future evolution must rely on modelling. Taking account of the different scenarios already mentioned, the climate models set a mean range of temperature increases for 2100 of between 1.4° C and 5.8°C [Fig.5]. Thus the 21st century will certainly be a century of upheaval,

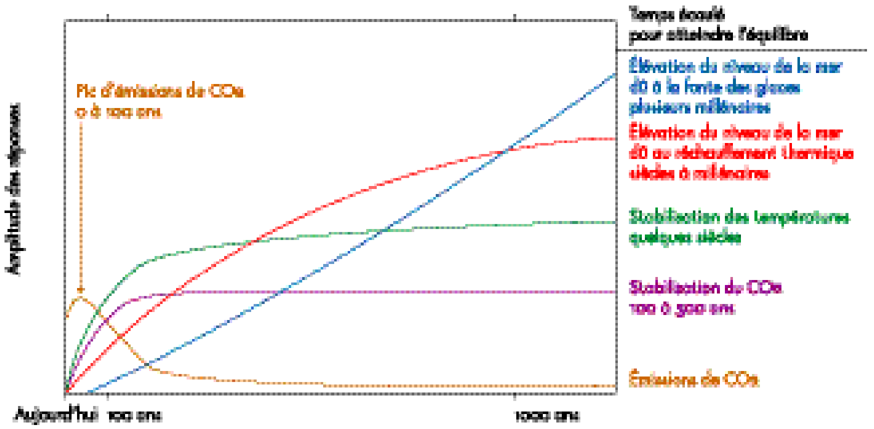
Figure 5. Prediction, until 2100, of the mean temperature increase for the planet and at sea level for the different scenarios proposed by the Ipcc.



characterised by extremely rapid transition and a considerable amplification of warming compared with that observed in the 20th century. The magnitude of the range stems from two main causes, each of which accounts for about half of the uncertainty. The first is obviously our imperfect knowledge of the system and the relative imprecision of the models we have already used. The second is linked to the difficulty of predicting our behaviour in terms of emissions of greenhouse gases. This warming will be accompanied by a rise in the sea level, largely linked to the dilatation of the ocean and for which estimates range between 9 and 88 cm.

One aspect that the third IPCC report brings to the fore relates to the inertia of the system[Fig.6]. We have discussed this in relation to the link between atmospheric concentration and carbon dioxide emissions. It also plays a part with regard to the temperature and an even greater one in relation to the level of the sea. Let's imagine ourselves at a moment in the future when concentrations have stabilised. The mean temperature of the planet will nevertheless continue to increase with – depending on the circumstances – from 50 to 90% of the warming already completed. This is because the inertia of the surface ocean takes time to balance out with the atmosphere. Depending on the stabilisation level of the greenhouse

Figure 6. This figure illustrates the inertia of the different components of the climatic system.



effect, the temperature, once balance has been achieved, may have increased by 3 to 8° C. For the level of the sea, the inertia is much greater because the ocean as a whole is involved in the process of thermal dilation. Once carbon dioxide gases have balanced, the level of the sea will continue to rise in a practically linear fashion for several centuries: if it has risen by 50 cm at the end of the century, it will have risen more than 2 metres by the middle of the millennium. Added to this is the non-negligible risk that the Greenland icecap, situated at an upper latitude where the warming is amplified, might begin to melt and contribute a few metres more to the rising of the sea level. Even given a voluntary policy leading to a stabilisation of the greenhouse effect, we can reasonably fear, over the next few centuries, temperature increases along the lines of those that accompanied the change from a glacial period to an interglacial period and an increase in sea level of up to 5 metres. Given these figures, it is hardly necessary to emphasise the absolute necessity of a policy to reduce emissions.

Moreover, these indicators correspond to average values, mostly estimated using models, which are only capable of examining the outline of scenarios. But, like any system that suffers a disturbance, the climatic system is also subject to increased variability around these mean figures. This variability may translate into a greater frequency of extreme events: hotter or colder periods, increased rainfall or intense drought, more destructive storms. It also implies a modification of the phenomena that control the natural variability of the climate on inter-annual scales. These derive mainly from interactions between the oceans and the atmosphere, for example, El Niño which regularly affects the tropical Pacific Ocean every two to four years. It is characterised by the displacement of the hot surface waters from West to East of the Pacific and leads to a considerable modification of precipitation patterns in these regions. It generates severe droughts in Australia, Indonesia and Northeast Brazil and violent floods in Peru, Argentina and as far as California. Recently observed El Niño events seem to show that the intensity of this phenomenon increases in a hotter climate.

Trying to foresee these climate changes on relevant scales of local-to-regional phenomena is an additional difficulty. This can only be done using a tool for modelling and simulating the terrestrial environment system that has been developed over the last twenty years. This tool is extremely complex because, based on the laws of physics, dynamics and chemistry, it simulates the behaviour of the different compartments of the environment: the ocean, atmosphere, terrestrial and marine biospheres and cryosphere. These models are all the more complex because they must take into account not only the behaviour of each compartment, but also the interactions that link them. Of course they are far from perfect for two basic reasons.

The first is that our understanding of how the whole system works is still incomplete. The second is due to the fact that the models cannot simulate this operation with the virtually infinite resolution that would be required in order to recreate the incredibly detailed scale of the phenomenon being modelled (spatial resolution of at least one centimetre, and temporal resolution greater than one second). Today's models have grids of several tens of kilometres and time scales of a few days, even a month. This therefore supposes that phenomena on spatially shorter and temporally faster scales have to be estimated, which adds up to an important source of uncertainty. One of the essential difficulties is the extreme difference in the spatial and temporal scales, and particularly the fact that the differentiation of processes on vertical scales operates over distances that are much shorter than in the horizontal dimension. A variation in altitude of a few tens of metres in the ocean or atmosphere leads to very great differences. In this context, validation of these models taking into account all the data available to us today is still an important stage. These validations are based both on a comparison with current observations and on the reconstitution of past climates.

The consequences of climate change.
An additional difficulty appears when we try to foresee the potential consequences of climate change. For our forecasts to make sense and enable adaptive or correctional measures, they must be evaluated on space scales that are at most regional or even local. But as a general rule the most powerful models can only manage evolution ranges for mean values. They are less reliable as soon as they are asked to quantify climatic variability in time and space. For the temperature at the surface of the globe, the models converge to show that warming will be more intense in the upper latitudes, particularly in the Northern hemisphere. But when we try to study precipitation, although all models predict an intensification of the water cycle with increased precipitation in the upper and mid latitudes, with dry periods in tropical regions and lower latitudes, the limit between these two systems continues to be considerably difficult to define. However, given this uncertainty, we could say "it will rain more to the North and less to the South of a line passing through the centre of France, give or take 1500 km"! Which – as everyone would agree – leaves a certain margin of manœuvre for developing land use in mainland France...

Nevertheless, a certain number of potential consequences of climate change can already be outlined in a fairly precise fashion. If the Earth warms up overall, the isotherms will move, leading to modifications in ecosystems: mutations in the major types of vegetation, typified by a retreat of woodlands, increased drought in tropical latitudes and the danger of extreme conditions. Moreover, certain rather fragile ecosystems will be particularly sensitive to climate changes, particularly those in the mountains and along coastlines. In this latter case, the combined effect of local climate changes and the rising sea level could have major consequences when we bear in mind that a large part of the population of the world lives near coastline, particularly in the deltas of great rivers. With regard to France, because of the uncertainties already mentioned it is difficult to foresee the consequences of a climate change on a regional scale. The climate will in all likelihood be dryer in the South and more rainy in the North. Extreme events like storms could become more frequent and snowlines could recede in the Alps.

As we have already pointed out, all models show that apart from average values, it is the variability of the climate that stands to be amplified in the course of the coming decades. Variability depends to a large degree on the interactions between the different compartments of the Earth and is therefore all the more difficult to predict with any accuracy. It is nevertheless likely that desert and sub-desert regions will be particularly affected. In other words, some developing countries that are already facing difficult food problems run the risk of being even greater losers in the event of a climate change. Another difficulty derives from the fact that data from the past is often insufficiently precise to enable us to predict the future. A reference might be the optimum period of the Holocene, some 8000 years ago, when temperatures were on average 2 to 3° C higher than current values. France was then a gigantic forest with varied types of vegetation. But conditions were also too different in terms of land use for us to be able to draw any conclusions whatsoever. However, what we do learn from these reconstitutions of the past is that a temperature gap of a few degrees in the mean value is enough to completely modify the nature of ecosystems.

But approach to climate change must not be limited to a simple linear extrapolation of current evolutions on a scale of decades or centuries. We shall probably not be spared an earlier "surprise" because of the non-linear nature of the interactions between the oceans, the atmosphere and the biosphere. Such a non-linear effect has already been produced in the atmosphere in the form of the "ozone hole" over the Antarctic. In the case of a climate change, a slowing down of the Gulf Stream is sometimes mentioned as an example. The Gulf Stream is a warm current that carries thermal energy from equatorial and tropical zones to the West of Europe, enabling us to have a much milder climate than our Canadian friends, who are nevertheless situated at the same latitudes. It is linked to and fed by the down-welling of water in the upper latitudes of the North Arctic ocean. But although the melting of the sea ice in this region, which seems to be on the increase in recent decades, has no influence on the level of the sea, it will however reduce the salinity of the ocean because it is made up of fresh water. And as salinity is one of the factors that determine down-welling of water, a reduction in salinity could lead to a slowing down of the current. We know that this situation of no Gulf Stream has already existed several times in the past over a scale of several hundreds of thousands of years. Sediments contain traces of much colder periods. In the present case, such a swing could happen over a few decades and force us to quickly adapt to a climate like that of Quebec. Thus the average warming of the Earth could lead, because of climatic instability, to a rapid cooling of certain regions. However, the most complex coupled models do not confirm this risk. In the event of a climatic warming, these models do indeed predict a slowing down of the Gulf Stream linked to increased evaporation in the tropical regions associated with the extra precipitation in the North Atlantic. But what they predict for Western Europe in this case is simply less warming, rather than cooling down.

An IPCC workgroup is also interested in the consequences of climate change for human health. It is important to realise at the outset that their appreciation is very largely qualitative. The first consequences could be linked to a new growth in extreme phenomena such as cyclones, floods or heat waves. However, the frequency of very cold periods could be reduced in our latitudes. We can also consider secondary effects: for example, a greater frequency of dry periods can lead to erosion, and thus a greater quantity of dust and pollen in suspension in the atmosphere, increasing the risk of allergies. In low and mid latitude zones the increase in mean temperature could lead to a new outbreak of infectious diseases like malaria, dengue fever, yellow fever or encephalitis and the risk of these tropical diseases spreading to more Northerly regions. Other factors can also influence human health, such as reduced yields from agricultural production, particularly in tropical zones, with the occurrence of more intense drought periods and problems exacerbated by malnutrition and famine. Finally, it is clearly obvious that the vulnerability of populations will be a direct result of their natural resources and technical and social resources. It therefore seems reasonable to believe that the more fragile populations will yet again suffer the maximum consequences in terms of food and health in the event of climate changes.

