COMBATING DESERTIFICATION

Freshwater Resources and the Rehabilitation of Degraded Areas in the Drylands

Proceedings of the International Seminar

N'DJAMENA
CHAD

30 October to 4 November 2000

UNESCO-MAB Drylands Series No. 1

INTERNATIONAL SEMINAR ON COMBATING DESERTIFICATION

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Sahara and Sahel Observatory (OSS)

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Volume Editors: Amélie Dupuy, Cathy Lee, Thomas Schaaf

Publication Editor: Samantha Wauchope

United Nations Educational, Scientific and
Cultural Organization (UNESCO)

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Proceedings of the
International Seminar on Combating Desertification:
Freshwater Resources and the Rehabilitation of Degraded Areas in the Drylands
held in N'Djamena, Chad, 30 October to 4 November 2000

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Preface

It is estimated that desertification affects about one-sixth of the world's population and seventy percent of all drylands, amounting to 3.6 billion hectares, or one quarter of the total land area of the world. As defined by the United Nations Convention to Combat Desertification (UNCCD), desertification means land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors which include climatic variations and human activities. The reduction or loss of the biological or economic productivity of rainfed or irrigated croplands, ranges, pastures and woodlands in these climatic zones entails serious land degradation that is most visible in terms of soil erosion, deterioration of the physical, chemical, biological and economic properties of soil, and long-term loss of natural vegetation. *Agenda 21,* adopted at the United Nations Conference on Environment and Development (UNCED), held in 1992 in Rio de Janeiro, Brazil, estimates that in order to reduce poverty in desertification-affected areas, both a cause and consequence of environmental degradation, attempts must be made to restore degraded lands and to provide adequate freshwater resources for consumption by human beings and livestock, as well as for crops.

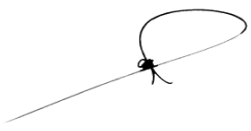
The contributions contained in this publication stem from an international seminar on desertification that was held in N'Djamena (Chad) from 30 October to 4 November 2000. Over fifty scientists from fourteen countries and international organizations representing various scientific disciplines took part in this important event. They addressed issues of desertification, in particular with regard to restoring degraded dryland areas, and the conservation and sustained management of freshwater resources in the world's dry zones. Accordingly, these proceedings contain a series of case studies from Africa and Asia providing not only new insights into site-specific problems but also solutions which may be adapted to resolve similar problems in other desertification-affected areas of the world. Moreover, the work of various international organizations working in the field of combating desertification is presented here: the Food and Agriculture Organization (FAO); UNESCO, with its Man and the Biosphere (MAB) Programme, its International Hydrological Programme (IHP) and its World Heritage Centre; the UNCCD Secretariat; ISESCO; the Sahara and Sahel Observatory (OSS) and the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS).

UNESCO and ISESCO, the main sponsors of the seminar, believe that, today more than ever, science and its applications are indispensable for effectively combating desertification. Science can provide solutions to pressing environmental and economic problems in the world's marginal lands, solutions that have to be backed up by government action, particularly through appropriate education and research programmes at the national and regional levels.

We are indebted to all other sponsoring agencies and organizations that contributed to make this seminar possible, and in particular we wish to thank the Government of Chad for hosting the event in its capital.

W. Erdelen
Assistant Director-General for Natural Sciences
UNESCO

Mohamed Hashem Falougi
Deputy Director-General
ISESCO



Opening Session

The United Nations Convention to Combat Desertification (UNCCD)

Opening Address by Ahmed Cissoko, Senior Scientific Officer, CST Coordinator of the UNCCD

In the name of the Executive Secretary of the Convention and myself, I would like to address my sincere thanks and my deepest gratitude to the Chadian authorities and organizers for their invitation to us to participate at this international seminar on combating desertification in terms of freshwater resources and the rehabilitation of degraded land in drylands.

I would like to briefly mention a few items of the United Nations Convention to Combat Desertification (UNCCD) of relevance to countries seriously affected by drought and/or desertification, in particular in Africa.

The Convention defines the international context of the battle against desertification. More precisely, it is an innovative legal framework for the promotion of sustainable development in fragile ecosystems. It determines ways to expand the roles of governments, local communities and regional, sub-regional, international and non-governmental organizations. In this respect, the Convention is an important instrument in combating poverty and developing local resources.

Desertification is present in most arid, semi-arid and dry sub-humid regions of the world, both in developing and developed countries and affecting more than one billion people. While the degree of desertification varies from one region to another, its effects are alike: it diminishes land productivity and biological diversity, and has an impact on water catchments and rain cycles. The results are an increase in poverty, a decline in quality of life and an acceleration of the phenomenon of migration, notably in rural regions.

To date, 169 countries and the European Community have ratified the Convention, in the short space of time since its inception on 26 December 1996. I believe that this reflects the extraordinary political will present in these countries. We truly hope that those countries that have not as yet ratified the Convention will do so very soon.

I would like to add that ratification often does not happen without lengthy debate through public information and awareness seminars, leading to parliamentary motions and accord.

This political resolve can be read as a clear mandate that we now have the responsibility to act upon.

Many countries have already taken significant institutional and legislative measures. Nations have appointed delegates responsible to administrator the UNCCD, and have identified relevant groups to contribute to its enactment. In numerous countries, we have witnessed open collaboration among a range of different groups in the spirit of a truly participatory process.

Furthermore, past policies to combat desertification have begun to be the object of a critical rethink. Where necessary, existing plans and projects are being re-examined and re-orientated to integrate them into new programmes under development. So far, thirty-four countries have elaborated National Action Programmes, or NAPs. Seventeen NAPs have been elaborated and validated in Africa.

A lot is expected from the Convention. It represents an innovative approach to the problems of development. It generates hope — both from our desire to regain control over Earth's principal source of riches and from the ambitious challenge of bringing disparate groups to work together towards a common goal. We share a responsibility to pursue the Convention's objectives. All of us here have a moral obligation to do whatever we can to drive back the limits of desertification.

Those member states affected by desertification are waiting for the international community to confirm, without ambiguity, that it is dedicated to resolving the problems of desertification and to supporting the efforts of these one billion individuals to return to a decent way of life — by providing programmes with the financial resources and technical assistance envisaged by the UNCCD.

The Convention does not only aim to regain fertile lands, despite the ambitiousness of such an objective. The measures this treaty recommends will contribute to establishing the foundations for a true policy of sustainable development.

The moment has come to rally together to rehabilitate degraded lands, to restore soil fertility and water

availability, to make wooded areas green again and to use the scientific and technical knowledge we have to conceive new sustainable practices.

Water is one of the world's most important natural resources. It has a great influence on a nation's economy. It is vital to life itself and to all human activities. For the past twenty years, growing pressure on water resources due to population growth and industrial, agricultural and domestic demand has been a major concern for the international community.

This crisis looming on our horizon calls for governments and society at large to look for solutions: to overcome the problems of water shortage and water pollution; to ensure the availability of fresh water; and to prevent tensions between states that share the same water sources.

It is estimated that in 1995, one-third of the world's population lived in countries where water was subject to moderate to strong constraints, and that this figure will reach two-thirds by 2015 — mostly in developing countries, where the changes needed to cope with such water shortage will have strong socio-economic repercussions.

Twenty percent of the world's population does not have access to clean water. Of this twenty percent, half do not have adequate means of water purification. Pollution, water contamination and the lack of appropriate water-processing facilities lead to loss of human life annually.

The analysis is perhaps depressing, but the crisis is not inevitable. Rational policies can reverse these trends. In fact, it is possible to equalize water supply and demand by combining conservation efforts and better water management. It is also possible to improve water and land use, and to reduce pollution and protect the environment.

I would like to emphasize here that water resource management is a very delicate and complex exercise. It has often failed through not being integrated into a global approach of economic development in arid regions.

Throughout the cycle of water use, rational water management poses complex technical and socio-economic problems. But while technical problems can generally be resolved by allocating adequate resources, socio-economic problems are of a different order. A number of proposed techniques or technologies seemingly well adapted to resolve physical or biological problems of water use have not been able to be implemented in a sustainable way because they were not adapted to the socio-economic context. Similarly, certain efficient techniques based on traditional practices and knowledge have been abandoned because the systems of production that generated them had become destabilized and no longer allowed for the continual management methods on which the techniques were based.

Local and traditional knowledge and practices were once commonly used to manage water resources and to conserve and rehabilitate lands. The Convention therefore emphasizes the importance of research activities that safeguard, integrate and enhance local and traditional knowledge, practices and skills. Such research should assure (in conformity with national policy and legislation) that the holders of this knowledge directly benefit, equitably and in accordance with terms commonly agreed upon, from any commercial use that could be made of it or any technological progress that could result.

The growing awareness of water problems on a world scale has led the United Nations and other organizations to forge partnerships. The World Bank, the European Union, the World Meteorological Organization and other contributors recently instigated the World Hydrological Cycle Observing System (WHYCOS) with the objective of increasing the amount of readily available hydrological data. UNESCO and other international institutions have also instigated initiatives in relation to water resources. As part of a Regional Action to Combat Desertification programme, UNCCD activities in Africa have included setting up a service for the

integrated management of rivers, lakes and hydro-geological basins.

The Committee of Science and Technology, a subsidiary body of the Conference of the Parties, has begun to put the UNCCD into practice by instigating a number of activities that indirectly contribute to the sustainable management of natural resources, including water. These activities include researching traditional knowledge, examining and evaluating existing services and studying environmental indicators and early warning systems.

Through the intermediary of special groups and international organizations, branches within the UNCCD Secretariat have facilitated, at the demand of the Parties, the development of specialized programmes. Programmes on the following themes have been or are soon to be implemented in Africa:

- Ecological monitoring, early warning systems and tele-detection, and cartography of natural resources
- Agro-forestry and land conservation
- Rational management and the development of crops for forage
- Integrated management of international water-courses, lakes and hydro-geological basins
- Renewable energies and eco-technologies
- Sustainable agricultural production systems
- Reinforcement of capabilities and the promotion of an enabling environment

The subjects that we will be examining over the next four days, concerning water resources and land rehabilitation in the drylands, are vital to the implementation of the Convention to Combat Desertification. I hope that this seminar will establish collaborations and reinforce synergies between the different partners working in this field.

Thank you.

UNESCO's International Hydrological Programme (IHP)

Opening Address by Abdin M.A. Salih, Deputy-Secretary of UNESCO-IHP

Excellence,
Ministers, Ambassadors,
Representatives of United Nations Organizations, IGOS and NGOS,
Ladies and Gentlemen,

It gives me a great pleasure to address you this morning on behalf of Mr. Koichiro Matsuura, Director General of UNESCO, who conveys to all of you his best regards and assures you of UNESCO's support in implementing the recommendations of this seminar.

It goes without saying that the subject of your seminar is of great global importance. However, it is in arid and semi-arid parts of the world, where eco-environmental systems, including the soil, water and vegetation, are extremely vulnerable to climatic changes as well as to human activities, that the problems of desertification are seriously felt. It is within these regions that it would be close to impossible to rehabilitate the environmental balance once it has become disturbed or severely degraded without very expensive and extensive actions. The situation has in many cases led to great crises and loss of productive lands to the desertification process. It is needless to emphasize that Africa in general, and the Sahel countries in particular (including of course Chad), are, in this regard, some of the most vulnerable areas in the world.

UNESCO had foreseen this looming crisis as early as the 1950's, when it established its famous Arid Zones Programme. Remarkable improvements in the knowledge base and in capacity-building were achieved and disseminated worldwide as a result of this unique programme.

As a follow-up to the Arid Zones Programme, over the years UNESCO has established a large number of environmental-research and capacity-building programmes in which the problems of the arid zones were central to their themes and actions. The most famous of these programmes are: the International Hydrological Programme (IHP) and the International Hydrological Decade; the Man and the Biosphere programme (MAB); the International Oceanographic Commission (IOC); the International Geological Correlation Programme (IGCP); the Coastal and Small Islands Project (CSI); and the Management of Social Transformation Programme (MOST).

Those responsible for these programmes, which are based at UNESCO's Science sectors, have worked closely among themselves and with supporting divisions in the Education, Culture and Communication sectors of UNESCO to promote inter-disciplinarity and inter-sectoriality among their actions. Obvious partners are World Heritage Centre and Environmental Education programmes, where the problems faced by arid zones have been explicitly addressed in close co-operation with the above-mentioned programmes.

It must also be emphasized here that both the IHP and MAB programmes have continued, in all phases, to give a high priority to enhancing our knowledge bases and advancing the policy and practice of capacity building in arid and semi-arid regions. More on the contributions of these two programmes will be presented in the coming few days. However, I must convey to you the good news that in recognition of the importance of these themes (IHP and MAB), the Executive Board of UNESCO last week adopted, in its one hundred and sixtieth session, 'Water Resources and Ecosystems' as the Principal Priority of the UNESCO's Science Sector. The board has also approved 'inter-disciplinarity' as a common theme for all the programmes of the organization. In this last regard, I am indeed pleased that this direction has been successfully put into practice in the preparation of this seminar; not only by relevant UNESCO programmes including IHP, MAB, and, the World Heritage Convention, but also by all of us here working together as obvious partners — the Islamic Educational, Scientific and Cultural Organization (ISESCO), the Sahara and Sahel Observatory (OSS), the Francophone Institute for Energy and the Environment (IEPF), the United Nations Convention to Combat Desertification (UNCCD), and the Permanent Inter-State Committee for Drought

Control in the Sahel (CILSS) — and by this wonderful host country of Chad. We could effectively utilize this collaboration as a network with specific practical recommendations, based on seminar deliberations. These recommendations could then be translated into an action plan to be implemented by all of us.

We must, then, ensure that this seminar will not only provide a forum for the presentation of a series of presentations concerning the combat against desertification — which are, needless to say, important results in themselves — but will go further into translating its results and conclusions into follow-up actions that make full use of our joint resources.

Ladies and Gentlemen, in reviewing the provisional agenda, the names of the distinguished participating experts and the beautiful environment and facilities provided by the host, no doubt we have the right recipe for a successful seminar. Let us work together to achieve the sought-after goals.

Before ending my address, I would like to thank, on behalf of UNESCO, the Government of Chad for their hospitality and good organizational arrangements, the partner organizations for their smooth and positive co-operation, the participants of the meeting for their presence and valuable contributions and, last but not least, you, our honourable invited guests for sharing with us this opening session in spite of your busy schedules.

Thank you.

UNESCO's Man and the Biosphere Programme (MAB)

Opening Address by Thomas Schaaf, MAB Programme Specialist, Division of Ecological Sciences, UNESCO

Mr. Chairperson,
Ladies and Gentlemen,

It is my great pleasure to welcome you to this international seminar on behalf of UNESCO's Man and the Biosphere Programme (MAB). We wish to especially thank the authorities of Chad for hosting this important event. Chad is a country particularly affected by desertification, and one of our hopes is that this seminar will forge new contacts among scientists from Chad and other desertification-affected countries in addressing common problems of land degradation in the drylands.

We hope that this seminar will foster collaboration and increase synergy among different institutions that are active in desertification research and control, such as the UNCCD, ISESCO, OSS, IEPF, and UNESCO, and that the scientific papers that will be presented at this seminar will lead to increased collaboration among dryland experts. As my colleague, Mr. Abdin Salih, has already pointed out, UNESCO puts a lot of emphasis on interdisciplinary research in working to solve environmental problems. Complex environmental issues such as desertification and land degradation require multi-facetted approaches and cannot be adequately addressed through sectoral initiatives. The Man and the Biosphere Programme (MAB) has emphasized this aspect since its creation in the early 1970s. This programme was designed to develop the basis, within the natural and the social sciences, for the conservation and sustainable use of natural resources, and for the improvement of the relationship between people and their environment. The MAB programme thus encourages interdisciplinary research, demonstration and training in natural resources management. Over the next decades, MAB will focus on new approaches to facilitating sustainable development, promoting environmental conservation and the wise use of natural resources. In accordance with the transdisciplinary and cross-cultural element of UNESCO's mandate in the fields of education, science, culture and communication, MAB promotes scientific research and information collection along with an appreciation of traditional knowledge of resource use; working towards implementing Agenda 21 and related Conventions, in particular the Convention on Biological Diversity and the Convention to Combat Desertification.

The present seminar has been designed to reflect three broad, interrelated themes. The first focuses on freshwater resources and desertification; the second theme addresses questions of dryland degradation and rehabilitation; and the third theme discusses desertification benchmarks and indicators. We hope that deliberating these themes will benefit countries in reaching the objectives of the UNCCD. We also hope that this seminar will stimulate future joint activities in dryland research; be it through enhanced regional collaboration or inter-institutional co-operation, in the field of capacity building and training or of application-oriented field research. It is our duty to address dryland and desertification issues, not only because an international convention on combating desertification exists, but primarily because desertification-affected countries are among the least-developed nations in the world. Science must be brought into the fight against land degradation; it then can play a vital role in alleviating poverty in the drylands.

I wish every success to this seminar and thank you for your attention.

The Islamic Educational, Scientific and Cultural Organization (ISESCO)

Opening Address by Danghal Diallo, Representative of ISESCO

Wassalamou Alaïkoum Warahmatou Allah Wabarakatouh

In the name of Allah, The Clement, The Merciful.

Your Excellence, Mr Abderahim Birème Hamid, Minister of National Education,
Your Excellence, Mr Mahamat Nouri, Minister of Farming,
Your Excellence, Mr Boukar Kadja Lami, Minister of the Environment,
Ladies and Gentleman,
Representatives of consular and diplomatic corps and regional and international organizations,
Honorable guests and experts;

It is particularly agreeable for me to speak on behalf of his Excellency, the Director–General of the Islamic Educational Scientific and Cultural Organization (ISESCO), Dr Abdulaziz Othman Altwaijri, at the occasion of the opening session of the International Seminar on Combating Desertification: Freshwater Resources and Rehabilitation of Degraded areas in Drylands.

This seminar is a cooperative venture involving ISESCO, the United Nations Educational Scientific and Cultural Organization (UNESCO), the Munazamat Al Dawa Al Islamia, the International Foundation for Energy (IEF) and the Francophone Institute for Energy and the Environment (IEPF), with the support of the Secretariat of the United Nations Convention to Combat Desertification (UNCCD) and the Sahara and Sahel Observatory (OSS), and in collaboration with the Ministry of National Education of Chad. It will bring together experts from Benin, Burkina Faso, Côte d'Ivoire, Djibouti, Egypt, France, Guinea-Bissau, Iran, Jordan, Kenya, Mali, Morocco, Mauritania, Niger, Nigeria, Pakistan, Senegal, Sudan, Chad, Togo and Tunisia, and representatives of regional and international organizations, notably the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), the Food and Agriculture Organization of the United Nations (FAO), IEPF, OSS, UNCCD and UNESCO. The seminar benefits from the warm welcome and excellent facilities provided by the host country. I would therefore, on behalf of ISESCO, express my fervent gratitude to the Chadian authorities.

The ceremony that brings us together today also offers me an opportune occasion to praise the constructive cooperation that unites ISESCO and its sister organization, UNESCO. This cooperation has already borne several fruits, and I sincerely believe that the results of this seminar will be counted among them.

For their part, ISESCO and the Francophone Institute for Energy and the Environment, IEPF, share many common objectives. Some twenty countries are both members of ISESCO and IEPF, another reason to invite ISESCO and IEPF to further reinforce their cooperation.

I would also like to take this opportunity to thank all those attending this opening session for honoring us with their presence. I wish all participants a wonderful and productive stay in N'djamena.

Excellencies,
Ladies and Gentlemen,

Created in 1982, and working within the framework of the Organization of Islamic Conference (OCI), ISESCO is an intergovernmental agency specialized in the fields of education, science, culture and communication. Its principal objectives, as established by its Charter, include strengthening the cooperation between Member States and developing applied science and the use of advanced technology within the unchanging values and ideas of Islam, as well as safeguarding the characteristics and specificity of the Islamic civilization, enhancing understanding between peoples and contributing to the establishment of peace and world security through education, science, culture and communication.

The science programmes of ISESCO promote scientific and technological teaching, research oriented towards scientific and technological development and its applications, environmental protection and the safeguarding of natural resources, and the social and human sciences.

Many of these programmes' objectives have been realized. ISESCO has organized a consultative seminar

on the phenomenon and control of desertification, and a workshop on combating sand encroachment and dune stabilization, and have published the results. ISESCO and UNESCO are cooperating in putting together and distributing information on the use of renewable energy sources, particularly in rural and isolated areas. ISESCO has also organized a regional seminar on biodiversity conservation and has developed studies relating to the prevention of natural catastrophes. In addition, ISESCO has developed and distributed among Member States a scientific study on the impact on the environment and man caused by Kuwaiti petrol-well fires in 1991.

Furthermore, the ISESCO programmes of the triennial Action Plan 2001-2003 emphasize environmental protection and the sustainable use of natural resources through information dissemination, teaching and training programmes on environmental issues, which focus on biodiversity management, desertification control, pollution and the depletion of the ozone layer and the production of renewable energy sources.

Excellencies,
Ladies and Gentlemen,

The issue of desertification deserves special attention not least due to the disastrous consequences it has on populations and the environment. Desertification and recurrent droughts are determining factors that seriously hamper sustainable development in the drylands and affect the quality of life of people in many regions of the world. The problem of desertification goes beyond national and regional borders: as well as implementing national action programmes, it is vital we coordinate recommended approaches and solutions, to combat desertification at the international level.

The availability, management and conservation of freshwater resources for human consumption, agriculture and farming activities are key factors determining the outcome of this combat. Two other factors include the rehabilitation of degraded areas and the conservation of natural ecosystems. In the course of this seminar we will attempt to define how these key factors are to be integrated into current work through the development of impact indicators to monitor and evaluate desertification in the drylands, as proposed by the UNCCD. This should encourage scientific collaboration among national actors and international scientific organizations, so as to initiate information transfer while seeking synergies in relation to activities led by multi-lateral organizations.

By publishing the proceedings of this seminar, a larger public will be able to benefit from the discussions of this important meeting.

I am deeply grateful to Mr Kodi Mahamat, Assistant Director General of the Chad Ministry of National Education, and to the members of the preparatory Committee for having assured the necessary arrangements for this seminar, thus contributing to its success.

I would also like to express my gratitude to Mr Abderraman Issa Youssef who, in his role as ISESCO correspondent in Chad, has provided valuable assistance in implementing ISESCO programmes in this great country.

I am convinced that seminar participants will have the occasion during their stay to exchange ideas and information on a subject that is extremely important for their countries, and to forge social and professional relationships that will, without a doubt, contribute to defining strategic lines of action and projects that will progressively lead to improving living conditions for men and women, and improving the agro-ecological areas in which they live.

Finally, please allow me, Excellency, Minister of National Education, to reiterate my profound gratitude for having honored us with your presence at this opening ceremony of the international seminar on combating desertification.

On behalf of His Excellence, the Director General of ISESCO, let me wish you again every success and thank you for your kind attention.

Wassalamou Alaïkoum Warahmatou Allah Wabarakatouh

The Sahara and Sahel Observatory (OSS)

Opening Address by Youssef Brahimi, OSS Advisor

Mr President,
Ladies,
Gentlemen,

On behalf of the Executive Secretary of the Sahara and Sahel Observatory (OSS) Mr Chedli Fezzani and myself, I would like to express our warmest thanks to the Islamic Educational, Scientific and Cultural Organization (ISESCO), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Francophone Institute for Energy and the Environment (IEPF) for having organized this important international meeting on the general problem of combating desertification, and on the particular problem of freshwater resource management and land rehabilitation in countries affected by drought and desertification.

Mr Fezzani asked that I express his apologies for not being able to be here with you today, this is due to pressing engagements in Tunis. Nonetheless, he asked me to wish you all a successful meeting.

Our deepest gratitude also goes out to the Chadian authorities and the Chadian Ministry of National Education for the warmth of the welcome and the organization of our stay. The efforts deployed provide the best working conditions to achieve quality work during this seminar.

Mr President,
Ladies,
Gentleman,

The Sahara and the Sahel Observatory is an international organization whose mission is to serve as a tool of cooperative exchange and an international setting for partnership and dialogue.

The OSS is aided in carrying out this mission by working under the auspices of the United Nations Convention to Combat Desertification (UNCCD) and Agenda 21. These represent key development instruments and a new approach to combating poverty and managing natural resources, placing the local population at the heart of the co-operation debate.

This approach is based on seeking constant dialogue among the different partners and actors in the combat against desertification. The international seminar taking place over the next few days in N'djamena constitutes for us an important step in strengthening this dialogue.

The recent transfer of the OSS headquarters in Africa to Tunis, and its transformation into an international organization are, moreover, proof not only of the African nations' constant interest in strengthening South-South co-operation, but also of the interest that Northern partners and member organizations of OSS within the United Nations system (UNESCO and the UNCCD Secretariat) have in developing suitable and flexible frameworks within which to strengthen synergies and co-operation among interested groups.

In relation to this last point, OSS's prime objective is to encourage the development and the valorization of the information capital of its partners, so as to make optimal use of appropriate measures to combat desertification. Our work at OSS is based on three fundamental principles: the need to encourage synergies between the different actors involved in combating desertification; the need to create a context in which experiences can be shared towards convergent objectives; and the importance of active participation on the part of all partners in implementing scientific and technical programmes corresponding to their needs.

To this end, this international seminar in N'djamena presents a splendid opportunity for an exchange of experiences among countries that share similar problems and constraints, and an exceptional occasion to bring concrete expression — through partnership agreements — to synergies between countries affected by desertification and the different institutions and organizations who support the combat against desertification.

It is in this spirit that OSS intends to contribute to this seminar and hopes to be able to share with you the results it achieves, and, above all, the challenges it raises, particularly with regard to African nations.

Before I finish, I wish to express to the Chadian authorities OSS's commitment to working with Chadian institutions, within the context of OSS programmes and equally within the context of joint programmes led by colleagues from the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), to support the implementation of the UNCCD in the Sahel countries. The OSS hopes that this meeting in N'djamena will serve equally to strengthen co-operation with the different actors in Chad involved in putting the UNCCD into practice.

The OSS wishes every success for the work of this seminar, and I thank you all for your attention.

1 Keynote Address: Desertification — its Causes and its Impact on Water Resources Management in Arid Regions

Siddig E. Ahmed, Professor of Water Resources, UNESCO Chair, Khartoum, Sudan

Introduction

The United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO) define desertification as a process of land degradation in areas vulnerable to severe edaphic or climatic aridity. This degradation leads to the reduction or destruction of the land's biological potential, to a deterioration of living standards and to the intensification of desert-like conditions. Desertification is most prevalent in arid and semi-arid areas, especially in developing countries receiving less than five hundred millimetres of rainfall annually and with bordering deserts.

Desertification is essentially a result of soil degradation. The direct effect of land degradation is either a decrease of land productivity or the complete abandonment of agricultural land, which leads to the food crisis confronted by arid regions. Severe soil degradation may ultimately result in complete desertification, as in the case of wind erosion. Deserts all over the world are known to be increasing at the expense of agricultural land; this is most severe in arid and semi-arid regions. In 1983, Dregne estimated that fifty million people had lost the capability to support themselves due to desertification, and had abandoned their agricultural way of life and settled in overcrowded cities. The following year UNEP estimated that a total of 4.5 billion hectares around the world — 35 percent of the Earth's surface — were at different stages of desertification. Approximately 850 million people, living under the threat of losing their homes and livelihoods, inhabit these areas.

Of all continents, Africa experiences the highest rate of desertification (UNEP 1987). Africa contains two distinct deserts, the Sahara in the north and the Kalahari in southwestern Africa. The sub-Saharan region comprises a very fragile ecological belt known as the Sahel. It stretches from west to east over nine countries from Mauritania and Senegal to Sudan. This region experiences an accelerated rate of desertification (UNEP 1987). In many of the arid regions, sustainable water availability per capita is already below the level that would allow enough food to be grown locally to feed the population. Moreover the situation is aggravated by desert encroachment creating an environment unfit for humans or animals.

It is very important to differentiate between the terms aridity, drought and desertification. Aridity is usually defined in term of low average precipitation or available water. Discounting the possibility of climatic change, aridity is a permanent feature; activities in arid regions are geared to meet this consistent dryness. Drought, on the other hand, is a temporary feature caused by climate fluctuations. Drought causes at least some interruption to normal activities in all areas affected by the temporary decrease in normal water availability. Arid regions are different from deserts, as perennial plants are either non-existant or are at least very sparse in desert regions, primarily because of water deficiency.

Within this century, it will become very clear that water resources management — the wise use and conservation of water resources — will probably represent the most important concern for human societies in many parts of the world. Water, whether from rainfall or other sources, supplies the soil with the moisture necessary for the growth of vegetative cover. As water stress develops, to the point where wilting becomes permanent, plant death may occur — with a consequent loss in vegetation cover. Such loss is almost invariably accompanied by sand creeping, enhancing the desertification process.

1. Causes of Desertification

Water is essential in maintaining human and animal life. Permanent water supplies tend to lead to permanent settlement. On the other hand, the provision of water at or near human settlements tends to increase the stresses on the local environment, which can ultimately lead to desertification. The causes of desertification can

include frequent droughts, deforestation, extensive cultivation and overgrazing.

1.1 DROUGHT

Drought affecting semi-arid regions is considered one of the main causes of desertification encroachment. Drought can be attributed to inadequate seasonal precipitation, a prolonged dry season or a series of sub-average rainy seasons.

Annual rainfall analysis of a number of countries in the North Africa Sub-Region (Algeria, Egypt, Libya, Mauritania, Morocco, Sudan and Tunisia) demonstrates a high variability in its temporal and spatial distribution. The ensuing drought, in varying degrees of frequency and severity, is a common phenomenon in the sub-region. The causes of below-average rainfall are still unknown. However, recent research has correlated the phenomenon with El Niño–La Niña events.

The El Niño phenomenon results from an increase in sea temperature, which, for unknown reasons, leads to changes in the direction of moist winds. Instead of moist wind blowing inland, it blows towards the sea — and is normally accompanied by severe drought. La Niña is the reverse of El Niño and is normally accompanied by floods.

These and other phenomena have influenced the North Africa Sub-Region, resulting in an increase in drought frequency. A study comparing annual rainfall variations as recorded at two stations in each country in the North Africa Sub-Region — the two stations representing the countries' areas of highest and lowest annual rainfall — shows that over the last four decades, rainfall has declined in almost all of these countries. Figure 1 illustrates this rainfall trend in two Sahel cities: Nouakchott in Mauritania and El Obeid in Sudan.

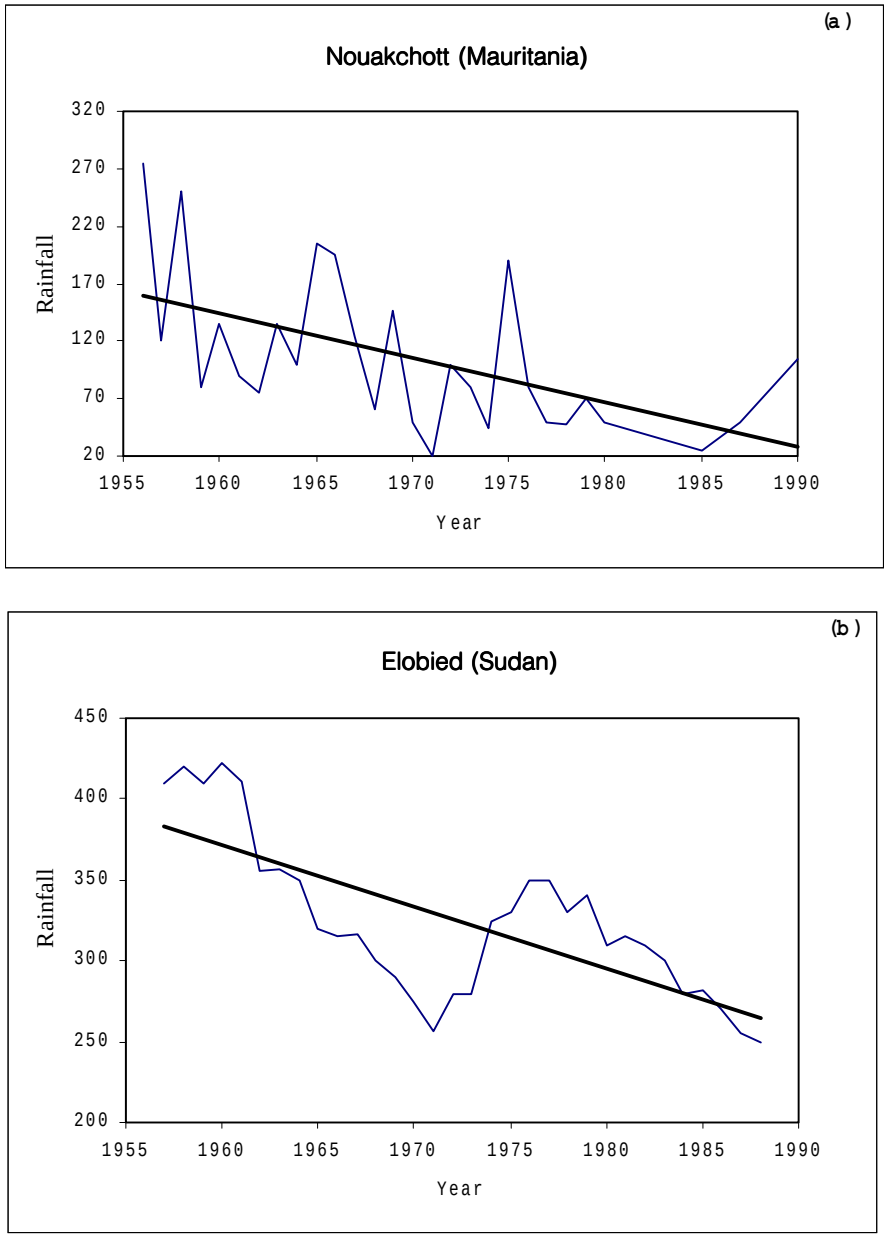


Figure 1: Shifts in annual rainfall in two Sahel cities

The incidence of drought in the region (defined in relation to each country's average annual rainfall) was found to vary from four to eight years of drought in an eleven-year period (see Table 1, below). Tunisia recorded the lowest incidence of drought and Morocco the highest (six to eight years). A similar study by Gilali and Gababy (1997) showed that Al Maghreb Alarabi suffered from episodic drought (Tunisia 1987–1989, Morocco 1979–1984 and 1991–1993) and that rainfall in the region decreased at a rate of forty millimetres per year.