Climate change, energy and sustainable development.
It is clear that climatologists cannot "cure" the climate. Given our current very considerable uncertainties about how the terrestrial environment system works, all attempts to repair it based on a man-made modification of one or another climatic process would be equivalent to playing the sorcerer's apprentice. The only method we have today of diminishing the effects

of anthropogenic disturbance is to limit its magnitude. We must therefore think about controlling emissions of greenhouse gases, which immediately brings us back to the problem of energy sources and sustainable development.

The growing awareness of the magnitude of the problem on a world scale dates back only to the beginning of the 1990s, with the signature of the Rio Convention on Climate Change. The 1997 Kyoto Protocol to reduce emissions sets a medium term objective to reduce the 1990 level of emissions by −5% between 2008-2012. We are far indeed from the 40% necessary in order to stabilise concentrations of greenhouse gases in the atmosphere, but the first measures are often the most difficult. Moreover, we have to take into account the fact that the extension of annual growth trends for emissions observed in the 1980s would lead to emissions in 2010 between 30% and 40% in excess of those for 1990. So the Kyoto protocol does in fact mark a genuine departure. Its objectives vary country by country. The United States made a commitment to a −7% reduction, Russia to %, Japan to −6% and the European union to −8%. Within the European sphere, the objective for France is 0%, −21% for Germany, and −12.5% for the United Kingdom, whereas Portugal and Greece can increase their emissions by 25% and Spain by 15%. For the moment, the developing countries, particularly China and India, are not affected by these reductions.

France occupies a special position in these negotiations, linked to the fact that the majority of electrical energy is produced by modes of production that are not based on fossil fuels: 80% is nuclear and about 15% is hydroelectric. For this reason, the principal contribution to greenhouse gases comes from agricultural activities (45 million tonnes), the majority coming directly or indirectly from animal husbandry. In a consolidated balance sheet (L'effet de serre, H. Le Treut et J.-M. Jancovici, Flammarion, 2001), the production of one tonne of wheat amounts to the emission of 110 kg of equivalent carbon, whereas the production of one tonne of meat corresponds to 8 tonnes of equivalent carbon. Direct emissions from industrial processes correspond to the second source of greenhouse gas emissions (35 million tonnes), followed by household consumption (25 million tonnes) and transport (25 million tonnes). In fact, greenhouse gas emissions diminished in France between 1970 and 1990 due to the development of nuclear energy, particularly in the previously mentioned sectors of energy consumption and industry. This explains why our country has been set a target in the context of the European Union of stabilising emissions in 2008-2012 compared with the level attained in 1990. This is nevertheless difficult to do in so far as important efforts have already been made in terms of means of energy production and the efficiency of industrial processes. The main flexibility is linked to our capacity to stabilise emissions in the transport and household consumption sectors, though these have a strong tendency to increase. This problem therefore calls into question the lifestyle of every one of us.

Four years after it was negotiated, the Kyoto protocol still hasn't been ratified although the agreements reached at Bonn and then at Marrakech in 2001 offer the hope that this will soon happen. For the protocol to come into effect a group of countries representing more than 55% of greenhouse gas emissions must become engaged in the process. The refusal of the United States to ratify the Kyoto protocol still stands although the European Union, Russia, Japan, Canada and Australia are among the signatories, and it now seems to be an established fact. But the position of the United States, the leading source of greenhouse gas in the world, is still setting conditions for a rapid reduction in emissions, despite the obvious willingness of other countries. It is more than likely that the objectives, however modest, fixed by the Kyoto protocol for the reference period 2008-2012 will not be achieved. Today the European Union has reduced its emissions by only −1%. As for the United States with an objective of +7%, they stand at +20% over the reference year of 1990. Only Eastern European countries and Russia have achieved their targets because of the massive slowdown of their economies in the 1990s, which has resulted in a reduction of 38% in emissions. Within the framework of setting up a world market for emission permits, this arouses much envy. Moreover, the difficulty that the principal countries have in complying with the objectives of the protocol is not unrelated to the positions they display today with regard to ratifying it. As for the developing countries, the mechanisms set up in the framework of the Rio de Janeiro convention and the Kyoto protocol, particularly those linked to development in its own right, hold out hope of a reasonable solution in the medium term.

The ratification of the Kyoto protocol is certainly a necessary first step if we bear in mind that a large part of the lives of future generations will depend on our capacity to take the necessary decisions rapidly. This is what is at stake when we speak of sustainable development on a planetary scale, without neglecting the developing countries. It implies a decisive change in our ways of living and consuming and a desire that must be shared with a large part of humanity. It is a decisive political issue for the 21st century.

The controversy surrounding carbon sinks.

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Introduction. The controversy surrounding carbon sinks reflects not only scientists' uncertainties, but also the divergence of their points of view. Those opposing the sinks, whether scientists, politicians or NGOs, refuse to consider them as having the same importance as other components in the fight against climate change.

Generally, two main approaches are put forward for limiting greenhouse gases: reduction of the main source, which is the consumption of fossil fuel (oil, gas and mineral coal), and storage of excess CO_2 in sinks. Those opposed to sinks see this second approach as a red herring, the true cause requiring elimination being emissions from fossil carbon. Promoters of sinks say they are a solution to limit quickly, and at a reasonable cost, the concentrations of greenhouse gas in the atmosphere. They also say that the two approaches are complementary.

At the level of international politics the negotiations have shown intense antagonism between the "umbrella" group (Canada, United States, Japan, Russian Federation, Australia, New Zealand, Norway, Iceland and the Ukraine), which is trying to impose the inclusion of sinks, and Europe, which is more cautious if not downright opposed to it.

The controversy concerns sinks as political objects i.e. the inclusion of sinks in the Kyoto Protocol. But the scientific results concern sinks as physical objects. The distinction between the physical and political definition of sinks is often unclear, which further confuses the debate.

What is a carbon sink? *A carbon sink is defined as a pool (reservoir) of carbon that, over a given period of time, absorbs more carbon overall than it releases. The opposite of a sink is a source.* The oceans and the continental biosphere can be regarded as carbon sinks. For present purposes we are interested only in the continental biosphere.

The two associated physical variables are the storage and flow of carbon. Storage is a characteristic of reservoirs, whereas sinks are defined by increasing stores or positive flow from the atmosphere toward the biosphere.

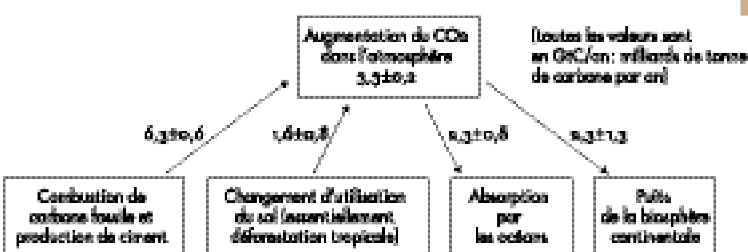
The sink as a physical object. The term carbon sink can describe a physical object of varying size, ranging from a forest strip to the global biosphere. For example, a plantation, a growing forest and the whole continental biosphere are all sinks.

On a world scale, the terrestrial biosphere currently constitutes a carbon sink that absorbs about 2.3 billion tonnes of carbon every year [Fig.1].

The sink as a political object. A sink can be defined politically in relation to the Kyoto Protocol. During international negotiations about climate change, questions about taking into account carbon emissions and absorption linked to land use and forestry form a separate subject of negotiation which is covered by the acronym LULUCF (*Land Use, Land-Use Change and Forestry*), or more commonly by "*sinks*."

The political definition of a sink relates to two different spatial scales. *The first scale is macroscopic*: the biosphere on a national scale, which comes into play in

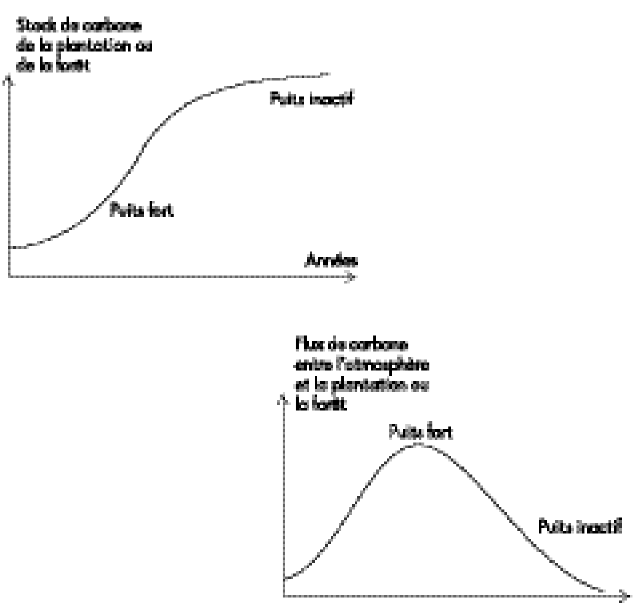
Figure 1. Flow of carbon between the atmosphere, the oceans and the continental biosphere for the period 1989-1998 (according to Watson et al., 2000)



the national accounting of countries that have made commitments to reducing emissions (the industrialised countries or "countries in Appendix I"). It is not the total flow of carbon surrounding the physical object that is taken into account, but only that caused by certain human activities. According to Article 3.3 of the Kyoto Protocol, these activities are afforestation, reforestation and deforestation. According to Article 3.4, other activities can be included, such as certain forestry management activities. Carbon storage included under this article must result from anthropogenic activities having taken place since 1990. Apart from the absence of precise definitions of the type of activities in question, there is another problem with regard to the anthropogenic character of the activities. It is not always scientifically possible to make a separation between the part of the sink due to recent human activities and the part due to nature. The existence of this article may be explained by the fact that certain countries had agreed to the Kyoto commitment on condition that a significant part of the sink be taken into account.

The second scale is local, sink projects like plantations or managed forests. These projects play a part in the Protocol by means of two mechanisms: the Clean Development Mechanism for projects in Southern countries and Joint Implementation for projects in the countries in Appendix I.

Figure 2. Simplified model of storage and flow of carbon in a planted forest



It is only by means of the CDM (Clean Development Mechanism) that tropical sinks will be integrated into the fight against climate change.

Without human intervention, a forest or a plantation absorbs carbon during its growth: it is a sink Fig.2. Then, when it reaches maturity, it is generally considered to be approximately balanced. It takes in about as much carbon as it emits into the atmosphere: the sink is said to be weak or inactive.

In reality, a mature forest can be either a sink or a source, though weak in comparison with an active sink. The criticism of all foresters is that a plantation or a managed forest is not intended to remain mature. It must be exploited and renewed. After sustainable exploitation the forest ecosystem reconstitutes its stock by becoming an active well. The exploitation balance sheet in terms of carbon will depend on the future of the products. If all the wood is abandoned and its value not enhanced, the balance sheet will be negative. However, if the wood is used as a raw material or as energy, the balance sheet may be positive, particularly if the energy use avoids the consumption of fossil carbon.

The May 2001 articles in Nature: the fertilizing effect of CO_2. In 1996, more than 3000 scientific texts had already been published about the effect of increasing CO_2 on plants (according to ProClim-OcCC, Forum on the climate and global change, Swiss Academy of Natural Sciences). For example, Bazzaz *et al.* (1990) show that, depending on the species, an atmosphere enriched in CO_2 leads to an increase or a decrease in the biomass of trees. Conroy *et al.* (1990) show that the fertilizing effect of CO_2 will be positive or negative depending on the soil and pluviometry.

The studies published in Nature in May 2001 are interesting because they deal with a real forest and not with microcosms like most previous studies. The results confirm that the currently observed stimulant effect of excess CO_2 on plants is only transitory. They show that the excess of carbon in the atmosphere will not be absorbed by the biosphere whose growth is stimulated. The study does not cast doubt on the fact that a growing plantation or a forest is a carbon sink that reduces the carbon in the atmosphere, and the message is sometimes interpreted in this narrow way.

The emphasis is put on the fertilizing effect of CO_2 and we forget the natural way plantations or forests grow. A growing plantation will always be a carbon sink, whether or not it is stimulated by a high CO_2 level.

Sinks: limited and temporary solutions. Those opposed to sinks say that this solution is *limited in time and space*. First of all, the available surfaces of the Earth are restricted and cannot be used to absorb emissions from fossil carbon consumption. Next, storage in sinks is temporary. The permanence of a sink can be jeopardized by many physical (e.g. fires), political or economic factors. Finally, even if the storage were permanent, carbon sinks would only push back the problem of reducing emissions. Sooner or later the sinks would become saturated and would absorb no more carbon.

Sinks represent a limited solution enabling us to "buy some time," as Bernard Saugier explained in Le Monde (November 10, 2000). From the point of view of national policies, "sink" activities can be implemented more rapidly than energy and transport technologies can be changed.

The sink solution cannot replace a reduction of greenhouse gases at the source. As for the question of the permanence of storage, it can be taken into account in national accounting or the mechanisms of the Kyoto Protocol. If a carbon sink is destroyed, the resulting emissions will be measured. Not only can the sink no longer be used to compensate for emissions, but the quantities previously credited for the sequestration of carbon will have to be debited in order to reflect the fact that the carbon has returned to the atmosphere.

Possibilities have been discussed for CDM (Clean Development Mechanism), such as Temporary Credits: storage in a sink would give rise to the issuing of a temporary carbon-credit with a limited validity. This period of validity could be extended if the sequestration endures.

The criticism of saturating sinks has already been discussed: rational exploitation and enhancement of products can reactivate the sink and avoid emissions through energy substitution.

Measurement, additionality and leaks. Those who oppose sinks stress the risk of involving sinks, whose real contribution we cannot evaluate in the fight against climate change. To estimate the real contribution of a sink, we would have to measure the quantity of carbon, evaluate any increased storage and estimate ripple effects.

According to those opposed to sinks, scientists don't know how to measure the carbon absorbed by a sink, nor how to estimate the quantity of CO_2 emissions compensated for by a sink. A lot of research today is being carried out into how to measure carbon flow and storage, as well as the dynamics of carbon in ecosystems (see Watson *et al.*, 2001[1]). Carbon storage can be evaluated using different methods that vary in terms of accuracy and cost.

Other criticisms of sinks deal with additionality and leaks from sink projects in relation to the CDM (Clean Development Mechanism). Because of the socio-economic processes a project interacts with, it is difficult to know the real effect of a project on greenhouse gases. Two questions arise.

The first relates to *additionality*: wouldn't the project have existed in any case, even without the CDM? The second relates to *leaks*: doesn't the project induce more deforestation (or emissions of carbon in general) outside the limits of the project? For example, if a plantation project excludes populations from agricultural

1 Special IPCC report on "Land Use, Land-Use Change and Forestry."

land, they will probably go and deforest other lands. The balance sheet for greenhouse effect gases may then be negative. These criticisms relate to how sink projects or CDM projects in general are implemented. To evaluate the additionality of a project, we must compare its carbon storage with that of the baseline scenario, which represents what would very likely happen without a project.

Major issues depend on these methods: if eligibility criteria are too strict, sinks may not attract any CDM investment. If they are too flexible, the environmental integrity of the Kyoto protocol will be jeopardized.

Will sinks have a negative effect on sustainable development? Their critics fear the negative effect of sinks, other than their effect on greenhouse gases. In their view, sinks present risks for development and the local environment. The creation of vast carbon sinks could freeze land-use to the detriment of local populations. Some NGOs denounce the North/South ethical and equity problems that CDM forestry poses.

To illustrate these, the World Rainforest Movement (Lohmann, 2000) uses the image of Southern communities who were driven from their lands by oil exploitation that feeds Northern consumers, then moved on again by carbon sinks to compensate for the emissions of those same consumers. The term "CO_2lonialism" has recently been coined for this.

According to critics, water or land resources could be degraded by large-scale plantation. The transformation of ecosystems into managed sinks could lead to a loss of biodiversity. Many NGOs fear the development of large surface areas of monospecific plantation to replace natural forests. For example, the WWFN (World Wide Fund for Nature) denounces the effects on forests of certain plantations designed to sequester carbon (Cadman, 2001).

Promoters of sinks make the opposite claims, that the consequences for development and the environment will be positive, using exactly the same arguments but turning them round the other way: projects to reconstitute the wooded cover will have positive effects on soils and hydrological systems. Reforestation activities and the reconstituted ecosystems will create employment, revenue and natural resources for local populations.

Who is right? Both, in all probability. Given that forestry projects have a tendency to occupy more space and affect more people than projects to change energy sources, we cannot deny that overall they will have stronger impacts on the environment and local development, whether these impacts are positive or negative.

Will sinks dilute efforts to reduce emissions? Their critics fear that sinks will water down efforts to reduce emissions. Sink activities may re-channel funds that could have served other policies to fight against climate change, such as developing renewable energies or energy efficiency programmes.

In concrete terms, some critics predict that the use of sinks is going to reduce the value of a tonne of carbon on the international emission permit market and that this will discourage the industrialists of the North from limiting their emissions. The promoters use the same argument but argue in the opposite direction. They say that sinks will make it possible to bring down the cost of reducing emissions while waiting for new clean technologies to be developed in the energy and transport sectors (Noble & Scholes, 2001[2]).

The real question concerns the relative advantages of the two strategies: invest massively today in carbon sequestration or concentrate efforts on reversing the increase in fossil carbon emissions. Temporary sequestration is economically worthwhile if the marginal costs of climate change damages are high (Lecocq and Chomitz, 2001). In other words, if the concentration of greenhouse gas in the atmosphere is close to a "limit threshold" beyond which climate change will have costly consequences, sequestration (even if temporary) is very desirable in order to "build a bridge over the pit." In the opposing case, the priority is on changing behaviour and technologies in order to reverse the growth in fossil carbon emissions. This theoretical approach is difficult to translate into political direction: and there is still the problem of quantifying the evolution of marginal damage caused by climate change.

The controversy surrounding carbon sinks and climate change in general, has accompanied and will continue to accompany international negotiations on the Kyoto Protocol. Even though both sides may sometimes slightly misuse scientific results, the attackers and defenders of carbon sinks have both had an opportunity to get their messages across, sometimes with considerable media coverage. However, this controversy does not really reflect the nature of the political debate taking place at conferences: negotiations relate to the rules that need to be applied in order – as far as possible – to make the system coherent, effective, operational, equitable and acceptable to all.

No agreement would have been reached at Bonn if sinks had not been included. One part of the negotiations related to the quotas to be attributed to each Party, article 3.4 for example (managing forestry and other activities). The scientific questions and controversy over sinks were far from the centre of the debate.

Although the Protocol does not yet have sufficient ratifications to be applied, the inclusion of certain rural activities in the fight against climate change was defined and confirmed at Bonn. Activities relating to deforestation, reforestation, afforestation, forest management, agricultural soil management and creating new vegetation in Appendix I countries will be included, as well as Clean Development Mechanism forestation and reforestation in Southern countries.

2 "Sinks can be deployed relatively rapidly at moderate cost and thus could play a useful bridging role while new energy technologies are developed. There is no difference in climatological effect between CO_2 taken up by the land and CO2 reduction due to other causes."

Discussions about the environmental integrity of the Kyoto Protocol or the impact on the environment and local development have not yet finished. They will scarcely have finished by 2003 – just in time to begin again to draw up the rules relating to commitments post 2012.

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Johannesburg: an opportunity that must be seized.

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Suddenly and late, our ecological awareness developed over the course of the 1960s, right in the middle of the Golden Age of Capitalism – what Jean Fourastié called *les Trente Glorieuses*. It was precipitated by the realisation of the magnitude of the "*damage of progress*" caused by economic growth and, paradoxically, by the catharsis of the conquest of space. Looking at the photos of our planet sent to us from the Moon by astronauts, we became aware of its finiteness and fragility. We also saw the dangers represented by the ever-increasing divide between our technical power and political systems unable to control it[1]. And lastly, we became aware of the necessity of a reconciliation with nature, of re-learning to understand it and to love it rather than dominating, exploiting and even pillaging it[2].

On a political level the consequences were rapid and spectacular, beginning with the Stockholm conference in 1972 enabling the United Nations to make the environment one of its priority concerns and – more importantly – linking it to the problem of development. Without going back to Jacques Weber's analysis in the opening chapter of this work, I would simply like to point out that in the space of a few years, most countries had equipped themselves with ministries for the environment and a host of new laws. Some, like Brazil, even devoted a whole section of their new constitution to protecting the environment.

A consensus – though unfortunately a rhetorical and superficial one – developed around the idea of sustainable development, a notion that was founded on the three pillars of social aims, environmental conditionalities and economic viability, with the result that the June 1992 United Nations Earth Summit at Rio de Janeiro was entitled "Environment and Development" and the Johannesburg summit is devoted to "Sustainable Development."

Although the twenty years between Stockholm and Rio were marked by a certain progress, the same can certainly not be said of the decade that followed the second conference, despite all the hopes it raised. Some observers go so far as to say that Johannesburg will be closer to Rio −10 rather than Rio +10.

In his report on the implementation of Agenda 21 drawn up at Rio, the Secretary General of the United Nations recognised that at Johannesburg they will have to discuss the absence of progress in eradicating poverty, the long-term unsustainability of consumption and production models in several parts of the world, the inability of institutional and programmed mechanisms effectively to integrate the social, economic and environmental dimensions of development, and the absence of financial resources and effective technology transfer mechanisms[3].

For those who are familiar with the euphemistic language of the United Nations, his report almost reads like a cry of alarm. In any case, the absence of progress in implementing Agenda 21 at a local, national and international level contrasts with the progress registered since Rio in terms of protecting biodiversity, understanding the threats caused by the greenhouse effect and managing desertification, as illustrated in the previous chapters.

To what do we owe this lack of results over the last decade? We believe that the main reason is related to the fact that the development of ecological awareness represented a veritable epistemological revolution, the full magnitude of which we have not yet realised.