1.2 EXTENSIVE CULTIVATION

Rain-fed agriculture plays a very important role in the national economy of many developing countries, offering food supply stability and providing a large share of staple food. Although in many of these countries, rain-fed agriculture has the capability for substantial horizontal and vertical expansion of potential resources at low cost, a rapid increase of human and animal populations necessitates a corresponding expansion of cultivated areas; leading to land over-utilization and thus causing land degradation.

Shifting cultivation is common practice in many arid regions and is sometimes called traditional agriculture (TA). It involves the preparation of cultivated land by tree logging and the clearing of weeds, securing soil moisture for the crops. This is repeated year after year, resulting in destruction of the vegetation cover, and ultimately in soil deterioration and reduced productivity. The most widespread reaction to a dry year is to increase the area of cultivation by taking in fallow land or pasture wherever possible, although some rotation is practised.

By rotating sorghum with other crops such as sesame, groundnuts or millet, TA leads to a decline in soil fertility over time. It then becomes necessary to shift to a new cultivable area. In mechanized agriculture (MA), trees are completely uprooted when new land is opened, to facilitate mechanization. Allowing the tree root system and some trees to remain on the land would result in faster regrowth and would protect the topsoil from erosion.

1.3 DEFORESTATION

The disappearance of many trees from rain-fed areas has contributed significantly to land degradation and the deterioration of soil fertility. Forests are constantly being cut down for fuel and negligible replanting is carried out. As populations grow and concentrate in farming communities and villages, the treeless areas around these settlements increase. Villagers have to travel further to fetch firewood, and different tree species are increasingly exploited (for both fuel and construction) as the better ones disappear. The collection of wood ultimately becomes commercialized, with men taking over the work from women. As the distance from the wood source increases, too, wood tends to be made into charcoal to facilitate its transportation.

In Sudan, for example, it is estimated that firewood consumption is about three cubic metres per person per year: the annual requirement for the total population is about

Table 1: Rainfall patterns & drought frequency in the North Africa Sub-Region

Country	Station	Annual Rainfall (mm)			Reliability of Rainfall (mm)		Drought Frequency (No. of years out of 11 years)
		Min	Max	Average	50%	80%	
Algeria	Skikda	513	855	669	657	583	4
	El Shalaf	212	527	329	285		6
Egypt	Alexandria	9	389	152	75	32	6
	Cairo	7	79	22	9	4	6
Libya	Tripoli	149	532	282	209	161	7
	Sirat	38	194	130	92	46	6
Mauritania	Kiedmagha	13	533	325	157	54	5
	Edrar	1.6	369	105	35	11	7
Morocco	Ifran	463	1777	861	736	586	8
	Warzazat	63	263	122	94	68	6
Sudan	Juba	669	1310	953	873	749	6
	Fashir	109	638	235	171	118	8
Tunisia	Tabaruka	662	1178	883	817	706	5
	Ramaza	64	104	80	81	67	4

eighty million cubic metres per year. The demand for wood explains the depletion of trees along Sudan's roads and around its villages and towns, which are generally surrounded by circles of woodless land — with a radius that sometimes exceeds 160 kilometres (Mainguet 1991).

This absence of forests results in extensive wind erosion, and the microclimate becomes increasingly arid. The dry season becomes more accentuated and precipitation decreases.

1.4 OVERGRAZING

Around water points, and especially where people have settled in permanent communities, grazing dramatically reduces soil cover. This has a tremendous effect on soil degradation and hence desertification. Overgrazing is worse where water points have been sited in close proximity. In such cases, the grazing areas around the water points overlap. The area of overlap is then heavily grazed.

In the past, nomadic herdsmen maintained the delicate balance between livestock numbers and the carrying capacity of pasture. But this balance has recently been disturbed, through the expansion of dry farming in traditional grazing lands and an increase in animal populations. Apart from the degradation of natural vegetation cover, over-grazing results in a decrease in the quality of the pasture. In these areas, most of the palatable species have been replaced by *Cyprus conglomeratus*.

1.5 SOIL FACTORS

Different types of soil are more prone to erosion. A number of different factors may be distinguished:

- Soil moisture content: only dry soils undergo erosion;
- Soil texture: fine particles are more vulnerable to erosion than coarse ones;
- Cementing materials: an absence of cementing materials (such as organic matter) makes soil more prone to erosion;
- Disaggregating practices: fine ploughing or the addition of disaggregating materials like calcium carbonate makes soil more prone to erosion;
- Condition of the topsoil: smooth surfaces are more prone to erosion than rough surfaces.

2. Impact of Desertification

2.1 SAND DRIFT AND DUNE FORMATION

In Sudan, recent surveys have revealed that most of the rain-fed agricultural land between latitudes 17° and 15° north is lost to desertification, due to the movement of sand from the Libyan Desert (FAO mission report, 1976). The length of the Nile between Dongola and Kariema is also affected by sand-dune encroachment and sand drift, which are engulfing productive agricultural lands and human settlements.

2.2 REDUCED FOOD PRODUCTION

One of the most serious consequences of desertification is a decline in food production. The production of dura (*Sorghum vulgare*), the main food staple in many parts of the drylands, has declined noticeably in recent years. In Sudan, maize and *dukhan* (millet) yields have dropped from 0.8 tonnes per hectare (maize) and 1.3 tonnes per hectare (millet) to 0.36 and 0.29 tonnes per hectare respectively during the same period.

2.3 REDUCED GUM ARABIC PRODUCTION

Sudan is a major producer of gum arabic, which is extracted from the acacia tree (*Acacia senegal*) and is second only to cotton as the country's main source of foreign currency. Due to the extermination of huge numbers of acacia trees, desertification has not only affected the country's foreign exchange balance, but also reduced the world's supply of gum arabic.

2.4 WILDLIFE

Desertification has also affected wildlife habitats. Many wildlife species, once abundant, have vanished, and those remaining are endangered. In Sudan's Dinder National Park, the number of ungulate species is declining rapidly, a result of competition with livestock for grazing lands. The gazelle (*Gazella someringi*), which was abundant until 1966, has completely disappeared from this area. The populations of *tiang* in the area have also declined. In the Wadi Howar area, the addax antelope has not been seen for the last fifteen years and the oryx has not been seen since 1973.

2.5 DISPUTES AND CONFLICTS

Tribal disputes have become chronic and acute. Hundreds, perhaps thousands, of people have lost their lives. The major cause of disputes is the growing shortage of grazing lands and water for livestock, and the encroachment of farmers (traditional farmers) into pastoral areas and vice versa.

2.6 IMPACT ON IRRIGATED LAND

The Gezira Scheme is very important to the Sudanese economy. Through a combination of natural and man-made factors, however, the scheme is now almost completely surrounded by bare, flat soil, and encroaching sand threatens the scheme. Sand encroachment affects the Gezira Scheme in the following ways:

Soils: Desertification changes the chemical and physical characteristics of the soil. Chemically, by adding nutrient-poor silicon material (sand) to the fertile clay topsoil of the Gezira, and physically, by altering the topsoil, its clay texture and structure, towards those of sandy soils.

Irrigation: Deposited soils change the level of irrigated land. The Gezira scheme is known for its extended

canalization network, which uses gravity to transport water for hundreds of kilometres throughout the scheme. The fields are twenty centimetres above the surface of the water in the canals. Any change in the levels of the fields will make irrigation problematic.

Filling of the irrigation canals with sand: Some of the canals and smaller watercourse in regions affected by severe wind-blown sand are completely filled with sand. Unlike silting, this "sanding" of the canals does not appear to be easily solved by mechanical dragging. This is due to the high rate of sanding and the behaviour of the removed sand.

3. Techniques to Control Desertification

Various techniques have been used to combat desert encroachment, some of which are described below.

3.1 SHELTERBELTS

Wind erosion is a common phenomenon whenever dry, sparsely vegetated soils are exposed to high winds. Fine particles are carried in the strong winds and deposited when the wind speed drops below a threshold level that is not capable of carrying the soil particle further. There are three forms of wind erosion: creep

Table 2: The effect of crop rotation on sorghum yields (Gedaref, Sudan)

Rotation	Yield (kg/ha)
First year	1736
After 2 years	771
After 3 years	664
After 4 years	536
After 5 years	450
After fallow	1543
After sesame or cotton	1178

Table 3: Effect of the date of sowing on sorghum yield

Planting Period	Number of Tests	Yield Index	Yield (kg/ha)
June 1–15	1	1.18	900
June 15–30	3	1.1	836
July 1–15	4	1.32	1007
July 15–30	3	1.35	1050
August 1–15	4	0.97	750
August 15–30	5	0.45	343

(7-25 percent), saltation (50-80 percent) and suspension (around 10 percent). Suspension carries soil particles for greater distances than either creep or saltation.

Shelterbelts and scattered trees are known to be one of the traditional and most important agroforestry tools used for microclimate modification. The effects of shelterbelts extend for a considerable distance on the leeward side of the belt (generally known as the sheltered or protected area) and to a lesser distance on the windward side of the belt.

Shelterbelts alter approaching winds in two ways. They deflect approaching air masses upward, creating a zone of higher wind velocity and higher kinetic energy that engulfs areas of high turbulence on both sides of the belt, with the one on the leeward side (turbulent wake flow) being greater than the one on the windward side, depending on air and shelter characteristics. The turbulent area continuously extracts its kinetic energy from the accelerated layer above it, resulting in more turbulence beyond the wind-protected area and subsequently gradually evening out the effect of the belt through vertical momentum transfer until the approaching wind conditions are restored.

The second way the shelterbelt influences the approaching wind is through the combination of drag force and momentum extraction. Through this effect the shelterbelt acts as a braking mechanism, increasing static pressure on the windward side of the shelterbelt and decreasing static pressure on the leeward side, with increased turbulence at the edges of these zones. Both effects on wind speed and turbulence are important in determining the efficiency of a belt. Other characteristics that determine a shelterbelt's efficiency, and therefore the behaviour of air as it moves within and around it, are its permeability, its crown-geometry, its length, width, and height, and the presence of any gaps in the belt.

3.2 CHANGING CULTURAL PRACTICES

In most arid regions where traditional agriculture is practiced, crop rotation is not used. Yet research has shown that alternating, for example, sorghum with sesame, or leaving the land fallow, even for one season, could lead to substantial yield increases. See Table 2.

Another determinant factor is planting date. In rainfed agriculture, the importance of planting crops early to increase yield potential is well known. However, farmers tend to plant late to economize on the cost of weeding. The planting date is generally dependent on the volume of early rain showers, usually waiting until one hundred millimetres has fallen, which will fill the soil cracks and initiate weed growth. The first disking eradicates early weeds, while crops are sown during the second disking. Table 3 shows the effect the date of sowing has on the sorghum yield.

3.3 AGROFORESTRY

Agroforestry refers to the practice of growing trees or bushes alongside an agricultural crop or in lands used for livestock pasture. Rural populations in the Sahel have long practised agroforestry: for example, Sahelian farmers often plant crops such as millet, sorghum, maize and groundnuts under a park of acacia trees — *Acacia albida*.

Agroforestry can contribute to rural development in the Sahel by:

- Increasing food and fodder supply
- Providing a substantial supply of fuel wood,
- Protecting the productive potential of a given site and improving its environment and carrying capacity.

The best sites for agroforestry are areas in which the water table is shallow and trees can survive on capillary water. The design represented in Figure 2, below, has been suggested for such areas:

1. A development centre: this includes a deep well, an administrative building, a residential area, a marketplace, shops, workshops and small plots with trickle irrigation for home gardens and vegetable production.

2. An inner zone: this includes (a) agroforestry plots, each approximately one hundred hectares in size, to be managed by about twenty family units; and (b) intensively managed, fenced grasslands with a high percentage of tree and shrub cover.

3. An outer zone: this includes (c) forest plantation (e.g. with *Acacia senegal*, *Prospopis africana* and *Prospopis jule* flora), production of gum arabic, firewood; (d) protected areas (eventually fenced); (e) protected areas for natural regeneration of local species.

4. The Impact of Desertification on Water Resources Management

4.1 WATER YIELD

As stated earlier, desertification and drought are interlinked. The occurrence of drought advances the process of desertification, which increases the possibility of drought and its frequency. This leads to high rainfall variability with the following impacts:

- Seasonal variations in runoff quantities
- Less recharge of groundwater resources

4.2 WATER USE

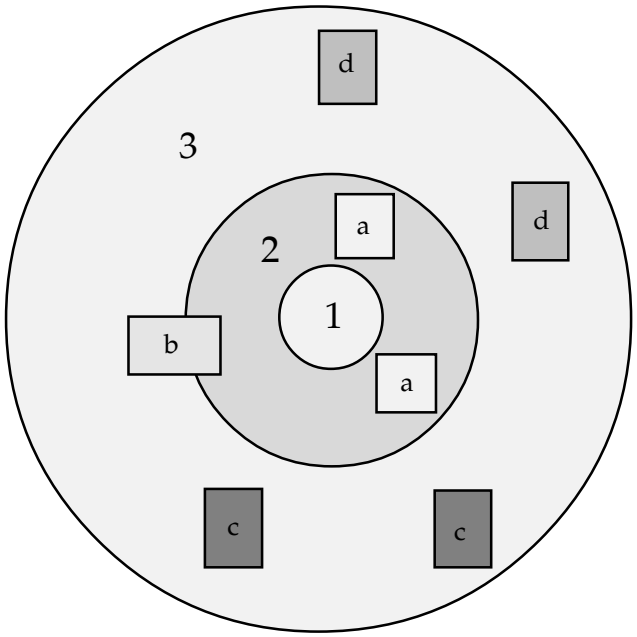
Desertification affects water use in the following ways:

- It increases dependence on groundwater to supply drinking water.
- It increases the water requirements of some irrigation schemes.

The reduction in runoff that results from low rainfall, particularly in arid regions, leads governments to rely heavily on groundwater for domestic water supplies. This can lead to the depletion of part of the groundwater basin: the use of some basins has already been ruled out, by any standard acceptable measures, for safe and economic development.

Many of the large irrigation schemes in arid regions have been designed to supplement rainwater. Over the last five years, however, irrigation requirements have increased drastically. In the Gezira Scheme in Sudan, for example, seasonal irrigation requirements have been increased to more than 150 percent of their original volumes during certain months of the season (July to September).

Figure 2: Land use in the area surrounding the well sites



5. Water Requirements of Techniques Used to Combat Desertification

The main techniques used to combat and/or mitigate desertification can be summarized as follows:

- Planting shelterbelts. Shelterbelts are generally comprised of eucalyptus trees; grown in eight to ten rows, twenty to thirty metres apart. One kilometre of shelterbelt thus covers two to three hectares of land.
- Agroforestry. Trees and other crops (sorghum, millet, sesame etc) are interspersed with the main crop.
- Supplementary irrigation. This provides water in rain-fed areas at times of water depletion.

The water requirements of these three methods can be calculated by applying the Penman-Monteith rule to the appropriate crop coefficients. Table 4 summarizes the water requirements based on Sudan climatic conditions.

Table 4: Water Requirements

Practice	Water Requirements m3/ha/season
Shelterbelts	30,000
Agroforestry	21,000
Supplementary Irrigations: — irrigation at three stages — irrigation at first & second stages only	 2500 (for optimum yield) 1700 (60% of optimum yield)

6. Water Sources

6.1 RAINFALL HARVESTING

Water-harvesting techniques have been developed for growing crops or for rehabiliting and developing grazing lands in arid and semi-arid areas, where rainfall is inadequate for rain-fed agriculture and where water is lacking. Rainfall and runoff is collected in a natural or modified catchment, through which it is directed to specific sites, such as cultivated areas and cisterns (stored in dams or underground), or it is used to replenish aquifers. Water harvesting ensures that a greater percentage of rainfall is put to beneficial use. Using these techniques, rainfall of few millimetres in a catchment area can be equivalent to several hundred millimetres of rainfall when supplied to a cultivated field in a semi-arid area.

6.2 FLOODWATER HARNESSING

Floodwater harnessing has been practised for millennia in many arid and semi-arid regions. There are many forms of traditional and modern floodwater harnessing. ACSAD, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and ROSTAS recognize the following techniques:

- Uncontrolled water spreading, which involves the diversion of water via artificial or natural canals, which are usually located near the *wadi* channel.
- Controlled water spreading — by building a check dam as a diverting canal to direct water towards the land to be cultivated.
- Collecting runoff in check dams — a traditional system where small earth-fill or rock-fill dams are constructed on the beds of ephemeral *wadis* to collect water and sediment. In addition to slowing down runoff, soils suitable for crop production are accumulated.