The introduction of the environmental dimension forces the socio-economists to radically modify the time and space scales in which they will have to work from now on, forcing them to think both very short term and very long term simultaneously, and to reason in terms of local, national and global impacts, extending into the biosphere, as Marc Mormont put it: "*Thinking here and now at the same time as tomorrow and far away*[4]." Again, in the eyes of this author, sustainable development aims at a reconciliation between the local and the planetary, nature as a resource and nature as a system, the short term of immediate needs and the long term of future generations.

From a standards point of view, the ambition is to create a universal society of well-being that ensures its inhabitants effective access to the rights of man – political, civic and civil, economic – beginning with the right to a decent job –, social and cultural; lastly, collective rights to development, the environment, to cities and to childhood[5]. This society must be served by an "*economy of permanence*," a Ghandi-like concept in contrast to the "*prey economy*" (Raubwirtschaft), or it must build "*a civilization of being with a fair distribution of having*"[6] through reconciliation with nature.

Ecology thus becomes a vast natural history, interlacing with human history to produce a co-evolution of our species and planet. In order to understand it and steer it in the right direction –

1 On this point, see Ruffolo, G. (1988), *Potenza e potere. La fluttuazione gigante dell'Occidente*, Laterza, Bari.
2 Théodore Monod, who devoted enlightening pages to this subject, attributes our attitude toward nature to an inheritance from "*l'anthropomorphisme triumphaliste et orgueilleux des grands monothéismes*." Monod, Th., *Et si l'aventure humaine devait échouer*, Livre de poche, Paris, 2000, page 159.
3 United Nations Economic and Social Council, *Implementing Agenda 21 – Report of the Secretary General* (E/CN.17/2002/PC.2/7, 19 December 2001, paragraph 218).
4 Preface to Edwin Zaccaï's work, *Le développement durable – Dynamisme et constitution d'un projet*, Pie, Peter Lang/Presse Universitaire Européenne, 2002, Brussels.
5 The approach to development through rights owes much to the work of Amartya Sen (see his book *Development as Freedom*). On his side, Jérôme Ballet proposes to define exclusion based on privation or non-access to rights ("L'exclusion, une approche par les droits," *Problèmes économiques* no. 2748, 13 February 2002).
6 The expression comes from Joseph Lebret. In his previously quoted work, Théodore Monod oppposes civilisation – the aspect of quantity and having – to culture, the aspect of being, open to the quality of human relations and to free creativity.

avoiding the dangerous drift that can lead to questioning the very future of life in the biosphere – we can no longer avoid adopting a systematic approach across many disciplines. This should be very different from the sector-based procedures and anarchy caused by the many, fragmented decisions imposed by the market; a system that was actually supposed to bring about universal harmony.

This effectively means rising above the narrow vision of the market economy, by definition short-sighted and indifferent to the external social and environmental concerns produced by economic activities, when these are driven exclusively by the quest for efficient allocation of resources and the profit that results from it. It is not a question of denying the very important role of markets in our economies, but of recognising that they are only one institution among others – as pointed out by Amartya Sen – and that they require regulation through arbitration for five different *efficacies* that do not always work in harmony with each other: *allocative efficacy*, we have already mentioned, and with which we can associate the name of Adam Smith; *innovative efficacy*, inspired by Schumpter, which cannot be left to be driven purely by business, but requires strong public investment in research – now more than ever before; *Keynesian efficacy*, which is measured by the yardstick of full employment of all production factors, beginning with the work-force; *social efficacy*; and lastly, *eco-efficacy*, which must be sought on two levels.

On a micro-economic level the emphasis should be on the productivity of resources and not just solely on the productivity of men. It should be possible in the relatively near future to double production while reducing input by half and even to aim at reducing fossil energy consumption by a factor of 10.

However, such a procedure is not sufficient in itself to place humanity on a pathway to sustainable development. To do that would involve – above all – a review of our style of consumption and development. In other words, the transition toward sustainable development supposes a modification in the profile of demand, prior to attacking the methods of supply (i.e. the choice of techniques and locations). Experience shows that it is very difficult in practice to tackle changes in the "demand" variable that

7 On this point see, among others, Edwin Zaccaï's well docmuented work, *op. cit.* general bibliography of the book and of the first chapter.

8 On this point see CEPAL, 2002, *Globalizacíon y desarrollo*, Santiago.

9 On this point, see *Making sustainable commitments, an environment strategy for the World Bank*, Washington, 2001. This strategy proposes to improve the quality of life, the quality of growth and the quality of "global commons."

10 By confusing development with poor development, some authors despair of the very concept of development and speak of "post-development" in a way we find unconvincing. UNESCO recently devoted a symposium entitled "Unmaking Development, Remaking the World" to this post-modernist trend (28 February – 3 March 2002).

require a social consensus and ethical maturity that few societies are able to achieve today. The main issue, in fact, is how to get the "haves" to implement a self-imposed limit on their material needs, getting them to ask the question: "How much is enough?"

In the course of the last thirty years, abundant literature has been produced around the question of sustainable development as a prescriptive concept, both encouraged by the United Nations and independent of them[7].

The same does not apply for the setting up of the process of sustainable development, which requires political decisions and institutional organisation, preceded by a vast public debate concerning civilisation projects, effective strategic scheduling and the mobilisation of technical and financial resources among the have countries. To this we must add increased aid to the South and a re-writing of the rules of play for international economics in accordance with the principle of unequal treatment for the unequal – affirmative action in other words – in favour of the weakest partners. We must return to the idea that international economic law has a duty to protect the weaker States from the stronger ones by giving more rights to the former and more responsibilities to the latter[8].

On an institutional level the transition toward sustainable development cannot take place as long as this absolutely central problem – one that goes to the highest levels of government – is dealt with by Ministries for the Environment, as if sustainable development was merely a footnote to environmental policies. In reality the environment is only one of many dimensions involved in the concept of development.

With regard to public aid from industrialised countries to developing countries, over the last decade we have witnessed it shrink to nothing, accompanied by a decline in the position of Southern countries in the world economy. There have been several international crises – with the Argentine fiasco leading the way. This shows, yet again, that development is not a linear process, that it can be influenced by profound involutions, that we must add qualitative criteria to our quantitative ones, so that quality of life and well-being act as central categories in the definition of development targets[9]. Whilst we wait for a form of development founded on the winning trio of social, environmental and economic solutions, poor development continues to gain ground[10]. The whole world must face up to a serious crisis of unemployment and under-employment that affects, according to the calculations of the Bit, nearly one third of the world's workforce i.e. 1 billion men and women. In the course of the next decade it is essential to create at least 500 million new and decent jobs in order to accommodate new arrivals on the work market and reduce the catastrophe a little.

However, growth without employment or with little employment is not fatal. We are far from having explored the full potential of growth driven by employment[11].

In many places it is still possible to promote rural development based on small farmer agriculture and the creation of many non-agricultural jobs. According to a charter proposed by the *Confédération Paysanne*, small farmer agriculture is founded on a social dimension that is based on employment and solidarity, an economic efficacy that enables small farmers to live with relatively modest production volumes, this being the only way to retain many assets and, lastly, respect for the consumer and nature[12].

In addition to this, many jobs in the field of public works can use labour intensive techniques as they are not subject to international competition. This applies to construction, particularly in the field of self-build, assisted by municipal housing, and to social services – a lack of which is a problem all over the world. Personnel services can also provide employment, as can the quest for greater productivity in natural resources – as mentioned above – which is particularly important in relation to sustainable development.

Emplyoment can be created in collecting and recycling of urban waste, savings in energy, water and other natural resources. Also making better use of agricultural waste and more careful maintenance of infrastructures such as facilities, housing, vehicle fleets of all sorts, with a view to extending their useful life, can be create jobs and be profitable at a macro-economic level through savings in resources[13]. These solutions win on all three levels.

This example is only one element in a strategy for a transition toward sustainable development, which includes much greater issues, such as changes to our habitats, and transport systems that promote the collective at the expense of the individual and rail at the expense of road.

The transport problem enables us to see the advantage of joint international action aimed at implementing such a strategy. This could function as

11 See Sachs, I., "L'économie politique du développement des économies mixtes selon Kalecki: croissance tirée par l'emploi," *Mondes en développement*, Paris, vol. 27, no. 106, 1999, pp 23-24.

12 See Confédération paysanne, *Changeons de politique agricole*, Mille et Une Nuits, Paris, 2002, pp 132-134.

13 Extending the useful life of equipment and infrastructures reduces the demand of reposition investments, in other words, makes it possible to increase the share of net investments in the volume of gross investments.

14 Thomas L. Friedman ("The war on terror – America's failure of imagination," The New York Times, 20 May 2002) reproaches President Bush with not having launched the day after the attacks a Manhattan project destined to give the United States energy independence through a vigorous energy saving programme and the promotion of renewable energies in order to reduce oil imports gradually. America can win the battle against evil only by convincing its partners, particularly Europe, that it is actively promoting good by reducing its overconsumption of fossil energies and by ratifying the Kyoto agreement.

a powerful lever to help the world economy to emerge from the massive slump currently affecting it. Moreover, after the attacks of September 11, 2001, there cannot be any question of conducting the fight against terrorism solely by military means. More than ever, getting to the roots demands thorough action to promote the development, whose absence is the breeding ground for all fundamentalism[14].

The 1992 Earth Summit proposed Agenda 21, which was meant to accomplish this in more favourable international conditions than we have today. The drift toward neo-liberalism did not allow for progress in this direction. Paradoxically, the deterioration in the international situation has strengthened the arguments in its favour.

Let us return to Keynesianism and, moreover, let us opt for a more pro-social version of Keynesianism, as opposed to the conservative variation which gives priority to the arms race[15]. Let us propose a world wide plan for a transition to sustainable development while clearly distinguishing the different yet convergent national strategies for Northern countries from those of the South and, naturally, a long-overdue reform of the international system[16].

In order for the industrialised countries to be credible, they must be able to question their styles of consumption and development. They must ask the question "How much is enough?" They must take their cities and systems of transport back to the drawing board and they must give priority to non-material elements in their civilisation projects.

As for the Southern hemisphere countries, they must realise that attempting to imitate the North is incompatible with the principles of greater social justice and a drastic reduction in the reigning social inequalities. The more they want to imitate the way of life and consumption of the countries of the North, the greater the gulf will be between the minority "haves" who will enjoy

15 In spite of the outrageous claims of liberal rhetoric, the American government practices Keynesian-type policies. As Paul Krugmann advised so well, the rest of the world should not do what the US tells them to do, but what it does ("Don't do what we say, do what we do"). The very timely publication of a collection of articles by John Maynard Keynes with the significant title *La pauvreté dans l'abondance*, gives an idea of the relevance of his ideas (Gallimard, Paris, 2002; préface de Jean-Paul Fitoussi and Axel Leijonhufvud).

16 The end of the Washington consensus and Joseph Stiglitz's caustic criticism of international financial institutions, upon which he is in a good position to comment (Stiglitz, 2002. *Gobalization and its Discontents*) create a favourable situation in which to approach this subject and to return, perhaps, as the Ifi programme run by Agir ici, the Aitec and the Crid, suggests, to the position defended by Keynes on the occasion of the first Bretton Woods negotiations: "What could be better than a universal currency for world monetary stability? And what could be better than a system of taxes for the "too rich" and loans for the "too poor" in order to avoid inequalities between countries and within countries?" ("Que faire du FMI et de la Banque Mondiale?" Crid, *Les cahiers de la solidarité*, March 2002.

the benefits and the excluded and semi-excluded "have-not" majority condemned to a sort of social apartheid.

As we have already said, unequal treatment of the unequal constitutes a principle from which there can be no deviation. This implies differentiated responsibilities between the privileged and those discriminated against, particularly in terms of distributing financial costs.

In the light of these considerations and the new situation created by the attacks of September 11, 2001, the Johannesburg summit might appear to be an ideal occasion finally to make the move toward sustainable development on a planetary scale, particularly since the UNEP has just presented a sombre picture of the world environment on the eve of 2030 by highlighting uncontrolled urbanisation, the damage caused by road transport and water shortages, which will first affect the most deprived populations.

I say "might" because this opportunity does not seem to have been grasped, judging by the preparatory work for the conference and, most of all, the way the Monterey conference went, although it was essential because its aim was to formulate a financial plan for sustainable development.

After the attacks of September 11, 2001, and Argentina's descent into economic hell, it would be extremely embarrassing for a summit attended by many heads of state to end with an exercise in rhetoric and declarations of good intentions without any precise commitments accompanied by figures and dates. Even the vice-president of the World Bank called recently on industrialised countries to do more than pay lip-service to the fight against poverty[17].

Nor must we overestimate the action of "citizen" businesses, converted to sustainable development and longing to show their social responsibility in this way. Of course their participation could be considerable and we must endeavour to regulate the market so that it integrates the environmental dimension[18] but it is insufficient in itself, as is an over-application of purely technical solutions (a *technological fix*). It is urgent to give sustainable development the central place it should occupy among international and national institutions as an organising concept for all sectoral actions and all economic and social policies.

We believe this advance at an institutional level is now possible if the heads of state desire it. However, a serious plan for the transition to sustainable development, even if strategic, cannot possibly be prepared in time. The only solution would be to take the necessary measures at Johannesburg so that such a plan could be drawn up as an immediate

17 Stern, Nicolas, "La lutte contre la pauvreté: joindre le geste à la parole," *Le Monde*, 22 mai 2002.

18 Maurice Strong parle du "*greening of the market system*" (Strong, M. 2000, *Where on Earth are we Going?*, Texere LLC, New York, p 375).

extension of the conference by mandating a top level international commission to this end, similar to the Brandt and Bruntland commissions. The commission could lay the ground work in the different regions of the planet for sustainable development, in order to consult civil society and citizens' movements as broadly as possible.

We are faced with a choice between three scenarios. The first, based on an extrapolation from existing broad trends, is the catastrophe scenario which, depending on the place, could derive equally well from a social split as from an ecological disaster, each affecting the other. The second, favoured by big business, consists in reality of a search for techniques that are more respectful of the environment, and which could give rise to cleaner growth – though not necessarily the creation of any more work and, at best, growth in harmony with nature but very expensive in terms of social consequences. This leads us to the third scenario, that of sustainable development as it has been defined and discussed in this book. The result is of capital importance.

Further reading.

Books / Publications.

A.

Aménagement et nature (Development and Nature), 1998.

Un siècle d'environnement (A century of environment), Paris, Aménagement et nature, March. An issue of the review including many authors from a variety of fields: M. Batisse, S. Antoine, I. Sachs, P. Acot, H. Tazieff, Perennius, Roland de Millier. Also contains a valuable French language anthology on the environment, most aspects of which this issue covers.

Science Academy (Usa). 1992.

Une planète, un avenir. (One planet, one future) Le Sang de la terre publications. Paris. 193 p. This book accurately reflects the state of scientific knowledge of global phenomena, and underlines the interdependence of peoples. This text was published in the same year as the Rio Conference.

Action 21. April 1993.

Texts from the United Nations Conference on the environment and development, Rio de Janeiro: statements, agreement, Agenda 21. New York, Geneva, United Nations.

All the texts from Rio 1992. Will enable progress to be assessed after Johannesburg.

Arendt, H. 1961.

La condition de l'homme moderne (The condition of Modern Man), Paris, Pocket.

The author takes up many ecological themes in his treatment of sustainability (a term not yet invented at the time). This warns us against the instrumentalisation of nature and people, and destructive productivism. Published shortly before Rachel Carson's celebrated book, this work is little known to environmentalists.

Aubert, F. & Sylvestre, J.-P. 1998.

Écologie et société (Ecology and society). Dijon, Editions Éducagri and Editions Crdp, 224 pages.

A good introduction to the subject, in a rich collection that makes easy reading.

Aubertin, C. & Vivien, F.D. 1998.

Les enjeux de la biodiversité (Biodiversity: the stakes at issue). Economica, Paris, 12 pp.

A well-informed "social scientific" and "economic" point of view on the stakes at issue concerning biodiversity. Clear analysis of the situation from this viewpoint, and highly approachable for non-specialists.

B.

Bahuchet, S. & Demaret, P. de (ed.), 2000.
Les peuples des forêts tropicales aujourd'hui (The peoples of the tropical forests today). 5 volumes, edited by Aft-Ulb, in collaboration with the UE. Volume 1: *Forêts des tropiques, forêts anthropiques: sociodiversité, biodiversité* (Tropical forests, anthropical forest: sociodiversity, biodiversity). 132 p.
Monumental synthesis about the peoples who inhabit the world's tropical forests, and whose future is far from certain.

Barbault, R. 1994.
Des baleines, des bactéries et des hommes (Of whales, bacteria and men). Odile Jacob, Paris, 338 p.
Essay on the biodiversity dynamic and the wish to popularise. Gives the ecological and evolutionary context, making it possible to understand diversity in living organisms and what effect it has on how the earth functions and how humans societies develop. For enlightened but not necessarily specialist readers.

Barbault, R. 1997.
Biodiversité. "Les fondamentaux" (Biodiversity. "The fundamentals"), Hachette, Paris, 159 p.
Small introductory textbook on the biodiversity and biology sciences, especially conservation. For first and second year university students.

Barbault, R. 2000.
"La vie, un succès durable" ("Life: a sustainable success"), *Natures, sciences, sociétés*, 8: 40-46.
The concept of sustainable development as seen by an ecologist, taking the special case of the "life" phenomenon. For enlightened non-specialist readers.

Barbault, R. 2000.
Écologie générale. Structure et fonctionnement de la biosphère (General ecology. Structure and workings of the bisosphere). Paris, Dunod, 5th edition, 326 p.
This textbook, written by first-year students, is one of the best possible introductions to scientific ecology and biodiversity. An excellent starting point for understanding the issues linked to the complexity of the biosphere.

Barbier, E.B., Burgess, J.-C. & Folke, C. 1994.
Paradise lost? The ecological economics of biodiversity. Earthscan, New York, 268 p.
An excellent ecological economics textbook centred on biodiversity issues. Accessible to non-specialists.

Barraqué, B. (ed.), 1995.
Les politiques de l'eau en Europe (The politics of water in Europe). Paris, La Découverte, 303 p.
The title is self explanatory; the book consists of a collection of high quality texts.

Burgenmeier, B. 2000
Principes écologiques et sociaux du marché (Ecological and social principles of the market). Paris, Economica, 306 p.
Is the market compatible with the requirements of sustainability? The author explores this area and concludes that markets need to be regulated under threat of losing their own status as regulator. The book is also an essay on environmental ethics and economy. For academics.

C.

Carson, R. 1963.

Printemps silencieux (Silent Spring). Preface by Roger Heim. Plon, Paris. 283 p., re-printed LGF, Paris, 1968, Le Livre de poche, nº 2378 [*Silent Spring*. Boston, Houghton Mifflin, 1962].

Seminal work in the field of militant political ecology, based on an analysis of the excessive use of chemicals on the environment .

Chapin, F.S. *et al.* 2000.

"Consequences of changing biodiversity," *Nature*, 405: 234-242.

The changes in biodiversity caused by mankind's actions are affecting ecosystem processes and the vulnerability of ecosystems to global changes. This is having profound consequences on the uses man makes of ecosystems.

Chauvet, M. & Olivier, L. 1993.

La biodiversité, un enjeu planétaire. Préserver notre patrimoine génétique (Biodiversity: a world issue. Preserving our genetic heritage). Éditions Le Sang de la terre, Paris, 416 p.

Highly approachable summary of the nature of biodiversity and the issues at stake, with a strong focus on genetic resources and their management.

Cmed, 1988.

Notre avenir à tous (Our Common Future). Report by the World Commission on the environment and development ('Bruntland Rapport'). Montréal, Éditions du Fleuve, 434 p.

The celebrated Bruntland Report, which gives a definition, subsequently made "official," of sustainable development. The commission, set up in 1983, worked for five years to produce this report, which goes far beyond the single definition with which it is associated.

Costanza, R. (ed.), 1991.

Ecological Economics. The Science and Management of Sustainability. Columbia Univ. Press, New York, 527 p.

One of the early seminal works on ecological economics. A collection of many articles of great interest, which attempt to lay the foundations for a sustainable management science. Post-graduate/university professor level

Costanza, R. *et al.* 1997.

"The value of the world's ecosystem services and natural capital," *Nature*, 387: 253-260.

A somewhat flashy and controversial article, but one giving pause for thought on what economical valuation of planetary ecosystems really means. Just how much are we worth?

Coude-Gaussen, G. & Rognon, P. N.D.

Désertification et aménagement au Maghreb (Desertification and development in the Maghreb). Paris, L'Harmattan, 314 p.

The title gives a full explanation of the subject, which examines developmental solutions for desertification in the Maghreb.

Czech, B. 2000.
"The importance of ecological economics to wildlife conservation," *Wildlife Society Bulletin*, 28 (special coverage): 2-69.
Article for specialists and the curious: on the economical importance of preserving nature, with an explanation of the vigorous emergence of the new, so-called ecological economy. Clear and easily approachable.

D.