6.3 TREATED WASTEWATER

One way to augment water resources to be used for various purposes, including combating desertification, is to reuse treated domestic wastewater. An example of this is an agricultural project that was implemented in Egypt, in northwest Cairo, as early as 1915, in which primary-treated wastewater was used to irrigate approximately one thousand hectares of land. It is estimated that the total quantity of reused, treated wastewater in Egypt was about 0.7 billion cubic metres in 1995/96. Wastewater treatment could become an important source of water reuse, and should be considered in any new water resources development policy. The major issues of concern associated with treated wastewater reuse include public-health and environmental hazards, as well as technical, institutional, sociocultural and sustainability aspects.

6.4 GROUNDWATER

Attempts can be made to combat drought by using untapped groundwater resources. Groundwater basins include the Sahara Nubian basin and the Chad basin. Vast untapped groundwater resources are also known to exist in Niger, Mali and Mauritania.

The Saharan Nubian basin covers the northern part of Darfur in Sudan, extending northward from the Tagabo-Meidob groundwater divide to the Egyptian border and encompassing an area of 324,656 square kilometres. The Chad basin, with Lake Chad as its lowest level, constitutes another immense reservoir of subterranean water — one of the largest closed river basins in the world. Such groundwater can be used in marginal areas to control desertification by providing water to shelterbelts. Groundwater in conjunction with harvested water can be used for irrigation to sustain traditional rain-fed agriculture.

7. Strategies to Combat Desertification

Drought is a temporary, more-or-less cyclic, phenomenon that can occur in almost all climates. Desertification, on the other hand, is largely a direct result of man's irrational activities, and can even occur in areas where water is plentiful. Integrated land-use policies are imperative, since the solution to desertification centres on improved land use. These plans should have human needs as their primary concern. Many projects in the past lacked extension services and the vision of raising awareness among rural communities. Policy makers and planners have too often adopted fragmented, compartmentalized, ad hoc and short-term approaches when dealing with ecological planning, whereas a holistic overview is essential.

Projects, when identified, will have to involve the concerted efforts of central and local governments and the private and public sectors, as well as international organizations. Rehabilitation programmes and project models should be based on:

- The capabilities of the systems' resources
- Current land-use practices
- Community participation
- Small-scale projects

Strategies to combat desertification must be based on local conditions. Strategists need to determine the local vegetation's potential to be used as human food and animal fodder in times of famine, and should adopt feasible technologies that are suitable to the local environment. Strategies to combat desertification may also include the following:

- Assessing the potential for treated wastewater to be reused for irrigation
- Encouraging the use of rainwater harvesting and floodwater harnessing techniques
- Encouraging the conjunctive use of harvested groundwater and rainwater
- Rehabilitating *hafirs*
- Rehabilitating water yards, where pumped water is available
- Planting shelterbelts
- Implementing small-scale irrigation projects
- Looking for alternative sources of energy
- Improving animal husbandry conditions and practices
- Farming clay areas, to relieve pressure on sandy areas
- Creating small-scale industries based on available raw materials such as tanneries, handicraft production, oil mills, etc.

Meanwhile, it is crucial that efforts be targeted towards raising the level of desertification awareness and involvement through mass media and classroom tuition. It is also important to foster co-operation between countries with similar problems, particularly through exchange visits and human resources training. The international community has a very important role to play, by providing financial support and the appropriate technology.

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2 Water Harvesting Techniques in West and Central Africa

Sourakata Bangoura, FAO Regional Technical Administrator for Water Resources (FAO-RAF), Ghana

Introduction

Water is one of the most vital natural resources for the socio-economic growth of a country and for the survival of humanity. A concise understanding of available water resources is therefore indispensable to the creation of development projects and in order to appreciate the requirements of sustainable development.

The inhabitants of arid and semi-arid areas are subjected to irregular and often insufficient rainfall, which can have catastrophic effects on their agricultural industries. Recurrent drought and eventually desertification threatens the survival of these people. In conditions such as these, "irrigation might have been the ideal solution, had it not been for the high cost of the basic infrastructure" (Siegert, FAO, 1991).

Arid areas like the Sahara and the Sahel have one short and sporadic rainy season, followed by a dry season of eight to nine months. Annual rainfall is one hundred to four hundred millimetres. Overgrazing (due to an increase in livestock that is often linked to cultural factors) and the gathering of firewood (leading to bush fires, drought and the destruction of vegetation) have in these areas lead to increased degradation of lands, and to desertification.

Semi-arid zones like the Sudano–Sahel are characterised by a three-to-four month long rainy season with an annual rainfall in the region of four hundred to six hundred millimetres. The Sudano–Sahel would seem to be one of the most at risk in Africa, due to the huge inconsistencies in rainfall. The gravity of these climatic perturbations in Africa, and notably the frequent droughts, has been brought to world attention since the 1970s. An estimated one million 'ecological refugees', a sixth of its population, was forced to leave Burkina Faso during the Sahel drought of the early 1970s, and another 500,000 people fled Mali during the same period (Source: FAO Conservation and Restoration of African Lands, 1990)

In this light, numerous governing bodies and institutions over the past thirty years have initiated broad-based programs and projects aimed at the conservation and regulated usage of freshwater resources.

Runoff harvesting is the most favoured among a number of possible technical options: it can be carried out safely and it prevents soil erosion while maintaining a necessary level of groundwater.

Although there have been encouraging results in certain programmes, the majority of programmes have failed to obtain the expected results, or have failed to achieve their assigned objectives. This poor performance on the part of conservation projects and water resources management has largely been due to an often interventionist approach and a reliance on techniques that are unsuitable to the local socio-economic and ecological conditions and the real needs of local beneficiaries.

Conscious of the fact that the management of water resources and desertification processes constitutes a challenge for the development of the African continent, FAO has taken measures to study long-term solutions to the problem of increasing agricultural yields in eroded lands.

In this context, FAO, in close collaboration with appropriate groups within the United Nations, has developed the International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD). This represents an integral part of the United Nation's implementation of the Mar del Plata Action Plan, which emphasizes the importance of using water efficiently — a key element towards the effective management of water resources to ensure sustainable agricultural production. With the help of African experts, the FAO has also launched the International Scheme for the Conservation and Rehabilitation of African Lands (ISCRAL).

The FAO has also evaluated the potential of Africa's water resources. It has studied endogenous resource management techniques and, importantly, the socio-economical, political and environmental impact of these techniques. The results of case studies carried out by the FAO have been presented at sub-regional conferences in Cairo in 1993, Harare in 1998 and Niamey in 1999.

Through the Special Programme for Food Security (SPFS), the FAO supports member countries in their long-term management of water resources. The programme backs projects that regulate water usage by using low-cost water management techniques, such as water harvesting or the use of hand pumps to irrigate smaller plots of land. "Improving Land Use in the Keita Valley, Niger", an integrated development programme that uses various water-harvesting techniques, is one example of the technical support given to African countries by FAO in the hope of slowing down desertification and restoring eroded soil.

Programmes instigated by the FAO aim to strengthen countries' capacities to develop their water-collecting techniques, and include training sessions on the use of these techniques.

1. Water Harvesting in the Western and Central African Sub-Region

In FAO terms, water harvesting refers, in general, to collecting water runoff for productive usage. Water runoff can be collected in tanks positioned on rooftops or at ground level, often from intermittent spells of rain, via a range of possible techniques dependant on how the water is to be used. Productive ways of using runoff include filling reservoirs for domestic use and providing water for market gardens or small fruit orchards and, to a lesser extent, for pisciculture (K. Siegert, FAO, Rome, 1991)

Participants at the Western and Central African Workshop on Water Harvesting, held in Niamey in October 1999, carried out an extensive survey on the major techniques used in different countries to collect water. As Table 1 shows, the most common techniques used are microcatchments, water-spreading bunds, contour stone bunds, artificial lakes and earthen bunds. Other techniques are used in certain countries: notably furrows, contour ridges, bench terracing, *zaïs* or *tassas*, Matengo pits (grass-fallow tied ridging), permeable rock dams, semi-circular bunds, scarifying and impluvium

Most of these techniques can be set up manually and at low cost by the beneficiaries, and are easily replicable. Minor maintenance work can generally be done by hand, although in certain cases maintenance may require a great amount of labour. Transport costs and the limited lifespan of the works constitute the major constraints. (See Table 1 overleaf.)

The following methods are recommended:

- Combine water-harvesting techniques with projects to improve farming yields, particularly by re-organizing farming systems according to the water available, improving necessary nutritive elements (using mineral fertilizer or organic manure), encouraging the use of mulching and providing pesticide and suitable farm equipment.
- Combine different water-harvesting techniques. For example, contour stone bunds can be used in conjunction with *zai* and mulching or manure.
- Integrate water-harvesting techniques and management of surface water and groundwater resources.

1.3 IMPACTS OF WATER-HARVESTING TECHNIQUES

Socio-Economic Impacts

In terms of revenue, work scheduling, land consolidation and rural migration, the best results are achieved from the techniques of constructing stone and earthen contour bunds and spreader bunds or terraced *wadis*, *zai* and *boulis* (artificial pools dug at the foot or midway up a slope at a point where there is a convergence of runoff).

For a project to be successful from a socio-economical standpoint, ITIS recommended that:

- A participative approach should be adopted in designing and implementing water-harvesting projects to ensure their sustainability.
- More financial assistance should be directed towards public-awareness programmes and the organization and training of scheme beneficiaries.
- An agricultural credit union should be established, to enable greater participation on the part of the beneficiaries in the financing of the scheme.
- Transport and distribution infrastructures must be improved.
- Additional study is needed of the socio-economic impacts of these schemes — including the impact on women and any effects they may have on land laws — in co-operation with the beneficiaries, NGOs and national organizations.
- Maintenance of the works and infrastructures must be the responsibility of the beneficiaries.
- The techniques that are recommended must be profitable for the local communities.

Institutional and Political Impacts

The existence and the contents of water resources policies and strategies vary from one country to another. In many countries, moreover, responsibility for the design and implementation of water-harvesting and conservation techniques is shared between several decision-making bodies.

It was also noted that certain countries have given priority to large-scale hydro-agricultural projects to the detriment of simpler, and much less expensive, techniques that could be administered and maintained by the recipients themselves.

The absence of a clear land policy prevents water-harvesting and spreading techniques from being more widely used.

Table 1: Water-Harvesting Techniques Used in the Sub-Regions of West and Central Africa

Technique	Country	Geographical Conditions	Advantages
1. Microcatchments	All	Valleys and depressions, lower slopes	Multi-purpose; large-scale production; groundwater is replenished
2. Spreading bunds	Except Nigeria	Valleys	Groundwater is replenished; reproducible
3. Trenches	Niger; Burkino Faso; Chad	Inclines, plateaux	Restores vegetation; recuperates surrounding land; upkeep regular but not continual
4. Contour ridging	Niger; Burkino Faso	Inclines	Restores rangelands; land for agricultural production
5. Bench terracing	Niger; Chad; Gambia; Nigeria	Inclines, plateaux	Restores rangelands; land for agricultural production
6. Contour stone bunds	Except Gambia and Senegal	Inclines, plateaux	Restores vegetation; recuperates surrounding land; upkeep regular but not continual; fights soil erosion
7. Semi-circular bunds	Niger; Burkino Faso	Low-gradient inclines	High output; promotes reforestation
8. *Zaï*	Niger; Burkino Faso	Plateaux; low-gradient inclines	Increased output; recuperates surrounding land
9. Artificial lakes	Except Gambia, Senegal, Mauritania	Lowlands; valleys	Multiple uses; groundwater is replenished
10. Contour earthen bunds	All	Valleys and depressions, lower slopes	Groundwater is replenished; low cost-per-hectare co-efficient
11. Matengo pits	Niger; Gambia; Nigeria; Burkino Faso	Plateaux; inclines	Conserves humidity
12. Permeable stone dams	Niger; Burkino Faso; Mauritania	Valleys; watercourses (*wadis*)	Reproducible; fights soil erosion; recuperates surrounding land
13. Scarifying	Niger	Plateaux	
14. Impluvium	Niger; Cape Verde; Cameroon; Mauritania	Anywhere, especially on slopes	Increases availability of water

Disadvantages	Cost	Level of Technology	
		Initial	Upkeep
Costly; some upkeep required; can harbour water-transmitted diseases	Costly in terms of what the recipient can afford	Mechanical	By the beneficiaries
Constant upkeep required; low level of production; costly	Costly in terms of what the recipient can afford	Mechanical	By the beneficiaries
Large workforce needed	Low cost, within beneficiaries' budget	Manual	By the beneficiaries
Large workforce needed	Low cost, within beneficiaries' budget	Manual	By the beneficiaries
Large workforce needed; mechanical	Low cost, within beneficiaries' budget	Mixed	By the beneficiaries
Transport of materials can pose difficulties	Low cost, within beneficiaries' budget	Manual	By the beneficiaries
Constant upkeep required; large workforce needed; precarious	Low cost, within beneficiaries' budget	Mixed	By the beneficiaries
Limited lifespan; large workforce needed; limited availability of organic materials	Low cost, within beneficiaries' budget	Manual	By the beneficiaries
Costly; can harbour water-related diseases	Costly, not within beneficiaries' budget	Mechanical/ Mixed	By the beneficiaries
Limited lifespan; frequent upkeep required	Within beneficiaries' budget	Mechanical	By the beneficiaries
Limited lifespan	Within beneficiaries' budget	Manual	By the beneficiaries
Transport of materials can be difficult	Within beneficiaries' budget	Mixed	By the beneficiaries
	Within beneficiaries' budget	Mechanical	By the beneficiaries
Large workforce needed; costly (for modern impluvium)	Variable	Mixed	By the beneficiaries

Source: FAO/RAF, Proceedings of the Western and Central African Workshop on Water Harvesting, October 1999, Niamey, Niger, unpublished

With regard to inadequacies raised in the policies and strategies of implementing water-harvesting techniques, given the importance of securing food resources, it is recommended:

- To set up relevant institutional mechanisms for the co-ordination, supervision and follow-up/evaluation of water-harvesting projects and programmes, so as to avoid the dispersion of decision-making centres and to support the sharing of experiences on local, national and sub-regional levels.
- To define clear policies and strategies that privilege land-management methods in which beneficiaries are responsible for the maintenance of new projects.
- To define and apply a clear and precise land policy before and during implementation of the projects;
- To instigate, on a regional level, an African water harvesting association

Environmental Impacts

From the results presented in Table 2, it can be seen that water-harvesting techniques, when used in conjunction with land-conservation techniques, can successfully restore vegetation in desert regions. The recovery of peripheral land is one of the principal advantages of these techniques in areas where the cultivable grounds are a limiting factor, as is the case on the Central Plateau of Burkina Faso.

Moreover, water harvesting supports rural forest by increasing the survival rate of native trees and bushes, and by replenishing aquifers. This positive effect on forests is often described by local people, but inadequate long-term research has studied the phenomenon. On the other hand, it is noted that water reserves, in particular microcatchments, are sometimes hydrous sources of diseases such as bilharzias (schistosomiasis).

2. Constraints to Adopting Water-Harvesting Techniques

The most common constraints we are confronted with when undertaking water-harvesting projects relate to maintaining the systems once they have been constructed and to the need to provide training. From our analyses, we found that the greater the maintenance needs, the less successfully the local community will adopt the technique. The techniques most successfully adopted are those that are simple, inexpensive and easily manageable by the local community: these include dry stone bunds, semi-circular bunds and the planting of vegetative strips. On the other hand, techniques such as constructing artificial lakes and diversion dams are not within reach for small rural communities, while small earthen bunds and mulching require significant human investment and are not sustainable.

3. Challenges

One of the major challenges with which humanity will be confronted during this new millennium is the long-term management of water resources in the face of pressing demands from an ever-increasing population for a limited resource. In arid and semi-arid countries, this situation is even more alarming when one takes into account climatic conditions that allow little hope of increased water supplies. In spite of the efforts of governments, national and international institutions and the people in these countries towards a prudent and sustainable exploitation of natural resource such as water and land, a lot remains to be done to control land degradation and desertification while promoting better management of water resources.

It has been proven that water-harvesting is likely:

- to increase agricultural output;
- to improve pasture;
- to help regenerate forest in degraded areas;
- to minimise the effects of erosion;
- to replenish groundwater.

Conclusions

Although each climatic and geographical region favours a certain number of water- and land-conservation techniques, the final choice must respond to the criteria of technical, socio-economic, political, institutional and environmental sustainability, as much in the planning and construction stages as in implementation. Low-cost techniques that are easily replicable by local communities prove to be the most promising for the sustainable, long-term management of water resources.

Table 2: Environmental Impact of Water-Harvesting Techniques

	Rank	Effect on Erosion	Water Conservation	Effect on Flora	Effect on Fauna	Rehabilitation	Durability of effects
Permeable stone dams	1	++	++	+	+	++	++
Furrows and embankments	2	+++	++	+	0	++	+
Contour stone bunds	2	+	++	+	+	++	++
Terraces	2	++	+++	++	0	-	+++
Shelterbelts	2	+	++	++	+	+	++
Zai or *Tasa*	3	+	++	+	+	++	+
Semi-circular bunds	3	+	++	+	+	++	+
Stone Barrage	3	+	++	+	+	+	++
Trenches	4	+	++	++	0	+	+
Microcatchments	4	+	++	++	+	-	++
Diversion dykes	5	0	++	++	+	-	++
Boulis/artificial lakes	6	-	++	++	+	-	++
Earthen dykes	7	+++	++	+	0	-	-
Mulching	7	+	++	+	+	+	- -
Subsoiling	8	+	+	+	0	+	- -

Source: FAO/RAF, Proceedings of the Western and Central African Workshop on Water Harvesting, October 1999, Niamey, Niger, unpublished

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3 Water Harvesting and Spreading in the Arid Zones of Sudan

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Introduction

Most of Sudan is arid or semi-arid, with groundwater either scarce or only available by drilling boreholes at very high cost. During the rainy season, runoff is limited to intermittent streams that run along broad depressions or *wadis*. While some of these streams reach the Nile, most simply vanish into the desert. The rural and nomadic populations in these areas are forced to migrate during the dry period in search of water and grazing land.

The Sudanese Government and the local population have explored and pursued possible means of using runoff water in arid and semi-arid regions to secure the availability of drinking water, food and fodder and to discourage this migratory trend. Water harvesting and spreading — using traditional and advanced techniques — is considered essential, as it enables the population to exploit the alluvial clay of the *wadis*, thereby relieving the pressure of animal and human presence on the fragile sandy soils. Besides controlling the state of desertification on sands, water harvesting and spreading secures food and fodder during years of drought and low rainfall.

1.Techniques Used

1.1 TRADITIONAL METHODS

Rainfall is harvested in the *wadi* bed by means of small earth embankments locally called *terus*, synonymous with terraces in English. Parallel bunds are built along contour lines and against the direction of the watercourse or runoff flow. Terraced *wadis* retain the water, allowing ample time for it to seep deep into the soil, with excess flowing into successive terraces below. Land behind the terraces then contains enough water to meet the requirements of plant crops.

Terraces of traditional *wadi* bunds, thirty to fifty centimetres high, are manually constructed with simple tools. They require constant upkeep, as the hydraulic pressure can cause breaching, or even washout.

1.2 MODERN TECHNIQUES

One way in which traditional terraced *wadis* have been modified is by enlarging upon the traditional design and constructing the bunds in a semi-circular pattern, incorporating spillways to spread the harvested water over the field.

A second technique, necessitating heavy earth-moving machinery, is to construct large bunds across the *wadi* to harvest part of the overland flow. Excess water is diverted along diversion ditches to irrigate adjacent plots. Wealthier farmers who can afford the high cost of construction employ this technique.

A third technique consists of constructing a dam, four to five metres high, across the seasonal stream, creating a large reservoir. A concrete-lined spillway is constructed on the *wadi* course to carry excess water away from the reservoir. The reservoir extends over a vast acreage, and usually fills up with a combination of rain and runoff, containing enormous quantities of silt. Water for irrigation is directed through twenty-five centimetre-diameter pipes from the reservoir into the main canal. Valves fitted to these pipes control the volume of water that enters the canal. With this system, not only can the area below the dam be cultivated, but also the land upstream: as water recedes, it exposes highly fertile soil containing residual moisture. This technique has advantages over the previous ones, namely:

- During the dry season, farmers continue to benefit from the rainy season. In case of a "low rainfall" rainy season or a particularly long dry spell, water can be supplemented from the reservoir.
- Winter and summer crops can both be grown using this technique.
- During the rainy season, the seasonal stream and the rains themselves will replenish the water that has been drawn from the reservoir for irrigation.
- The water requirements of crops downstream can be assured.

Similar techniques have been adapted for storing water for drinking purposes. These include:

Hafirs

Hafirs are man-made reservoirs dug into watershed flow areas. Water is collected by gravitational flow or by pumping. *Hafirs* can be made in clay or silt soils, with the depth of the pit not exceeding ten metres. Ridges made of removed soil bound the pit, and construction usually incorporates a system to filter out silt and debris before the runoff enters the pit. A barbed-wire fence surrounds the reservoir, to keep animals away. In sandy areas, the inner side of the *hafir* is lined with an impermeable layer of polythene to hinder infiltration. Unfortunately, however, termites sometimes damage this material.

A canal links the *hafir* to a nearby shallow well where people can draw their water.

Infiltration Dams

Infiltration dams are designed to slow down water runoff to allow the water enough time to infiltrate the soil, replenish the aquifer and increase well production.

2. Advantages and Disadvantages

2.1 ADVANTAGES

The essential advantages of water spreading and harvesting are the following:

- The methods are simple.
- Most of these techniques are inexpensive. This is especially true of earthen bunds.
- The techniques control soil erosion.
- By making use of the fertile alluvial clay of the *wadis*, agricultural pressure on fragile sandy soils is reduced.
- Through water spreading and harvesting it is possible to make green fodder available throughout the year.

2.2 DISADVANTAGES

There are few disadvantages to these systems, and they are overweighed by the above advantages. The disadvantages include:

- Success is dependant on sufficiently heavy rains that allow enough runoff
- The depth of soil moisture is uneven, due to relief differences.
- Poor drainage conditions have a negative impact on the physical properties of the soil.
- It is difficult to control flooding when breaching occurs. This calls for active monitoring during flood periods.
- There is a lack of reliable data on the annual occurrence and volume of runoff in most *wadis.*
- Progressive silt deposition reduces a dam's capacity.

4 Harvesting Rainwater to Rehabilitate Deserts: A Case Study of Cholistan in Pakistan

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Introduction

More than 6.1 billion hectares of land, or one-third of the earth's surface, are drylands, out of which nearly one billion hectares are hyper-arid lands and deserts. These lands are inhabited and are home to one quarter of the world's population. Of the 179.6 million hectares that make up the total geographical area of Pakistan, more than 90 percent is dry, with about 70 million hectares considered as arid or semi-arid regions. Approximately 11 million hectares of these lands are desert. The major freshwater resources of Pakistan are surface waters, in the form of rivers and tributaries, and groundwater in the Indus Basin. The country's surface-water resources total 173 billion cubic metres, of which 76.0 billion cubic metres is lost by evaporation and seepage.

At present, 53.06 billion cubic metres of groundwater in the Indus Basin is extracted annually. In addition, annual rainwater in the basin amounts to 49.30 billion cubic metres. The utilization of these freshwater resources by Indus River Irrigation, the world's biggest contiguous irrigation system, has enabled cultivation of an additional 16.2 million hectares, bringing Pakistan's total cultivated area to 21.4 million hectares.

The growing population in Pakistan requires a corresponding increase in irrigated acreage as well as desert rehabilitation. However, the main constraint in the development of these deserts is the availability of fresh water. Thar, Cholistan, Thal and Chaghi-Kharan are potential lands for future development. Conventional water resources are almost exhausted and non-conventional resources like rainwater, reuse of fresh drainage effluent, desalinization and the reuse of municipal water are still potential areas for development in the water sector in Pakistan.

The most economical of these is the use of rainwater. Fresh groundwater is available only in Thal, as other deserts are underlain by saline water. The Pakistan Council of Research in Water Resources established the Desert Field Research Station in Cholistan to examine the potential for desert reclamation through the conjunctive use of rainwater and saline groundwater. Rainwater harvesting played a vital role in the research station's rehabilitation of dry sand dunes, converting an area of more than eighty hectares into grassland. Their initial experiments revealed that employing a well-designed water-harvesting system to collect and distribute rainwater could play a vital role in curbing desertification in the Cholistan Desert.

Our PhD programme in Fortran 90 has developed a model of the optimum design for such a rainwater-harvesting system. The model simulates the collection and conservation in reservoirs of the quality and quantity of water required for supplementary irrigation throughout the year. It is a simulation model that integrates water-harvesting techniques (within a compartmented reservoir system) with operational and engineering techniques to reduce evaporation and seepage losses, which are the main constraints on the system. The model incorporates all topographic, climatic, hydrologic, engineering and economic factors of the system. It calculates the catchment area needed, the total yield from this catchment (in the form of a storm hydrograph), evaporation and seepage, a benefit-cost ratio, the rate of returns and net benefit on ten-day, annual and project lifetime bases. At least three hundred computer runs were taken to optimize the design of the water-harvesting system in the Cholistan Desert. The model and its results will be presented in the Seminar.

1. Pakistan

1.1 BACKGROUND

Pakistan came into being on the 14th of August 1947 as a result of the partition of British India into two sovereign Hindu and Muslim states. Situated between latitudes 23° 30' and 36° 45' north and between longitudes 61° and 75° 31' east, Pakistan stretches over 1,600 km from north to south and is about 885 km wide east to

west; covering a total area of 796,095 km². It comprises four provinces — Balochistan, the North-Western Frontier Province, Punjab and Sindh — as well as the Federally Administrated Tribal Areas and the Federal Capital Area. Of these, Balochistan is the largest with an area of 347,190 km², followed by the Punjab at 205,344 km², Sindh at 140,914 km², and the North-Western Frontier Province at 74,521 km². The Federally Administrated Tribal Areas (FATA) encompass 27,220 km², and the Federal Capital Area (Islamabad) 906 km².

Pakistan comprises six major physical divisions or regions: (1) the northern mountains; (2) the western offshoots of the Himalayas; (3) Balochistan plateau; (4) Potwar plateau and the Salt range; (5) the upper and lower Indus plains; and (6) the Thar Desert.

The estimated population of Pakistan on 1 January 1991 was 113.78 million, with an annual growth rate of 3.1 percent. The crude annual birth rate is high, at 40.5 per 1,000 inhabitants, and the annual death rate stands at 10 per 1,000 inhabitants.

The majority of the population are Muslim. A small minority of Hindus, mostly big landowners, have settled in the border districts of the Sind. Christians form about three percent of the total population. With the exception of the Head of State and the Prime Minister, every post is open to all minorities

1.2 CLIMATE AND LAND RESOURCES

Located in the north of the Tropic of Cancer, Pakistan possesses a great range of climatic diversity, from some of the hottest regions in the world (the Jacobabad and Sibi districts) to the snowy cold regions of Balochistan and the northern mountain areas. Along the coastal belt, the climate is modified by sea breezes. Although Pakistan is on the fringe of the monsoon climate, its rainfall is barely sufficient and its climate is essentially dry. Due to the diversity of the climate though, a large variety of crops are cultivated, balancing the agricultural economy of the country.

In the plains, the minimum temperature in January varies from 4°C to 15°C and in June/July from 30°C to 39°C. The maximum temperature in January varies from 17°C to 24°C and in June/July from 37°C to 45°C. Jacobabad has recorded an absolute maximum of 52°C. The minimum temperatures in the northern mountains and in parts of Balochistan are well below freezing point.

The total area of Pakistan is 79.6 million hectares, of which 70 million hectares is considered arid and semi arid. About 41 million hectares are entirely arid, including 11 million hectares of desert. The total irrigated area of the country is about 16 million hectares. The majority of the population derives its livelihood from these arid and semi-arid regions, and these are the areas now becoming depleted because of the over-exploitation of soils, plants and water resources. Pakistan's major deserts are the Thar Desert (4.3 million hectares), Cholistan Desert (2.6 million hectares), Thal Desert (2.3 million hectares) and the Chaghi-Kharan Desert. D.I.Khan Desert and other smaller deserts make up an additional one million hectares. The groundwater in these deserts is essentially saline, with few patches of fresh water, apart from the Thal Desert, where fresh water is available in appreciable quantities.

1.3 FRESHWATER RESOURCES

Hydrologically, Pakistan is divided into two regions: the Indus Basin and the dry area of Balochistan. The Indus Basin is part of the catchment area of the Indus River System, which has several tributary rivers — the major ones joining the Indus plain on its east side are the Jhelum, Chenab, Ravi and Sutlej. Part of the catchment area of the Indus and its tributaries falls in adjoining countries: India, China and Afghanistan. The catchment area of the Indus contains seven of the world's highest peaks and seven of the largest glaciers. Pakistan's two other main drainage basins, the Kharan Closed Basin and the Makran Coastal Basin, are together only a third the size of the Indus basin.

The main freshwater resources of Pakistan are those of the Indus Basin. The inflow at the Indus river system rim station is 172.7 billion cubic metres per year, and direct precipitation and groundwater provide an additional 49.3 billion cubic metres and 53 billion cubic metres respectively. Of this, 12 billion cubic metres is required to carry salt to the sea. After accounting for system maintenance and evaporation and seepage loss, net available water resources total 197 billion cubic metres. Freshwater resources outside the Indus Basin rarely exceed five billion cubic metres.

It is apparent that Pakistan is a country with water resource constraints, rather than one limited by insufficient land. In the past, Pakistan had sufficient water resources, but its easily exploitable conventional water resources are now almost exhausted, and Pakistan has become a water deficient country. The continual increase in Pakistan's water demands will require 231 billion cubic metres in 2010 — far more than the 192 billion cubic metres per year that will be available if the prevailing agricultural yield is maintained. But the gap between water demand and actual resources can be reduced by effective management of existing conventional water resources and proper exploitation of non-conventional water resources: through rainwater harvesting, reverse osmosis and use of drainage effluent and saline groundwater. Rainwater is evidently the cheapest of all these resources.

1.4 RAINWATER HARVESTING IN PAKISTAN

Rainwater harvesting is practised in almost all parts of Pakistan. A variety of techniques, depending on water

use, topography and regional climate, have been in practice for centuries. In the hilly areas of the Balochistan, rainwater harvesting is practised at three levels: micro, medium and macro — or *Manada*, *Kushlaba* and *Banadat Saliba* respectively. In the Punjab uplands, the *wadi* type of water harvesting is practised, which is locally called *Rud-Kahoi,* or hill torrents. Desert dwellers collect rainwater from inter-dune clay patches that are stored in small manmade ponds called *tobas* or *kunds*.

2. The Cholistan Desert

Cholistan is a sandy desert in the Punjab province covering about 2.6 million hectares of land. The area has a hyper-arid climate, and rainfall is low, variable and erratic. Mean annual rainfall varies from one hundred millimetres in the north to two hundred millimetres in the south. These figures are slightly higher along the India–Pakistan border, where annual rainfall can reach 250 millimetres. Most of the rainfall occurs during the monsoon period. The mean annual temperature in the Cholistan is 27.7^{0}C: the average summer temperature is 35.5^{0}C, while the average winter temperature is 18^{0}C. The average maximum monthly temperature climbs to 46^{0}C with average minimums of up to 7^{0}C. Maximum temperatures experienced in the Cholistan have reached 52^{0}C, with a lowest recorded temperature of -2^{0}C. The soils of the area are formed from alluvium and aeolian materials.

The Cholistan desert is divided into two parts: Greater and Lesser Cholistan. Lesser Cholistan comprises softly undulating sand dunes alternating with low sandy ridges, while Greater Cholistan, the southern part of the desert, consists mostly of rolling to steep sand dunes, ridges and depressions. The sand dunes of smaller Cholistan has rolling to undulating topography whereas about 44 percent of Greater Cholistan's dunes present a steep topography. The height of the dunes varies from 30 to 125 metres. Non-saline sandy soils make about 27 percent of the topsoil and non-saline loamy soils about 12 percent, whereas saline sandy soils represent about 17 percent of the total land of the Cholistan desert.

The total population of Cholistan is about 110,000 thousand people, increasing at an annual rate of about 3 percent. The Cholistan is underlain by saline water and has no perennial streams or rivers: rainwater is the only source of drinking water for humans and livestock.

The desert dwellers are pasture grazers with nomadic lifestyles. They collect rainwater in natural depressions (*dahrs)* between the dunes, where soils are composed of dense clay with very low infiltration rates. These soils serve as good natural catchments in which to harvest water on a small scale. The nomads collect runoff from these catchments and store them in man-made ponds. However, due to the poor design and high evaporation loss of these ponds, storage lasts only two to four months. When water in these ponds becomes exhausted, the desert dwellers move to nearby irrigated areas in search of water. This cycle of nomads migrating from the desert to irrigated areas and back again disturbs the socio-economic stability of the desert.

3. Water Harvesting and Rehabilitation of the Cholistan Desert

The Pakistan Research Council was entrusted to perform desertification monitoring and mapping in 1982. Mapping of the Cholistan was completed in 1986. Mechanical and biological techniques to control desertification began to be introduced in the area in 1988.

The main problem in the early stages was the lack of any water to use as irrigation in establishing vegetation cover on the sand dunes. Rainwater was the only source available at the site, and the first efforts to harvest this resource began in 1989. A water-harvesting storage pond with a capacity of eighty thousand cubic feet was constructed in a small catchment area of about ninety hectares, not far from the village of Dingarh. The collected rainwater could last for eight months, and was utilized to supply nurseries growing drought-resistant and salt-tolerant trees like *Acacia arabica*, *Tamarix*, *Acacia prosopis*, *Zizyphus*, *Parkinsonia*, *Ampliceps* and *Australian prosopis*. During the first year of the experiment, five acres of these trees were cultivated. Two water-harvesting ponds were constructed in the same catchment area in the following two years, and the plantations were extended to twenty acres — with the addition of grasses, bushes and some economically valuable plants like Jojoba.