Damian, M. & Graz, J.-C. 2001.
Commerce international et développement soutenable (International trade and sustainable development). Paris, Economica, 224 p.
Dansereau, P. 1976.
Le cadre d'une recherche écologique interdisciplinaire (Framework for interdisciplinary ecological research). Montréal, Pum.
Recognised as one of the founders of modern ecology, this observer of the scene devotes himself to the study of man's relations with his environment, giving making ecology respectable on an international scale. By the author sometimes dubbed the "Canadian Théodore Monod."
Delaunay, J. 1972.
Halte à la croissance? Enquête sur le Club de Rome (Limits to growth? Inquiry into the The Club of Rome), follow-up by Donnella H. and Dennis L. Meadows, Jörgen Randers and William W. Behrens III (of Mit), Report on the limits of growth, Paris, Fayard.
Published in 1972 under the controversial title "Limits to growth," the Meadows report decisively posed the problem of "limits" and showed how material constraints, emerging from all sides, were going to block the movement towards growth without limits.
Descola, P. 1993.
Les lances du crépuscule. Relations Jivaro, Haute Amazonie (The lances of twilight. Jivaro relations. High Amazonia). Paris, Plon, Coll. "Terre humaine," 505 p.
Very fine book for comprehending to what point the division of the world into "nature" and "culture" is a recent historical accident peculiar to the West. Shows that most peoples divide the world into very different categories. For the Achuar Indians, plants and animals are "persons" like humans, gifted with a conscience and will, and who communicate.
Review: Aménagement et nature, 1998.
La désertification. Numéro spécial No. 129, June 114 p.
De Steiger, J.E. 1997.
The Age of Environmentalism. McGraw Hills, 292 p.
For readers who want to find out more about the people behind the names that have built up thinking on the environment in the United States: R. Carson; Pigou and Coase, K. Boulding; L. White; P. Ehrlich; G. Hardin; B. Comonner; H. Daly; Mit Team; A. Ness.

di Castri, F. & Younès, T. (ed.), 1996.
Biodiversity, science and development. Towards a next partnership. Cab International, Wallingford (Uk), 646 p.
Book on biodiversity, by several authors. They deal with the relations that exist between the diversity of living organisms, the sciences and the possibilities for development, including in the political and cultural context of possible North/South conflicts and partnerships.

Dorst, J. 1965.
Avant que Nature meure (Before Nature dies). Gland, Wwf.
In 1965, in this book that became a great classic, Jean Dorst sounded the alarm bells about the dangers posed to the entire living world by man's activities.

Drouin, J.-M. 1991.
Réinventer la nature: l'écologie et son histoire (Reinventing nature: ecology and its history). Paris, Desclée de Brouwer, 208 p.
A history of ecological ideas completely beyond "political ecology."
A clear and precise description of how the discipline now known as scientific ecology has grown up.

E.

L'Écologiste (review), 2001.
"Développement durable: une contradiction" (Sustainable development: a contradiction in terms), special issue, vol.2, no. 4.
A rich dossier containing short, incisive articles by well-known scientists, together with a summary ranging from prehistory to the concept of sustainable development.

Erlich, R.P. 1972.
La bombe P. 7 milliards d'hommes en l'an 2000 (The Population Bomb. 7 billion people in 2000). Fayard/Les Amis de la terre.
In 1972, Paul Ehrlich published his famous book The Population Bomb, in which he stated that we have lost the battle to feed all mankind. The world population increased more quickly than ever before in the history of mankind during the Sixties. If growth continued at this rate for the next 900 years or so, there would be 60 million billion people on Earth, meaning 120 people per square metre, including the oceans. Paul Erlich's warning contributed to setting the tone of those times.

F.

Faucheux, S. & Noël, J.-F. 1995.
Économie des ressources naturelles et de l'environnement (Economy of natural resources and the environment). Paris, Armand Colin, 370 p.
One of the rare textbooks in French; the book is suitable for final year university students.

Ferry, L. 1992.
Le nouvel ordre écologique: l'arbre, l'animal et l'homme (The new ecological order: trees, animals and men). Bernard Grasset. Paris. 277 p.
An important book that endeavours to show the development of man's entry into relation with nature, and defends the heritage of the Enlightenment against ecologism.
Aroused much discussion when it first appeared because of its somewhat hasty and acerbic judgements. There is a fascinating chapter on trials brought against animals in France up to the 18th century.

G.

Gadgil, M. & Guha, R. 1995.
Ecology and equity. The use and abuse of nature in contemporary India. New York & London, Routledge, 213 p.
A book, already a classic, on the relations between ecology and equity, by two major Indian scientists.

Gaston, K. (ed.), 2000.
Biodiversity: a biology of numbers and difference. Blackwell Science, Oxford, 396 p.
A series of essays by specialists on what makes living organisms diverse, analysed from the angle of both biology and the biology of differences.

Gaston, K.J. 2000.
"Global patterns in biodiversity," *Nature*, 405: 220-227.
The distribution of biodiversity on a global scale can be expressed by a number of characteristic graphs

Georgescu-Roegen, N. 1979.
Demain la décroissance. Entropie, écologie, économie (Tomorrow, decline. Entropy, ecology, economics). Lausanne.
An ecological reflection on the economy, whose aim is to show that decline is now inevitable in order for development to be really sustainable in the very long term.

Godard, O. 1994.
"Le développement durable: paysage intellectuel" (Sustainable development: the intellectual landscape), *Nature, sciences, sociétés*, vol. 2, no. 4: 309-322.
Important article for understanding what separates the different approaches to "strong" or "weak" sustainability.

Godard, O. (ed.), 1997.
Le principe de précaution dans la conduite des affaires humaines (The precaution principle in the conduct of human business). Paris, Mh and Inra, 351 p.
Book by several authors with a sound introduction by the editor, reviewing the meanings and application of the principle in various fields.

Griffon, M. (ed.), 1996.
Vers une révolution doublement verte. Actes d'un séminaire (Moving towards a doubly green revolution. Seminar reports), Poitiers, Futuroscope, 8 and 9 Nov. 1995, 206 p.
Reports from an international seminar devoted to researching the basis for a new type of green revolution, in harmony with the concept of sustainability.

Grouzis, M., Le Floc'h, E., Bille, J.C. & Cornet, A. (ed.), 1992.
L'aridité, une contrainte au développement (Aridity, a restriction on development). Paris, Orstom, Coll. Idt, 597 p.
Numerous contributions on aridity and its relations with development. This book shows how to distinguish between aridity, drought and desertification, among other things.

H.

Hammarskjöld, D. 1975.
Un autre développement. Rapport à l'Assemblée générale des Nations Unies (Another development. Report to the General Meeting of the United Nations). Uppsala, Dag Hammarskjöld Foundation, 136 p.
One of the most important reports of the Seventies, in the dynamic of growing awareness of the relations between environment and development, understood as both social and economic. French researchers made a significant contribution to this report.

Hanna, S., Folke, C. & Mäler, K.G. (ed.), 1996.
Rights to nature. Ecological economics, cultural and political principles of institutions for the environment. Wash. D.C., Island Press, 298 p.
A book that helps to understand the decisive role of institutions in the sustainable management of the environment. These institutions, often local, are frequently underestimated by analysts.

Hardin, G. 1993.
Living within limits. Ecology, economics and population taboos. New York, Oxford, 339 p.
A so-called "Malthusian" exercise by one of the fathers of "sociobiology."
Hardin devotes the book to convincing the reader of the danger posed by "galloping population growth" to the Earth, and particularly that of poor people, which creates immediate pressure on resources. The theory concludes that we need to reduce the world population to 600 million inhabitants, an assumed figure that corresponds to an equally assumed "load capacity."

Hulot, N., Barbault, R. & Bourg, D. 1999.
Pour que la Terre reste humaine (Preserving Earth's humanity). Paris, Le Seuil, 171 p.
Institut de France. 2000.
Scientific, legal and economic consequences of the Kyoto agreement. Paris, Académie des sciences, Académie des sciences morales et politiques, éditions Tec. et Doc., 76 p.
Useful for those who want to find out about the non-environmental implications of the Kyoto Agreement on CO_2 emissions.

J.

Jollivet, M. (ed.), 1992.

Sciences de la nature, sciences de la société: les passeurs de frontières (Natural sciences, social sciences: the border-crossers). Paris, Cnrs éditions, 589 p.

This book is one of the most important contributions to French research on the interdisciplinary approach vital for addressing environmental questions.

Jollivet, M. (ed.), 2001.

Le développement durable, de l'utopie au concept. De nouveaux chantiers pour la recherche (Sustainable development, from Utopia to the concept. New areas for research) Elsevier, Paris, 288 p.

What sustainable development represents for researchers in different domains

For curious but not necessarily specialist readers.

K.

Kandel, R. 1990.

Le devenir des climats (The future of climates). Paris, Hachette, 127 p.

A good introduction to knowledge of climates. Easy reading.

Karsenty, A. 1999.

Les instruments économiques de la forêt tropicale. Le cas de l'Afrique centrale (The economical instruments of the tropical forest. The case of Central Africa). Paris, Maisonneuve et Larose, Cirad, 125 p.

Analysis of the use of various instruments enabling sustainable management of tropical forests. The author pays particular attention to the tax aspect.

Kate, K.T. 2002.

"Science and the Convention on Biological Diversity," *Science*, 295: 2371-2372.

Recent update on the institutional context for implementing the Convention on Biological Diversity (Cbd).

Kempf, H. 1994.

L'économie à l'épreuve de l'écologie (Economics put to the test by ecology). Paris, Hatier, 79 p.

Good introduction, illustrated by numerous cases, on the relations between economics and ecology.

Kourilsky, P. & Viney, G. 2000.

Le principe de précaution. Rapport au Premier ministre (The precaution principle. Report to the Prime Minister). Paris, Documentation française and Odile Jacob, 405 p.

The most complete reference book in French on the subject. Demonstrates clearly that the precaution principle is an incentive to action, not an obstacle.

L.

Lamy, M. 1999.

La diversité du vivant (The diversity of living organisms). Le Pommier-Fayard, 156 p.

A clear account of the diversity of living organisms. Baccalaureat ("A-level") or first year university students.

Larrère, C. 1997.
Les philosophies de l' environnement (Philosophies of the environment). Puf, Paris, 124 p.
Very subtle analysis of trends of thought, particularly in the United States, that inspired theorists and practitioners in nature protection until the emergence of modern conservation biology. Indispensable for understanding the cultural and philosophical foundations for the positions currently held as regards safeguarding living organisms.

Larrère, C. & Larrère, R. 1997.
Du bon usage de la nature. Pour une philosophie de l'environnement (Good use of Nature. A philosophy of the environment). Alto, Aubier, 355 p.
The two authors, one a philosopher, the other an agronomical engineer, re-examine the terms of a long debate opposing man with nature, and here stake out a new vision of the latter. A good use of Nature that encourages thinking for oneself.

Lawton, J.H. & May, R.M. (ed.), 1995.
Extinction rates. Oxford University Press, Oxford, 233 p.
Everything known about the biology of extinction in the past, present and future. Specialist reading.

Le Bras, H. 1994.
Les limites de la planète: mythes de la nature et de la population (The planet's limits: nature and population myths). Paris, Flammarion, 350 p.
In-depth and sometimes virulent criticism of Neo-Malthusianism and sociobiology. Hervé Le Bras does justice in particular to the "load capacity" idea outside experimental laboratory conditions.

Le Preste, P. 1997.
Écopolitique internationale (International ecopolitics). Montreal, Guérin Universitaire.
In-depth analysis of the international stakes at issue with environmental policies, by a major political scientist.