The encouraging results of water harvesting to rehabilitate Cholistan's drylands and to improve drinking-water supplies for the local population of Dingarh village and its livestock motivated the council to design a water-harvesting system based on scientific data for the optimal use of water resources. A computer simulation model was developed, which was later used to construct a three-compartment reservoir with a storage capacity of 0.66 million cubic. The water collected was used in conjunction with saline groundwater to convert sixty hectares of sand dunes into green land over the last ten years. The following paragraphs give a brief description of the theoretical background of the water-harvesting system and the computer model that was developed.

3.1 WATER HARVESTING SYSTEMS

Water harvesting is defined as the process of collecting natural precipitation from prepared catchments for beneficial use.

Although the term rainwater harvesting is used in different ways, the common characteristics of rainwater-harvesting techniques are:

- They are practiced in arid and semi-arid regions where surface runoff is often intermittent;
- They are based on the utilization of runoff, requiring both a runoff producing area and a runoff receiving area.

Due to the intermittent nature of runoff, storage is an integral part of any water-harvesting system. Harvested water may be stored directly in the soil profile or in small reservoirs, tanks or ponds. Water harvesting systems (WHS) are classified according to the type of storage used and the water use.

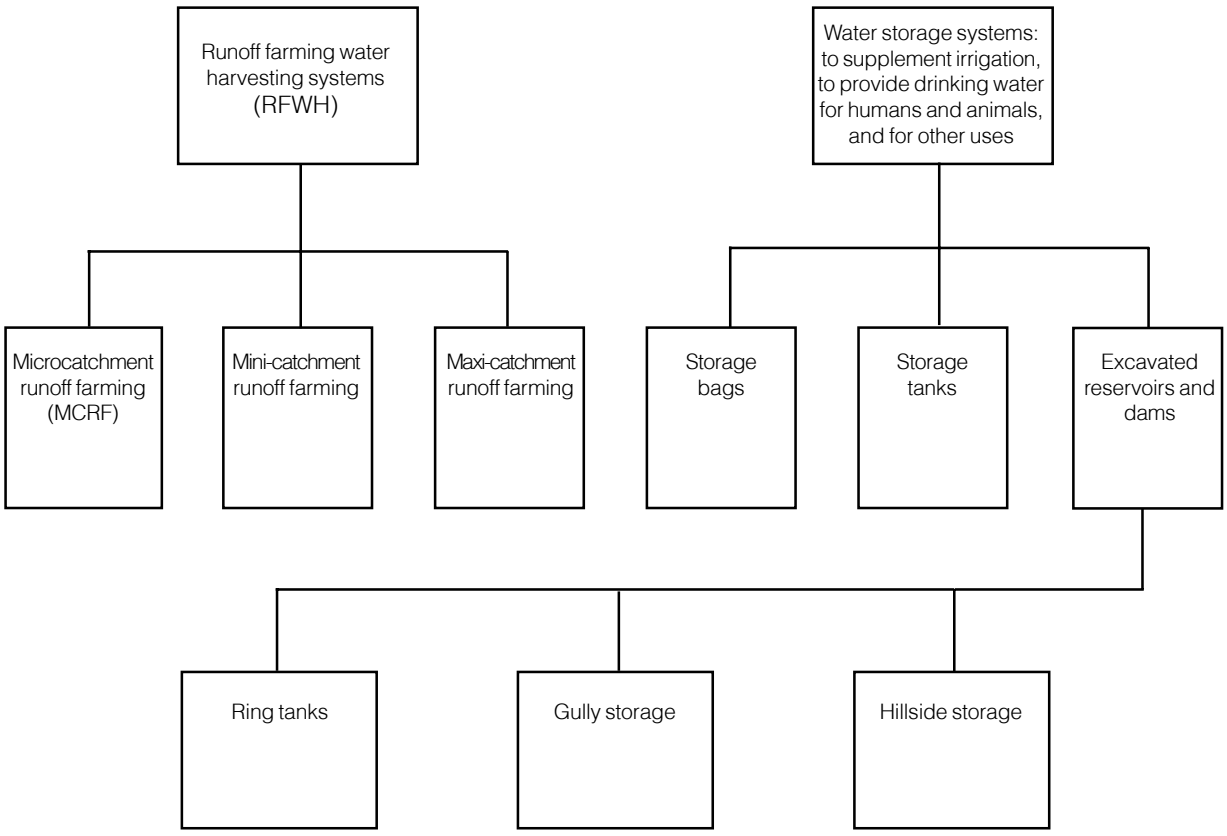
The Compartmented Reservoir Technique: Water Storage in Flat Areas

C. Brunt, an associate hydrologist at the Water Resources Research Center at the University of Arizona has presented an efficient technique for water storage in flat areas. The reservoir consists of a receiving compartment (A), located below the stream level, and therefore shallow. Compartments B and C have a smaller surface area but are deeper. The reservoir operates as follows: as runoff occurs throughout the rainy season, water is pumped from A to fill compartments B and C. Drinking water is then drawn from compartment A until the water lost by evaporation and seepage in B and C is equal to the remaining water in compartment A. At this stage, a pump is used to remove the remaining water in A to fully refill compartments B and C. This eliminates seepage and evaporation losses in compartment A. Water is then drawn from compartment B for consumption and drinking purposes until the water in compartment B is equal to that lost by evaporation and seepage in compartment C. At this stage, the pump is used again to remove the remaining water from B to refill C. This eliminates evaporation losses from compartment B. Compartment C is then filled and compartment B becomes empty. Water is then drawn from C.

The compartmented reservoir concept can be applied to existing or new reservoirs. As the pump is used to fill compartments on flat terrain, all compartments other than the receiving one can be enlarged by extending the embankment above the stream level.

Recent developments have made the pumps used in this water-storage model more economical. The use of high-volume pumps driven by tractors and trucks has also made the technique more viable.

Figure 1: Types of water-harvesting systems



5 Salt Intrusion in Coastal Areas of Saloum and the Casamance in Senegal

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Introduction

Situated at the extreme west of the African continent, between approximately 12° and 16.5° north latitude and between longitude 12° and 17° west, Senegal essentially stretches along a vast sedimentary basin, bordered by the Atlantic Ocean for almost 600 kilometres along its coast.

The drop in rainfall since 1968 is linked to climatic deterioration and the over-exploitation of water reserves, which have upset the freshwater/seawater balance along Senegal's coast. In uncultivated regions of Casamance and Sine Saloum provinces, this has resulted in the advancement of the seawater front towards watercourses and aquifers, with serious repercussions on water and land resources. The rise in salinity has led to a loss of both forest and agricultural lands, and the diminished quality of fresh water has reduced potable water resources significantly. The retraction of the saltwater plains is accompanied by an expansion of *tannes* — halophytic or brackish swamps. When one considers the economic value of the area in terms of human habitation, agriculture, fisheries and forestry, one begins to appreciate the importance of this problem.

This document provides an overview of the problems arising from salt intrusion into freshwater resources and introduces the actions Senegal has taken to combat this problem in order to protect or recuperate agricultural or forest lands.

1. Salt Intrusion

1.1 PHYSICAL CONTEXT

Soils and Vegetation

The study area is in the Ziguinchor region, to the southwest of Senegal. The lower and mid Casamance valley, which extends to the west of Kolda, is an area of regularly submerged tidal flats covered with mangrove swamps. As the older flats are salty and bare in certain areas and contain *tannes*, the topsoil would need to be removed if the area were to be used for rice cultivation.

In the high valleys, the soils are hydro-morphic and chemically of high quality. The land here is a patchwork of areas of rain-fed agriculture and light forest, while the forest becomes denser in the mangrove regions. (See Figures 1 and 2 following page.)

Rainfall

Rainfall in this area is characterized by alternating dry (November to April) and rainy (May to October) seasons — linked to the movement of the inter-tropical front — with the St. Helen anticyclone and its resulting monsoon bringing heavy rain. With climatic deterioration observed since 1968, rainfall levels have declined slightly. Annual rainfall has dropped from 1,500 millimetres (1951–1970) to 1,200 millimetres (1970–1990). Over the past three years, there has been a significant rise in rainfall levels. Figures 1 and 2 illustrate the changes in rainfall patterns in Ziguinchor.

The Hydrographic Network

The Casamance Basin is characterized by a very dense hydrographic tuft. Uphill from Kolda it is continental, with the watercourse bed no more than fifty metres wide. The bed widens progressively, reaching four kilometres in width below Sédhiou and eight kilometres towards the river mouth. The merging of several small watercourses that drain the high basin plateaux forms the hydrographic network: the Thiangol Dianguina, Khorine, Niampampo and Dioulacolon rivers. Further down, numerous tributaries from the Soungrougrou and the *bolongs* (small creeks) of the lower valley meet the Casamance: these include Kamobeul and Diouloulou *bolongs* and the backwaters of Baïla, Bignona, Guidel and Tanaff. The Casamance Basin also includes numerous mangrove forests, *tannes* and shallows, the coastal morphology of which changes towards the high basin.

Figure 1:Annual rainfall in Ziguinchor (millimetres)

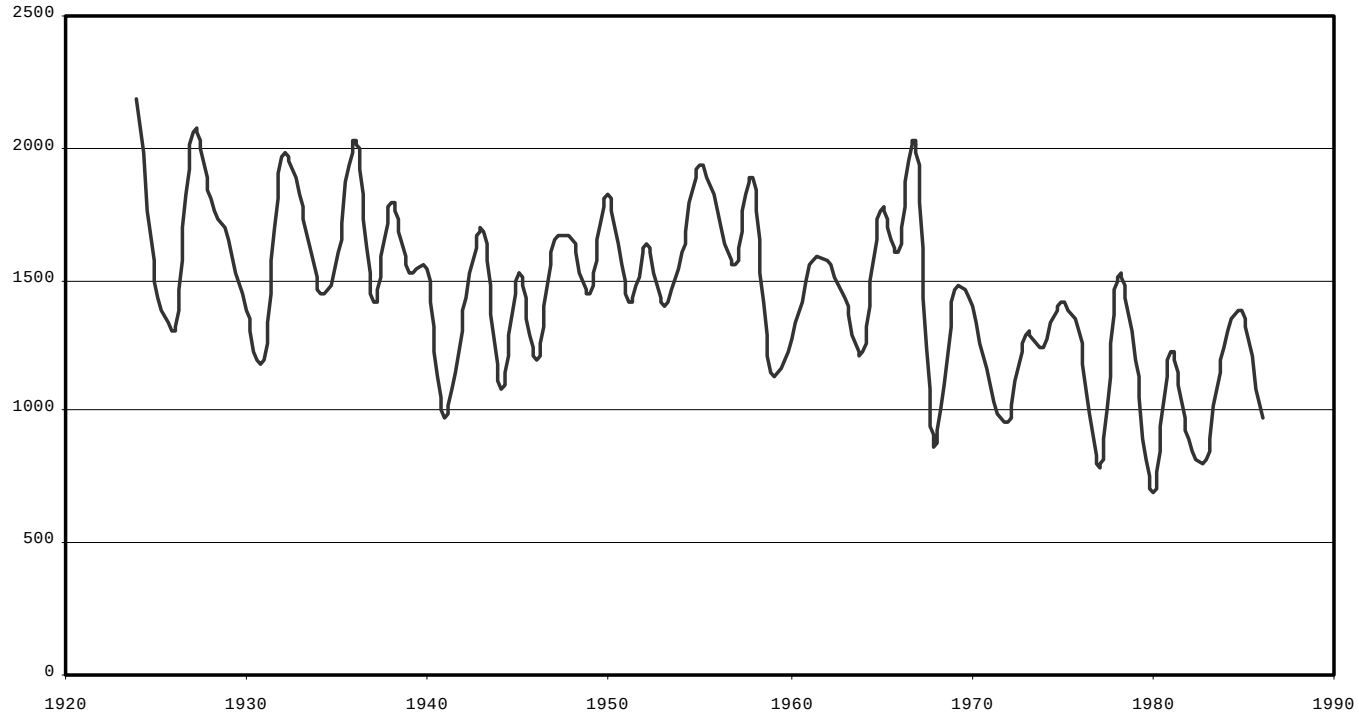
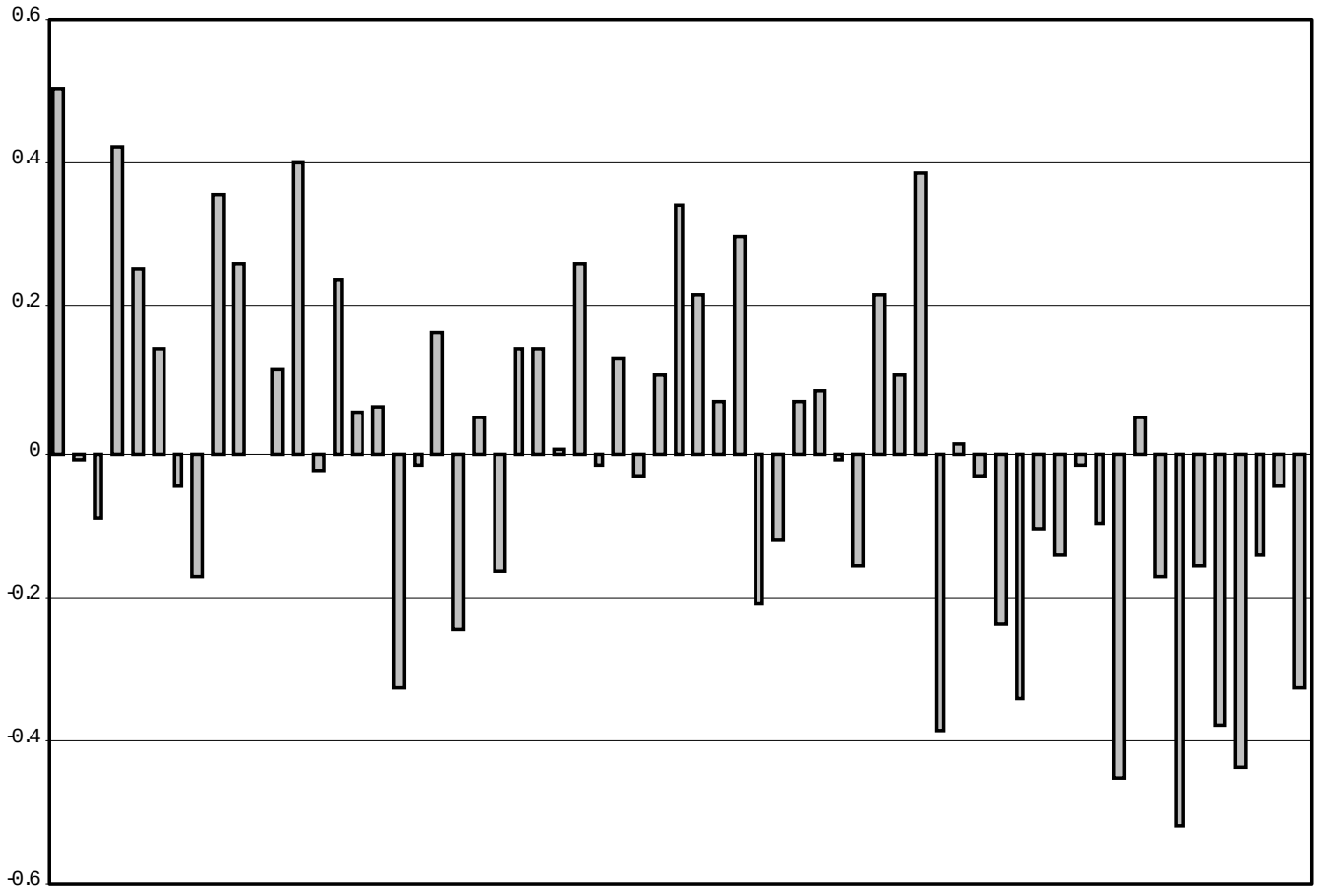


Figure 2: Annual rainfall in Ziguinchor, deviations from mean



1.2 SALT INTRUSION AND LAND SALINIZATION

The Casamance Basin stretches over sandy-clay sedimentary formations that follow a plateau relief shaped by the hydrographic network.

The watercourses are characterised by very gentle gradients, which impedes their flow despite the high rainfall. Kolda carries up to 36 million cubic metres of water per year, which is less than one percent of the area's rainfall. The minimal incline of these watercourses facilitate the intrusion of salt-laden water into the country's interior. Seawater is present in the majority of watercourses of low and mid Casamance. Seasonal tidal waves travel upstream along the river and its tributaries, often reaching Djibidjone on the backwaters of Baïla, 154 kilometres from the coast. These waves can reach a distance of up to 200 kilometres inland, far beyond Diaroumé.

One of the consequences of coastal water intrusion is increasing water and land salinity. During the wet season, the heavy rains act to wash the salt back out towards the ocean. Before 1972, the maximum salinity measured for inland waters was 50g/l (seawater salinity is 36g/l). However, in the past thirty years maximum salinity measurements have reached 100g/l. In Djibidjone, a concentration of 154g/l was measured 158 km from the mouth of the river. Salinity tends to increase due to Senegal's extremely high evaporation rate (reaching up to two metres per year) and the weak flow of its rivers, which is insufficient to wash salt that accumulates upstream out towards the ocean.