Lévêque, C. 1994.
Environnement et diversité du vivant (Environment and diversity of living organisms). Cité des sciences et de l'industrie, and Orstom, Presses Pocket, 127 p.
Small book, easy to read and full of information and analysis.

Lévêque, C. 1997.
La biodiversité (Biodiversity). Puf, Paris, 127 p.
Very clear essay on what biodiversity and its issues actually involve.

Lévêque, C. & Monolou, J.-C. 2001.
Biodiversité. Dynamique biologique et conservation (Biodiversity: the dynamics of biology and conservation). Dunod, Paris, 248 p.
Manual for university use on the dynamic of biodiversity and its conservation. Very comprehensive and easy to read, facilitated by a jargon-free style

Levin, S.A. (ed.), 2001.
Encyclopedia of Biodiversity, 5 volumes, Academic Press, San Diego, 5000 p.
All you ever wanted to know about the diversity of living organisms by the world's leading specialists in the subject; its nature from every angle, on all continents, from micro-organisms to giant sequoias; the dangers they face, what we know about the factors and rates concerning extinction; the issues raised; conservation practices and strategies, etc. Very comprehensive, and highly useful for journalists, teachers and so on, not to mention the curious.

Locatelli, B. 1996.
Forêts tropicales et cycle du carbone (Tropical Forests and the Carbon Cycle).
Montpellier, Cirad, coll. "Repères," 91 p.
One of the first ever books in French on carbon stocking by forest ecosystems: well documented and easy to read.

Lovelock, J.E. 1986 [1979].
La Terre est un être vivant. L'hypothèse Gaïa (Earth is a living being. The Gaia theory).
Le Rocher. 184 p.
The author conceives Earth as a living super-organism in which we are only one of the elements, rather like red blood cells, which have no autonomous existence. A serious book, and a stimulating theory, not responsible for any use of it made to promote belief in the Earth goddess. First published in 1979.

Lubchenco, J., Olson, A. M., Brubaker, L.B., Carpenter, S.R., Holland, M.M., Hubbel, S.P., Levin, S.A., MacMahon, J.A., Matson, P.A., Mellilo, J.-M., Mooney, H.A., Peterson, C.H., Pulliam, H.R., Real, L.A., Regal, P.J., & Risser, P.G. 1991.
"The sustainable biosphere initiative: an ecological research agenda," *Ecology*, 72: 371-412.
An important article marking the Ecological Society of America's awareness of the need to develop this discipline for studying the biosphere, in view of sustainable development.

M.

Mainguet, P. 1995.
L'homme et la sécheresse (Man and drought). Coll. "Géographie," Masson, Paris 335 p.
For a better understanding of how men adapt to drought and how, in some cases, they encourage it.

Mainguet, M. 1995.
Desertification – Natural background and human mismanagement. Springer-Verlag, Berlin, Germany.
Shows how errors in the management of environments affect drought.

Mazoyer, R. & Roudart, L. 1997.
Histoire des Agicultures du monde, du néolithique à la crise contemporaine (History of World Agricultures, from Neolithic times to modern crisis). Paris, Le Seuil, 544 p.
The dynamic of agrarian systems is presented from Neolithic times to the present day. A major book, where the links between agriculture, populations and environments are given special in-depth treatment.

Mégie, G. 1989.
Ozone: L'équilibre rompu (Ozone: the shattered balance). Presses du Cnrs. Paris. 260 p.
Book in which Gérard Mégie gives an updated account of the ozone layer and the means to remedy its increasing disappearance.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., & Kent, J. 2000.
"Biodiversity hotspots for conservation priorities," *Nature*, 403: 853-858.
Should we be concentrating our conservation efforts on a few biodiversity "hotspots" where it is particularly threatened?

N.

Nelissen, N. & Van der Straaten, Klinkers, L. (ed.), 1997.
Classics in environmental studies. An overview of classic texts in environmental studies.
The Hague, International Books, 423 p.
For those who want to know more about the stages in building the environment as a scientific domain.

O.

Ocde, 1999.
Manuel de protection de la biodiversité. Conception et mise en œuvre des mesures incitatives (Biodiversity protection manual. Conception and implementation of incentive measures). Paris, Ocde, 196 p.
This manual of biodiversity economics reviews possible incentives in view of sustainable management. It highlights ownership rights, not necessarily private ownership, as one of the major conditions of this sustainability.

O'Connor, M. (ed.), 1994.
Is capitalism sustainable? Political economy and the politics of ecology. New York, London, Guilford Press, 283 p.
Major book by several authors, which endeavours to asses the current economic system in relation to sustainability as defined by the Bruntland commission. A wide variety of authors and approaches to the subject.

O'Connor, M. & Spash, C.L. (ed.), 1999.
Valuation and the environment. Theory, methods and practices. London, Edward Elgar, "Advances in ecological economics," 339 p.
Book by several authors, which reviews the economic and social valuation methods for the environment, without limiting itself to valuation through agreements to pay. A good overall comparative view of the subject.

Orstom, 1993.
Une terre en renaissance (An earth reborn). Paris, Le Monde diplomatique, coll. "Savoirs," 127 p.
One year after Rio 1992, this document offers a wide range of articles covering most of the environmental domains and issues by a number of major authors of quality. The book has not become outdated, and remains highly useful.

Ostrom, E. 1989.
Governing the Commons. Cambridge Univ. Press.
Twenty years after Hardin's Tragedy of the Commons, Elinor Ostrom puts forward a new vision of resource appropriation schemes and shows that of all the systems, the ones that perform the least well seem to be the "all private" and "all public" schemes. With a review of a large number of "common pool" management forms she highlights the ability of these collective property forms to ensure sustainable management.

Osborn, F. 1949.
La planète au pillage (The planet pillaged). Payot. Paris.
The author calculates the earth's load capacity to be less than 2 billion people. An early detection of the population/resources/environment crisis. The authors concentrates on natural resources but has added overpopulation to the equation. The origins of current Neo-Malthusian thinking.

P.

Passet, R. 1979.
L'économique et le vivant (Economics and living organisms). Payot.
René Passet gives a lucid and relevant analysis of the contemporary world's crisis situation. Classical economic science, centring its approach on the optimal management of material and inanimate property, subjects man and nature to a law that is not necessarily theirs. This is a major book that has been reprinted several times.

Pontanier R., M'Hiri, A., Aronson, J., Akrimi, N. & Le Floc'h, E. (ed.), 1995.
L'homme peut-il refaire ce qu'il a défait?, Science et changements planétaires/Sécheresse (Can man remake what he has undone? Science and planetary changes/Drought). Paris, John Libbey, 455 p.
Numerous essays on the reversibility of ecological and social processes.

Purvis, A. & Hector, A. 2000.
"Getting the measure of biodiversity," *Nature*, 405: 212-219.
Can biodiversity be measured? Even if no number can express the diversity of living organisms, an analysis of this in its various forms is particularly productive for man, who is destroying it at an unprecedented pace.

R.

Rich, B. 1994.
Mortgaging the Earth. The World Bank, the environmental impoverishment and the crisis of development. Boston, Beacon Press, 376 p.
An acerbic and radical criticism of the World Bank in the degradation of the environment and the rise of poverty The Bank is put in the dock with particular reference to the reversal of capital flow, for the most part South/North oriented, through debt repayment. It is also brought into question over its big projects that destroy the environment and have serious social consequences, in particular the great dams.

Rifkin, J. 1998.
Le siècle biotech. Le commerce des gènes dans le meilleur des mondes (The biotech century. Gene trading in the best of all possible worlds). Paris, La Découverte, 348 p.
Exploration of the consequences of the biotechnological revolution, and the ever-expanding patent system for living organisms. The book includes an important chapter on eugenics in the United States between the wars, together with a vital discussion on the potential implications of biotechnologies on the status of the individual.

Rifkin, J. 2000.
L'âge de l'accès. La révolution de la nouvelle économie (The age of access. The revolution of the new economy). Paris, La Découverte, 396 p.
The authors endeavours to show that in this age of the Internet, intellectual property rights and globalisation, ownership in the classic sense is doomed to disappear to the profit of access rights markets.

Rochette, R.M. (ed.), 1989.
Le Sahel en lutte contre la désertification. Leçons d'expériences (The Sahel's struggle against desertification. Lessons from experience). Berlin, Cilss, Pac, Gtz, 52p.

Roqueplo, P. 1988.
Pluies acides: menaces pour l'Europe (Acid rain: dangers for Europe). Economica, Paris, 357 p.
Philippe Roqueplo has considerably furthered specialist conceptions in crisis situations and more generally environmental expertise, in a context of scientific uncertainty.

Roqueplo, P. 1993.
Climats sous surveillance. Limites et conditions de l'expertise scientifique (Climates under scrutiny. Limits and conditions of scientific expertise). Economica, 401 p.
In this book, climatic expertise is analysed in great detail. Vital reading for scientists and "decision makers" alike.

S.

Sachs, I. 1997.
L'écodéveloppement. Stratégie pour le XXI^e siècle (Ecodevelopment. Strategy for the 21st century). Syros, Paris, 124 p.
Sachs retraces the development, foundations and values of eco-development. He deals with what should have been the first steps into a new era: the Earth Summit at Rio in 1992.

Sandlund, O.T., Hindar, K. & Brown, A.H.D. (ed.), 1992.
Conservation of biodiversity for sustainable development. Scandinavian University Press, Oslo, 324 p.
Book by several authors illustrating the problems of conserving biodiversity in view of sustainable development. For specialists.

Schumacher, E.F. 1978.
Small is beautiful. Une société à la mesure de l'homme (a society in the image of man). Le Seuil, coll. "Points."
A major book in which Schumacher delivers a criticism of the mass production society. He reveals its absurdities, the dead-ends into which it is heading, and offers solutions whereby mankind's production system more closely reflects the ecological environment in order to reduce the imbalance.

Smouts, M.C. 2001.
Forêts tropicales, jungle internationale. Les revers d'une écopolitique mondiale (Tropical forests, international jungle. The other side of global ecopolitics.). Paris, Fondation nationale des sciences politiques, 349 p.
Close study of the national and international issues arising from tropical forest management, by one of the (too) rare French political scientists interested in environmental issues. Fascinating reading.

Solagral, 1994.
Biodiversité: le fruit convoité (Biodiversity: the coveted fruit). FPH/Solagral, 100 p.
A essay that successfully simplifies the issues and conflicts of interests aroused by biodiversity.

Solagral, 1998.
Gestion des ressources naturelles. Droits de propriété, institutions et marchés (Natural resource management. Property rights, institutions and markets). Reports from a day of debates, 101 p.
Solagral, which publishes Le Courrier de la planète, also organises days of debate on Important topics, giving rise to synthetic publications. In-depth, but nevertheless easy reading.

Solagral, 1999.
L'environnement dans les négociations commerciales multilatérales: un passage obligé? (The environment in multilateral negotiations: an inevitable route?) Reports from a day of debates, October, 112 p.

Stiglitz, J. 2002.
La grande désillusion. Paris, Fayard. [*Globalization and its discontents*. Norton, 2002].
A severe criticism of the Fmi by a Nobel prize winner, who was head economist for the World Bank and architect of the end of the "Washington consensus," which considered that the replacement of the State by the market and private sector would be enough to trigger growth... An in-depth book, very easy to read.

T.

Tevoedjre, A. 1978.
La pauvreté, richesse des peuples (Peoples: poverty and wealth). Éd. Ouvrières, coll. "Économie et humanisme."
The book develops the apparently paradoxical theory holding that "poverty can constitute a people's wealth." The imitation of industrialised countries' options by emerging countries leads to the neglect of their peoples' needs and aspirations.

Thoreau, H.D. 1992 [1854].
Walden ou la vie dans les bois (Walden or life in the woods). Paris, Gallimard, coll. "L'imaginaire," 263 p.
Together with Rachel Carson's *Silent Spring*, *Walden or Life in the Woods* is one of the two books that most contributed to the birth of ecocological awareness in the United States. They are the American equivalents of French books on the harmony of man and nature, and on the "good savage" extended to wild species. To be compared with the work by A. Harendt, published in 1961 (see above).

Tilman, D. 2000.
"Causes, consequences and ethics of biodiversity," *Nature*, 405: 208-211.
How can we account for the existence of such a large number of species on Earth? Whate are the effects of biodiversity on ecosystems? What responses as regards society can be expected from the erosion of biodiversity?

Troadec, J.P. (ed.), 1989.
L'homme et les ressources halieutiques (Man and halieutic resources). Brest, Ifremer, 817 p.
A few years before Rio, this book by several authors put the spotlight on access to and use of resources. The world's top specialists in the world for these questions in the fishing domain have contributed to this book, which is and will remain a reference work.

U.

UNDP.

Rapport sur le développement humain (Report on human development).

Each year, the UNDP publishes this report rich in original statistics and indices, such as the human development index and the human poverty index.

UNEP, 1992.

Global biodiversity strategy. Guidelines for action to save, study and use earth's biotic wealth sustainably and equitably. WRI, UICN, UNEP, 244 p.

Clear, well supported essay on biodiversity, putting forward a global strategy conceived in a spirit of sustainable development. Key work in the history of nature conservation.

UNEP, 1995.

Global biodiversity assessment. Cambridge University Press, 1140 p.

This monumental work, with contributions by more than a hundred authors from all over the world, represents the state of knowledge at the time of the Rio conference. For specialists and decision makers.

UNESCO, 1996.

Réserves de biosphère: la Stratégie de Séville et le cadre statutaire du Réseau mondial (Biosphere reserves: the Seville Strategy and the statutory framework of the global network). UNESCO, Paris, 20 p.

Small booklet that marks a turning point and the relaunch of the UNESCO Man and Biosphere programme (MAB), a programme from the seventies that attempted to lay down foundations and practices for sustainable development.

V.

VITOUSEK, P.M., MOONEY, H.A., LUBCHENCO, J. & MELLILO, J.-M. 1997.

"Human domination of earth's ecosystems," *Science*, 277: 494-499.

A reference article, which highlights and details the impact of the human species on the planet's ecosystems, given that this impact takes the form of competition between humans and the phytomass for solar energy. Here we have the viewpoint and foundations of the argument put forward by ecologists involved in debates on the need to safeguard the planet's big ecosystems.

VOITURIEZ, G. & JACQUES, G. 1999.

El Niño, réalité et fiction (El Niño, reality and fiction). Paris, UNESCO, 116 p.

A sound introduction to climatic variability, forecasts, and its environmental, economic and social effects.

VOITURIEZ, B. 1992.

Les climats de la Terre (The Earth's climates). Paris, Cité des sciences et de l'industrie, Presses Pocket, 127 p.

Good introduction to the subject, and easy reading.

W.

Weber, J. 1995.
Gestion des ressources renouvelables: fondements théoriques (Renewable resources management: theoretical foundations). Cirad-Green, 18 p. ["Gestão de recursos renovàveis: fundamentos teòricos de um programa de pesquisas"].
In Veira, P. F., et Weber, J. (ed.), *Gestão de recursos naturais renoaveis e desenvolvimento: Novos desafios para a pesquisa ambiental.* São Paolo, Cortez Editora, 1997, trad. de Pontbriand-Veira, A.S., et Lassus, C., 500 p.: 115-146.
A debate and update on the theoretical foundations of the question of renewable resource management. Viewpoint of an economist/anthropologist that balances the perspective adopted in the article by Costanza *et al.*

Wilson, E.O. (ed.), 1998.
Biodiversity. National Academic Press, Washington D. C. 521 p.
Seminal work propagating the new term "biodiversity" and giving the scientific context that tried to express itself behind the scenes at Rio during the Conference on the environment and development in June 1992.

Winter, G. 2002.
L'impatience des pauvres (The impatience of the poor). Paris, Puf, coll. "Histoire et société," 291 p.
Work largely based on the relations between development policies, the development of inequalities, and poverty. This book is an important contribution in view of Johannesburg 2002.

Z.

Zaccaï, E. 2002.
Le développement durable: dynamique et constitution d'un projet (Sustainable development: the dynamic and construction of a project). Brussels, Editions Peter Lange, 358 p.
This recently published book claims to be a stage on the road to Johannesburg. It retraces the phases in the genesis of sustainable development, through conferences on development and the environment.

Internet Sites.

http://www.un.org/french/events/wssd/

United Nations site on the World Summit. Contains the calendar of preparatory events, and preparatory documents. Rich in information.

http://www.worldsummit.org.za

The official site of the World Summit in South Africa. Comprehensive information on the progress of preparations.

http://www.climatenetwork.org/eco/

Several international NGOs contribute to the Eco newsletter, available on this site.

http://www.biodiv.org

The official site of the Biodoversity Convention.

http://www.crdi.org.sg

Site of the International development research centre, of the Canadian office for international development. Site with much information on sustainable development. Can be consulted in French.

http://www.agora21.org

To consult Agenda 21. Numerous links with other important sites. Can be consulted in French.

http://www.iisd.ca

International Institute for Sustainable Development, in Winnipeg, Canada. Highly documented information on climatic change, biodiversity and desertification. Can be consulted in French.

http://www.globenet.org/crid

http://www.comite21.org

French language site on the implementation of Agenda 21.

http://www.association4d.org

Site of the Association 4d, with a wealth of information and discussion on the various aspects of sustainable development.

http://www.un.org

United Nations site, where you can follow the preparations for the Johannesburg Summit and find the texts of the principle conventions: biodiversity, Agenda 21, etc. Numerous links to other United Nations departments.

http://www.fao.org

Site of the FAO.

http://www.unep.org

Site of the United Nations Programme for the environment.

http://www.undp.org

Site of the United Nations Programme for development. The best site for getting a clear idea of the world's economic and social development.

http://www.cnrs.fr

Site of the Cnrs, in which the reader will find information on the latest scientific developments as regards the environment.

http://www.cirad.fr and http://www.ird.fr

Sites of Cirad and Ird. Provide important sources of information on research in the intertropical world, development and the environment.

http://www.inra.fr

For everything to do with agronomy research and biotechnologies.

http://www.mnhn.fr

Offers a wealth of information on all aspects of the biosphere.

More specifically to do with biodiversity.

http://www.brg.fr

Site of the Bureau des ressources génétiques (genetic resources office), and http://gis-ifb.fr, site of the French institute for biodiversity.

http://www.unfccc.de/

Official site of the United Nations Convention on climatic change.
(the complete Kyoto text can be downloaded in French in Pdf format).

http://www.globalwarming.org

Information on global warming.

http://environnement.gouv.fr

Ministère de l'Écologie et du Développement durable (Ministry for Ecology and Sustainable Development).

http://diplomatie.gouv.fr

Ministère des Affaires étrangères (Ministry for Foreign Affairs).

http://www.documentation-francaise.gouv.fr

Enables access to, and for some, the option of downloading official reports and publications of the Documentation française.

http://bnf.fr

La Bibliothèque nationale de France François-Mitterrand online

http://www.unccd.int/

Official site of the Convention on desertification.

http://www.csf-desertification.org

Site of the French scientific commission for the Convention on desertification.

http://www.unesco.org/mab

Site of the Unesco "man and the biosphere" programme, with information on the strategy of Seville and the World Network of biosphere reserves.

http://www.irdc.ca/media/fdesert1.html

Site of the International Centre for Research and Development (Canadian Crdi).
A mine of information and documents, not only on desertification.

http://cari.asso.free.fr
Site of the Centre d'actions et de réalisations internationales; Active NGO, particularly as concerns desertification.

http://www.solagral.org/publications/
Site of Solagral, which publishes an excellent, high quality information review: Le Courrier de la planète. The issues, each with a topic, have addressed most issues in the Johannesburg World Summit.

http://www.iepf.org
On this site, it is possible to download and subscribe (for no charge) to the fascinating francophony review: Objectif Terre.

http://www.iucn.org
The site of the International Union for the Conservation of Nature contains major dossiers on the World Summit, in particular a section entitled "What does the World Summit represent for you as regards sustainable development?"

http://www.panda.org
Site of the International World Wild Fund (WWF). Also contains many documents supporting the positions taken by nature conservation movements.

Audiovisual.

A large number of audiovisual documents have been produced in France on the topics treated in this book.

The programme "Thalassa" (from the same production company as the programme entitled "Faut pas rêver") has put out many fine documentaries, which all share the theme of relations between man and nature rather than nature itself. The films on the environment explain how pollution is generated, and how ecosystems, like societies, attempt to face up to it. Whether it involves the Caspian Sea, the Petite Camargue area, or oil rigs, there is no hint of a black and white approach in these documents, whose beauty is matched with intelligence, tact and clarity.
http://www.france3.fr/semistatic/42-2333-NIL-1528.html

The Research Institute for Development (IRD) also has a catalogue of highly accessible films (also on video cassette) on nature and the environment, scientific expeditions, peoples of the sea and forest and how they interact with nature. These documents deal with the intertropical belt as a whole. The catalogue can be consulted on-line, together with a large photo library.
http://www.ird.fr and audovisuel@bondy.ird.fr

CIRAD (Centre of international cooperation in agronomical research for development) also offers audiovisual documents relating to the work of its research teams on the intertropical belt; and INRA, principally as regards the mainland French territory.
http://www.cirad.fr and http://www.inra.fr

The CNRS (national centre for scientific research) offers a film catalogue and photo library on line, with a huge catalogue.
http://www.cnrs.fr/diffusion/index.html

The MNHN (national museum of natural history) offers on-line access to a photo library, and also has a media library.
http://www.mnhn.fr/mnhn/pmh/Images/

As from 1995, it has now become obligatory to deposit all hertzian radio and television broadcasts programmes with a section in French at the INA (national audiovisual institute). These archives can be consulted, with access to numerous audiovisual documents relating to the environment, poverty, climatic change, drought and biodiversity.
http://www.ina.fr/visite/chercheurs/index/html

There are many other sites, which can be reached through the links contained in the sites suggested above.