This phenomenon has been accentuated by the climatic evolution of the last few decades. A strong increase in salinity has been observed in dry years (such as 1983 and 1984). Before the drought years of 1968, water salinity lessened the further one moved upstream from the mouth of the river. But during the wet seasons, direct rainfall, replenished groundwater sources and water runoff drove back intruded salt water from watercourses in coastal areas.

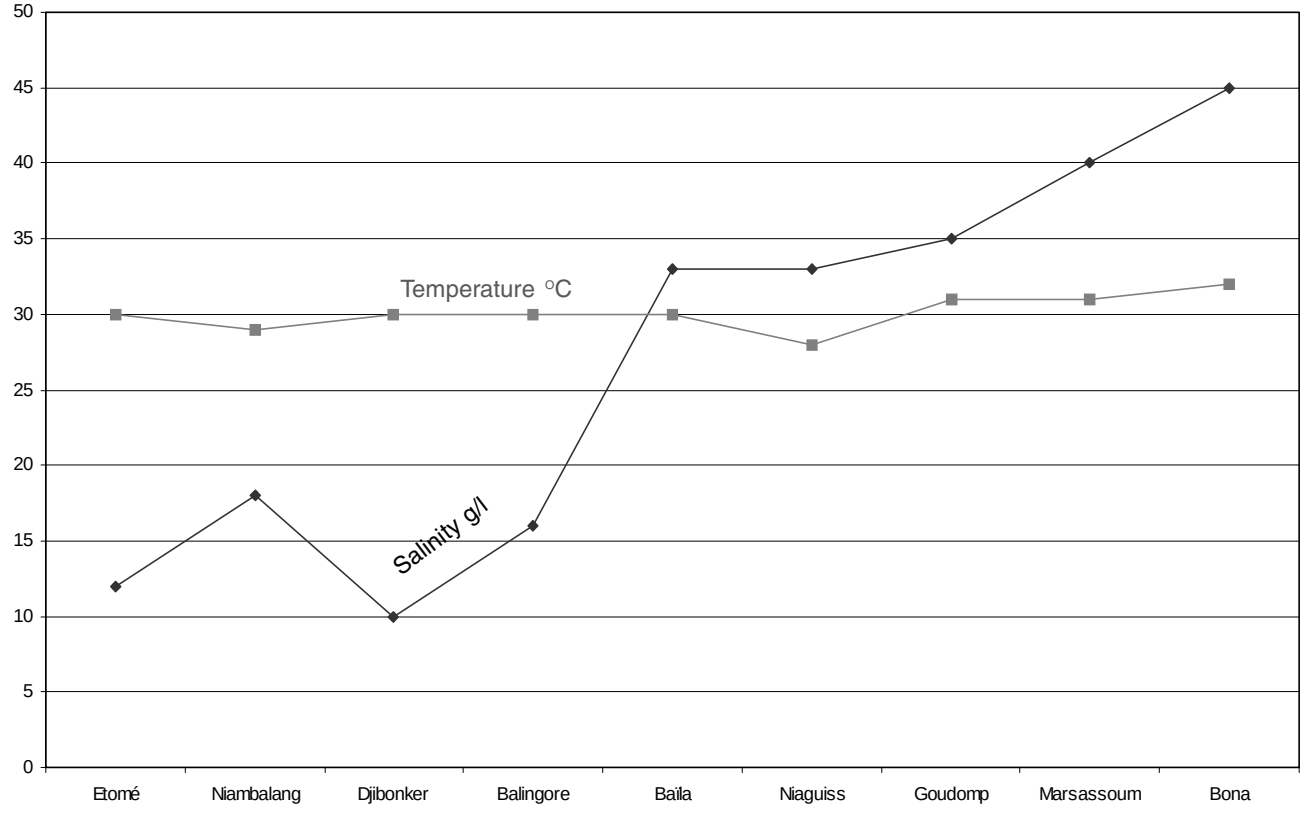
Along the Casamance, groundwater resources have considerably diminished as a result of low piezometric levels. The salinity gradient has been reversed: salinity now increases as you move upstream from the mouth of the river, and at a high rate. However, over the last few years, rainfall levels have risen, and this trend seems to be progressively changing.

2. The Consequences of Salt Intrusion

2.1 LOSS OF FOREST

The diminution of watercourses and the rise in salinity levels have led to a decline in mangrove forests. From 931 square kilometres of mangrove forests in 1973, only 887 square kilometres still remain. The drop is estimated at 25 percent, if forest density is taken into account. The density of Gambia's mangrove forests is estimated at 150 cubic metres per hectare.

Figure 3:Progression of salinity in the coastal areas of the Casamance



Other forests in mid-Casamance have also been affected by the rise in salinity, with many hectares of forest lost.

Mangroves contribute significantly to the national economy: they provide a habitat for oysters and their wood is used for fuel and construction.

2.2 INCREASE IN HALOPHYTIC SWAMPS — *TANNES*

Reduced rainfall has the following effects:

- It reduces available freshwater.
- It causes watercourses to become reduced in size, because of climatic deterioration. Watercourses were reduced by an estimated 60.2 km^2 from 1973 to 1979.
- It causes sea water to intrude upstream.

The absence of effective leaching, coupled with a rise in salt levels, has accelerated the increase in soil salinity and acidification, which has reached levels now that cannot support vegetation. This has led to a rise in the size and number of *tannes*, which between 1973 and 1979 increased from 73 km^2 to 126.75 km^2, and stands at 200 km^2 today.

Tannes are prominent along the backwater banks of Baïla, Diouloulou and Kamobeul Bolon. While they can support certain grasses when their salinity levels are not excessively high, they are bare when salinity levels are too great.

3. MEETING THE CHALLENGE

Casamance's rural community is made up of almost one million inhabitants, nearly 70 percent of its total population. Agriculture is the most dominant economic activity. This explains the importance of land and water resource management. It is with this in mind that the government of Senegal has initiated numerous projects aiming to consolidate new actions with those already undertaken: by constructing anti-salt protection mechanisms, improving farming techniques, securing water availability during winter months and increasing available agricultural land by recuperating land affected by soil salinity.

The principal actions taken to combat salinity in the area are based on:

- The construction of anti-salt dams.
- The construction of saltwater prevention dykes against intrusive tides.
- The construction of smaller dykes and drains.

Areas protected by anti-salt dams are washed by run-off, which is controlled by small regulation mechanisms. The anti-salt dams currently operational are:

- The dam at Guidel, which protects 800 hectares of land.
- The dam on the Bignona backwater near the village of Affiniam, which protects 5,000 hectares of land.
- Approximately fifty small anti-salt dams constructed with the participation of local communities which protect areas of land ranging from 100 to 200 hectares in the tributary valleys of the Casamance and Soungrougrou rivers.

Within the framework of improving farming techniques, studies undertaken by ORSTOM (now known as the *Institut de Recherche pour le Developpement*, IRD) and the *Institut Sénégalais de Recherche Agronomique* (ISRA, the Senegalese Institute of Agronomic Research) demonstrate that topsoil de-salination can be effective when traditional farming is combined with a drainage system that removes the dissolved salts.

During Casamance's rainy season, natural desalination occurs at low tide once a volume of 2,500 cubic metres of rainwater falls per hectare. Rice can thus be productively sown in the first two weeks of August. A freshwater reservoir is maintained and replenished by the feeder basin.

Table 1: Progression of soil use in Casamance from 1973 to 1979

Classes	Surface area (km^2) 1973	Surface area (km^2) 1979	Difference
Sand belts	115.75	139.5	+ 23.75
Dense vegetation	949	788.5	- 160.5
Mangrove	931.5	907.5	- 24
Clear sown vegetation	1093	1260.5	+ 167.5
Tannes	73	126.75	+ 53.75
Water	682.5	622	- 60.2

Table 2: DERBAC Activities in the Mampalago Valley in 1992. (Source: *Country Action Plan 1992)*

Valley	Surface area of lowlands	Problematic	Necessary action	Work carried out
Mampalago	1,370 km²	Salt intrusion of over 12 km from the coast	An anti-salination programme to be instigated.	Construction of anti-salinity dams.
		Insufficient differences in levels between the principal canal and other branches. Instantaneous runoff	Water conditions for rice cultivation to be improved	Construction of a series of of regulation dykes in order to improve water supply for rice cultivation
		Rice cultivation was diminishing.	Rice cultivation to be re-instigated and rice-cultivation methods restructured.	A return to aquatic rice cultivation has been encouraged, by guaranteeing water, appropriate techniques and access to adequate equipment
		Deforestation/soil erosion of plateaux and slopes Sand encroachment	Soil conservation and anti-erosion measures to be instigated	Agro-forestry techniques instigated to protect land invaded by sand Simple soil-conservation techniques, both individual and collective, introduced and developed

The following actions have been or are being undertaken through the many projects initiated by the Senegalese government:

- Development of the dam near the village of Affiniam
- The Integrated Development of the Casamance Project (PIDAC)
- The Lower Casamance Rural Development Project (DERBAC) — a follow-up to the PIDAC
- The Southern Water Management Project (PROGES)
- The Sedhiou Rice Cultivation Project (PRS)
- Integrated rural development project of the Mid Casamance (PRIMOCA) that replaced the PRS
- Guidel project
- Anti-salt campaign programme (PRODULAS)

The above table (Table 2) presents the problems of soil salinity, salt intrusion and sand encroachment and deforestation and erosion faced in the Mampalago Valley, affecting rice cultivation in the area, and the work that was subsequently carried out by DERBAC to respond to these problems in 1992.

Conclusion and Recommendations

The increasing salt intrusion presented in this report constitutes one of the major threats to agricultural and forest lands or, quite simply, to all lands, in low-lying coastal regions of southern Senegal. It is a phenomenon that has natural causes such as drought and rising sea levels. However, anthropogenic factors are often at the origin of the phenomenon or can aggravate the situation. A lack of foresight in planning hydro-agricultural land use has led to the following aggravating factors:

- Poorly positioned water works
- Poorly designed hydrological installations (especially an absence of drainage)
- Excess irrigation leading to a rise in salinity of saline groundwater
- Freshwater retained upstream causing hyper-salinity downstream
- Excessive water pumped from coastal dams
- Deforestation

Considering the threat this phenomenon poses, the actions taken so far to confront the problem have been surprisingly limited. The decline in rainfall and the

rising sea levels of the past few years will have the effect of increasing the advance of the salt front. Anti-salt dykes and dams would better protect forests and agricultural lands.

Methods that are already being used to predict, mitigate the impacts of or halt this salt intrusion should be augmented, taking into account the economic importance of the areas concerned in areas such as agriculture, wood production for fuel and construction, fishing and oyster production.

The study and monitoring of hydrological functioning and environmental indicators both of small feeder basins and the principal watercourse in Casamance should be improved, notably by involving local communities in decision-making and planning. To this effect, all limnimetric measuring stations in the Casamance should regularly monitor salinity and acidity levels.

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6 Water Resource Management in Côte d'Ivoire

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Introduction

The Republic of Côte d'Ivoire, with a surface area of 322,462 square kilometres, is located in Western Africa between 4° 30' and 10° 30' north latitude and between longitude 2° and 9° west. Mali and Burkino Faso border the country to the north, with Liberia and Guinea-Conakry to the west and Ghana to the east. To the south, the Côte d'Ivoire extends along approximately 500 kilometres of the Atlantic coast (Gulf of Guinea). The population is estimated at fifteen million people.

There are three distinct types of landscape in Côte d'Ivoire. From the north to the south they are:

- The tree savannah and/or shrub of the northern Sudanese type;
- The clear forest at the centre of the country, in a V-shape north of the city of Dimbokro;
- The dense Guinea forest of the south.

The hydraulic network of Côte d'Ivoire comprises four major watercourses, certain characteristics of which are presented in Table 1 below:

All these watercourses flow from the north to south, and into the Atlantic Ocean.

Water Resources in Côte d'Ivoire

1.1 GROUNDWATER RESOURCES

The availability of groundwater varies greatly from one region to another.

Hydraulic Reserves

The sedimentary coastal basin contains approximately seven billion (7^9) cubic metres of water in underground tertiary sediments. The crystalline platform contains approximately seventy-eight billion (78^9) cubic metres of water.

Renewable resources

Renewable resources in the Tertiary sediments are estimated at approximately 2.1 billion (2.1^9) cubic metres per year, while the Quaternary sediments have around 640 million cubic metres per year.

1.2 SURFACE-WATER RESOURCES

Atmospheric conditions in Côte d'Ivoire are characterized by their variability, in terms of both when and

Table 1: Cote d'Ivoire's Principal Watercourses

Watercourse	Surface area (km^2)	Length (km)	Average annual discharge ($m^3\ s^{-1}$)
Bandama	97,000	1,050	365
Comoé	78,000	1,160	105
Sassandra	75,000	840	575
Cavally	28,800	700	427

where it rains. In fact, in an average year, rainfall varies between 2400 millimetres in the extreme southwest and 950 millimetres in the northeast.

Rainfall supplies an estimated 459 billion cubic metres of water per year, of which an average 39 billion cubic metres flows out of the country.

Considering the quantity of rainfall, one would think that Côte d'Ivoire is a well-watered, well-drained country. This may appear the case, but in the past few years the country has suffered from the onslaught of an unstable climate accentuated by rampant desertification that is still badly managed, consequences of the combined effects of traditional farming methods and recurrent bush fires — especially in the centre and the north of the country.

Because of this, the northern half of the country frequently experiences serious water-shortages during the long months (December to August) of the dry season.

Hydroelectric dams (six) and hydro-agriculture (more than five hundred) have been set up in various parts of the country. The vast hydraulic programme launched in 1973 has not, to date, accomplished what it set out to achieve, although appreciable results have been observed in the field of domestic water supplies.

2. National Policy of Water Resource Management in Côte d'Ivoire

As many as a dozen Ministerial Departments in the Côte d'Ivoire are involved in the day-to-day management of the country's water resources. Among these are:

- The Ministry of Infrastructures
- The Ministry of Agriculture and Animal Resources
- The Ministry of Defence
- The Ministry of Development and the Environment
- The Ministry of Health and Social Protection

All these institutions function in a sector-based way, with no systematic co-ordination between them.

Faced with this multitude of contributors amid growing water needs, it became apparent that a more concrete policy of water resources management was necessary.

Law No. 98-755 on 23 December 1998 defined the principle of integrated water resources management using catchment basins. This Water Code provides a general definition of the institutions that are to be responsible for managing water resources.

2.1 THE WATER CODE

Objectives

The Water Code aims to establish an integrated management not only of water resources but also of hydraulic works and planning.

It aims to ensure, among other things:

- The implementation of an institutional framework characterized by a redefinition of the roles of the different institutions
- The coherent planning of water resources use at the catchment basin level as well as the national level
- Protection of water resources from all forms of pollution
- That water is valued as an economic resource and is distributed so as to satisfy the demands of its different functions
- The preservation of aquatic and humid ecosystems

Institutional Framework

The Côte d'Ivoire's national water resources management policy was defined by a declaration taken in the Ministerial Council, which also defined the structures responsible for its management. The policy is based on the principle of catchment-basin management and determines rules relating to the organization, to the configuration and to the functioning of catchment basins.

The institutional framework relies on a principle characterized by the distinction that is made between management and the different users. The policy declares water resources management to be the responsibility of the Government of Côte d'Ivoire, who must guarantee:

- The supply of potable water
- The protection, conservation and integrated management of water resources
- The satisfaction of other needs

The state is also responsible for providing security in the form of the Water Police.

Water Resources Protection

The protection of water resources is assured by:

- Policing measures
- The establishment of standards and norms of quality, determined according to the resources' different uses, and taking into consideration the most current scientific data in the field
- Protective boundaries (immediate, close or distant)
- Classification measures
- Administration of public utilities

Protection is assured by the introduction of specific norms, both quantitative and qualitative. Quantitative protection prohibits water wastage, with stricter rules applied in parts of the territory where water resources are rare or threatened. Qualitative protection includes ensuring that water used for human consumption is protected from pollutants. Water sampling points must be enclosed within protected areas within which any act or activity of a polluting nature is prohibited. Any

dumping, unloading of waste or radioactive effluents of any kind, capable of increasing or provoking the pollution of water resources, is prohibited. Any discharge of used water in the catchment area must respect the standards and norms in force. Fishing practices using explosives, drugs or toxic products capable of harming the quality of the aquatic environment are prohibited.

2.2 PILOT PROJECT OF INTEGRATED WATER MANAGEMENT

Following the introduction of the Water Code, Côte d'Ivoire instigated a pilot project of integrated water resources management in Bandama, to assess the constraints linked to setting up such an integrated system.

Bandama is one of Côte d'Ivoire's principle watercourses. It is 1,050 kilometres long, with a surface area of 97,000 kilometres. Its catchment basin, which is in the interior of the country, is representative of the situation faced by all of Côte d'Ivoire's great rivers; it is subjected to various water uses that provoke conflict situations between users. In the north of the country, the often-archaic construction methods used by small reserves place enormous pressure on water resources, disturbing the river system and provoking consequences downstream which cannot be evaluated. The irrigation of banana and pineapple plantations with chemical fertilizers and phyto-sanitary products also causes pollution problems in both surface and groundwater.

The pilot project of integrated water resources management in the Bandama basin consists of establishing an interactive geographic database to facilitate decision-making in the field of water resources management and use — in terms of assessment, prediction and planning, establishing and running water resources management mechanisms and systems. It will provide institutions concerned with water with a working tool that will take their particular interests into account, as well as the results they have achieved. It is a project aimed at showing the feasibility of a support system for decision-making in the water sector at the level of one catchment basin, before envisaging the system's application throughout the national network of basins.

For this reason, a Geographic Information System (GIS) has been developed for this basin. So far, data on the following aspects of water resources and their management has been made available:

- The hydraulic network
- Water reservoirs
- Geology and basin aquifers
- Agricultural dams
- Boring for potable water conveyance
- Boring for village hydraulics
- Pluviometric posts
- Hydrometric stations
- Watercourse quality observation stations

7 Keynote Address: Rehabilitation of Degraded Dryland Areas and the Need for Appropriate Plant Material

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Introduction

In addition to the stress that the severe dryland climate places on the environment, farming, overgrazing, poor use of water resources and the destruction of vegetation are just some of the more recognized human causes of the deterioration of dryland areas (Mediterranean and tropical). And for the last few decades, these phenomena have been worsening.

Everyone deplores the destruction of these regions, the encroachment of desert dunes, the drop in productivity of pastures, and the loss of fertility of fallow areas. These degradations can lead to the decline and even disappearance of species, a phenomenon that is often disregarded. While biodiversity remains a parameter that alerts us to the degradation of ecosystems, we are often satisfied with surveillance at the species level. In reality, the phenomenon is far more insidious. In the pastoral areas of the drylands, species have co-evolved over a long period with the pressure exerted by domestic animals. The absence of resources management — leading to the suppression or total absence of plant growth for pasture over a prolonged period of time — results in the disappearance of significant portions of these areas' most valuable plant species.

Restoration and rehabilitation ecology is one possible means to stop these processes from worsening and overcome or mitigate their consequences. It enables us to understand how those ecosystems that have as yet seen little degradation function, and so to re-establish (rehabilitate) the essential functions (sustained long-term production, resilience) of degraded ecosystems. Ideally, such rehabilitation operations should be based on the possibility of re-establishing native vegetal growth, with its wide aptitude to adapt to stress conditions and disturbances (including pastoral pressure). It is therefore urgent, in situations where this has not yet been undertaken, to conserve and protect genetic resources. It already appears certain that restoration-rehabilitation programmes will encounter difficulties in some situations because of a lack of suitable plant material. The role of protected areas, such as biosphere reserves, appears vital. Through the restoration of degraded ecosystems, biosphere reserves enable us to conciliate the imperatives of conservation-preservation and those of development aid.

1. Degradation of Land and Water Resources

Different agricultural practices and different ways of rearing cattle have left their mark on our landscapes, our ecosystems and our resources. Land and water resources have, moreover, progressively imposed upon human activities, right up to the choice of animal species reared. Terrains cultivated, resources used and farming activities have witnessed a succession of phases of expansion and regression, most often to the detriment of the land's resources.

Up until the middle of the last century, the relatively limited human pressure in arid and semi-arid zones enabled rural populations to follow coherent and adapted systems of resource use — leading nomadic lifestyles and regularly allowing land to lie fallow. Today, these practices have changed or have, at least, become largely unsuitable to the current situation, as a result of changes in the socio-economic context; with increases in herd sizes, private land-ownership, the quantity of land cultivated and the number of people living a sedentary lifestyle. This evolution has in many cases had serious consequences.

Defoliation obliges plants to reinvest a portion of their carbonaceous reserves in renewed growth. Studies have found that the level of pastoral pressure imposed and, more generally, the methods of pastoral management used, play an important role in the biological cycles of plant and animal species, and therefore in their chances of survival. Intensive grazing of natural pastureland results in the transformation of the environment itself. Of the plant species that are grazed, those more sensitive to such damage will rapidly decline in quantity, while those

more adapted to grazing will be favoured (e.g. with an increased production of new shoots). Plant species that are not grazed will also increase in quantity.

The level to which different edible species are grazed in drylands varies according to the type of animal and the composition of herds (Waechter, 1982). Camels and ovines appreciate different plants, and plants are favoured at different phases of their biological cycles. Unlike caprines, who rarely eat annual plant species, ovines eat such species with almost complete indifference to the biological stage the plant is at.

Grazing will necessarily influence the level of defoliation. Where animals graze freely, the more appetizing plants can maintain only a thin degree of plant cover, and their biological cycles are disturbed. These factors have repercussions on plant biomass, on biological composition and on the condition of the topsoil and the soil's hydric functioning (Floret *et al,* 1978; Floret and Pontanier, 1982), and can modify the ecosystem of arid and semi-arid zones of North Africa, affecting plant resiliance and the dynamics of secondary succession, for example (Le Houérou 1968, Floret and Le Floc'h 1972.). Overgrazing is generally considered one of the major causes of damge to natural ecosystems, second only to the planting of crops.

The reduction of plant cover that is engendered by over-grazing results in the modification of dominance relationships among species. In the arid region of North Africa, the degradation of shrub grass steppes (physiologically similar to shrub savannah) has been seen to pass through a phase dominated by low ligneous species, followed by a phase in which annual grasses or unappetizing perennials dominate (Le Houérou 1968), leading finally to the steppes' transformation into completely barren regions, with only a sporadic presence of annual species with short life-spans. From the initially homogenously wooded steppe, we end up with diverse physiologies depending on the mode of pastoral management applied (the level of pressure put on the grazing lands, the types of animal farmed). In pastoral systems still subject to strong grazing pressure, future plant physiognomies are for the most part unknown to us.

For thousands of years, with the phenomenon becoming seriously accentuated over the last few decades, rangelands have evolved under constant animal pressure. Abandoning grazing of these lands or imposing prolonged periods of protection may have serious consequences. Non-grazed plants (bushes, etc.) can develop leaf mass with the risk of dying in conditions of prolonged drought, as their root system is unable to satisfy the elevated evaporation / transpiration demands put on it. This situation becomes catastrophic for the area's vegetation. Similarly, fallen leaves can create a thick ground cover, inhibiting growth of the first springtime grasses.

The east wind is the principal erosive agent in the drylands. Initial studies by Le Houérou (1987) suggest that a cover of 25 percent of perennial vegetation is indispensable (but not always sufficient) to allow sand deposits to become greater in volume than loss due to erosion and reduction. By simulating a heavily grazed sandy steppe, Floret and Pontanier (1982) measured the annual loss of sand to be in the order of one hundred tonnes per hectare.

The mechanical effect of rain results in the formation of a film or crust, the thickness of which is a function of the vegetation cover, the intensity of the rain, the characteristics of the topsoil etc. The changed structure of the topsoil gives it a "glazed" appearance, and increases runoff while reducing the possibilities of germination and the emergence of shoots. There are large areas of such "glazed" soils in northern Africa and the Middle East, where plant formations are often degraded, and *Artemisia herba alba* or *Hammada scoparia* dominate.

Soil degradation leads in particular to a disturbance in its hydrological functioning (Floret *et al.* 1978, Floret and Pontanier 1982). Several parameters (infiltration coefficient, duration of water availability in the soil, soil profile water reserves) enable us to ascertain the extent of these phenomena. The destruction of steppic vegetation can lead to large tracts of land becoming barren, destroying the soil's seed stock and damaging the ecosystem's resilience.

Due to the great variability of climatic conditions and seasonal rain distribution, the annual production of a specific area remains largely unpredictable. For a given type of terrain, this production depends on its current condition (plant composition, fertility, etc.). Steppe vegetal growth is very closely linked to soil condition, and differences in growth patterns are a result of differences in rain distribution (in time and space), more than the quantity of actual rain.

These phenomena can be seen to differing degrees in many different regions. For most situations, though, it is still possible to recognize levels of degradation within the same type of milieu. In any given territory, some areas are less degraded than others, this is even more apparent in areas in which protection and conservation measures have been instigated.

Pastoral production should be, as much as possible, widespread and well developed. In the steppe regions of Africa, which are of low productivity, it is hoped that the ecosystems present a high degree of resistance and can thus respond positively to restoration actions (Aronson *et al. 1993a* and 1993*b*, etc.), and the negative effects of excess grazing can be mitigated. This resistance is itself regulated by the presence of appropriate plant species.

Knowledge of how plant species respond to grazing is of enormous interest if we are to understand the evolution of plant composition and species representation. In response to grazing, many species have been found

to evolve by changing their biological behaviour. A study undertaken in Mediterranean Egypt (Ghali 1984) monitored the development of steppe species under greatly contrasting conditions and grazing pressures (where protection measures had been instigated, grazing controlled or the region's traditional method of uncontrolled grazing had been followed). The different reactions of different plant species led to the following conclusions:

- The level of grazing pressure can influence the length of the vegetative phase. For *Plantago albicans* and *Gymnocarpos decander*, for example, strong grazing pressure is beneficial to the vegetative phase and lengthens its duration.
- Grazing, at a reasonable level, seems to stimulate reproduction (flowering and fructification) of *Thymelaea hirsute*, a species that is little grazed.
- Strong grazing pressure, even during abundant rains, prevents *Echiochilon fruticosum*, *Plantago albicans* and even *Gymnocarpos decander* from flowering and seeding, thus prohibiting their sexual reproduction. However, these species manage to flower and seed even in the dry season if grazing pressure is low.

Different species then have different fates. For example, *Echiochilon fruticosum* and G*ymnocarpos decander* are disadvantaged compared to *Plantago albicans*, which has a capacity for strong vegetative multiplication, while sexual multiplication of *Thymelaea hirsuta* is favoured by low-level grazing.

Species that are grazed when flowering or seeding are deprived of the possibility of reproducing. Plants that die are no longer replaced, and the density of the species recedes progressively, to the stage of becoming a rare species.

Species that have been subjected to regular grazing pressure over the centuries, and even over thousands of years, have co-evolved with animal behaviours. Take, for example, the case of *Argyrolobium uniflorum* (Chaieb 1989), which when grazed behaves as a perennial plant, but when protected becomes scarce and bi-annual. The same is witnessed with *Lasiurus scindicus*, a Saharan *graminae*, which becomes scarce when protected and in competition with other plant species, but also becomes scarce in overgrazed situations.

While grazed species are only rarely threatened with disappearance, ecotypes that are favoured by grazing animals have frequently been seen to die out. A study in Tunisia (Ferchichi *et al*., 1992) showed that the most vigorous population of *Cenchrus ciliaris* was to be found in a national park, where it had not been victim to this 'negative artificial selection', the sense used by Burkart (1976).

Plant species found in arid and semi-arid regions can be classified according to their capacity to produce relative to temperature (their "photosynthetic biochemical type" — Solbrig 1977, Ehleringer 1978). *Mediterranean* species are generally of the C^3 photosynthetic type, with a peak in production during the cold season, which in the Mediterranean region is the period of high water availability. *Tropical* species of the C^4 type are more productive, with maximal production at high temperatures, providing soil water is available (Floret *et al.* 1978, Chaieb *et al.* 1992, etc.). Soil degradation (erosion combined with a substantial reduction in reservoir capacity) in a site where two plant taxa co-exist can lead to an unprecedented exhaustion of water reserves by and benefiting C^3 species, during their low-temperature growth period (*Argyrolobium uniflorum*, *Stipa lagascae*, *Plantago albicans*, etc.). Thus deprived of water during periods favourable to their production, C^4 species (*Cenchrus ciliaris, Digitaria commutata*, etc.) may consequently present only mediocre growth. Generally very common, these species then become scarce and often disappear.

The disappearance, or even just a decline in quantity of these species is serious enough to lead to the almost complete domination of 'Mediterranean' species in arid and semi-arid regions, as found in northern Africa. The scarcity of otherwise successful species reduces regional productivity, even if the level of biodiversity and vegetation cover is maintained.

The growth and production of *Cenchrus ciliaris* is directly correlated to the level of water availability in the soil. Plants of the *Stipa* genus in southern Tunisia decline in numbers when faced with strong competition with other species (Chaïeb *et al.* 1995*a* and *b*), and so a certain level of grazing pressure is beneficial to them.

It is possible, and in fact not uncommon, to raise the protection of natural environments to the level of dogma, advocating that the conservation of plant resources demands that they be entirely protected against humans and their animals. This form of management is often seen in national parks and similar situations where all human intervention has been prohibited. Nature is in this way placed under a protective dome, creating a living museum. When pushed to the extreme, however, this attitude can prove to be extremely harmful, particularly in grazing areas and in arid and Saharan regions. It does not take into account the conditions under which the vegetation has evolved over time. Grazing pressure since time immemorial has participated in establishing a flora that has adapted to its environment and has co-evolved under this pressure. The abrupt abandonment of this pressure eventually leads to an exaggerated growth of plants whose development had previously been controlled through grazing. In the Saharan region, protected grazing areas have been found to fall subject to desertification processes following a particular dry season, during which the accumulated evapo-transpiration demand of foliage biomass could not be satisfied by the root system. On the other hand, plants with reduced biomass, due to grazing, did survive.

The degradation of land and water resources can be halted. This one of the objectives of restoration ecology. Techniques do exist. Some of these techniques are presented below, based on studies carried out in Tunisia. An in-depth evaluation of the most suitable plant material for this type of study remains to be carried out. It is then urgent to identify, for all major arid-zone ecosystems, situations in which such resources can be preserved. Arid zones, often seen as having low specific diversity, actually present great diversity at the intra-specific level (ecotypes, populations, etc.). It is vital to preserve this drought-resistant material, which has adapted to continuous grazing pressure. If not, we may well see the promises of restoration ecology come to nothing, due to a lack of suitable plant material. What is important, then, is not to try to constrain species from evolving, but to preserve these species from sudden extinction as a result of our poor treatment of them — whether this be from establishing a protection system that is too absolute, or from extensive and prolonged over-grazing. It is imperative that our natural resources and their future be managed in areas in which human activity is not excluded, but where human intervention is at once reasoned and reasonable. This form of preservation can be seen as one of the roles of biosphere reserves.

2. Restoration Ecology & Rehabilitation

Our understanding of the delicate equilibrium of ecosystems, their degradation and its possible irreversibility enable us to distinguish between two types of ecosystems: those that are still able to be returned to their previous state through sensible management or through changes in grazing practices and those for which rehabilitation is only possible through considerable human intervention.

Land rehabilitation and land reallocation require determined human intervention. This intervention, in the case of rehabilitation, involves jumpstarting processes that should, if possible, then be able to continue on their own momentum, in conjunction with restoration processes. With reallocation, the essential difference lies in the periodic necessity of supporting the artificial ecosystem once it has been set in place. For example, the planting of exotic shrub forage requires periodic irrigation, continual sowing (the replacement of dead plants), harvesting and, eventually, the establishment of a new plantation.

3. Rehabilitation: A Case Study

Before embarking on the rehabilitation of an ecosystem, the major causes that have led to its degradation must first be known. In this case study, degradation was essentially a result of a reduction in the quantity of viable seeds in the soil, combined with a change to the structure of the topsoil, seriously reducing water infiltration. Depending on the context, rehabilitation should then rely on one or other of these functional aspects of the ecosystem.

3.1 HYPOTHESES

We chose to reconstitute, through planting, a stock of viable seeds, selected on the basis of a certain number of hypotheses:

- Local species are better adapted than exotic species to the edaphic conditions of the area as well as to climatic fluctuations linked to the local climate.
- Once settled, perennial species possess the greatest ability to use water resources, scarce in the drylands.
- It is possible to combine perennial local species (low grasses and ligneous plants) so as to efficiently maximise water resources (producing high vegetative yields across different seasons). During the dry season, competition is fierce and will benefit those species capable of withstanding the harsh conditions. In a favourable year, many diverse species demonstrate the potential of their varied biological and production cycles, to the benefit of species that grow during the hot season and generally make more efficient use of soil water.
- Seeds from such combinations of species, also known as keynote species (Aronson *et al.* 1993*a*), can lead to the establishment of simplified ecosystems (comprised of a reduced number of species) that nevertheless present the essential traits (structure, production and resilience) of the complex ecosystem they are supposed to reproduce.
- Setting up such a simplified ecosystem can significantly reduce the time necessary for a heavily damaged ecosystem to return to its initial state, as the simplified ecosystem traps diaspores transported by the wind (when sufficient perennial cover has been established) and enables the soil's hydrique function to become reactivated, increasing the potential of its seed stock. The gradually acquired complexity of the new ecosystem will enhance its resilience and stability.

3.2 PRELIMINARY STUDIES

A series of studies undertaken over a twelve-year period integrated laboratory and field work in areas such as the genetic diversity of available plant material, studies of germination performances, phenology and behaviour under diverse conditions, efficiency related to water resources and responses to mixed water cycles (CCE, 1993).

3.3 EXPERIMENTS

The site of the study has an arid bio-climate with mild winters, with average annual rain levels estimated at 175 millimetres. The soil is made up of a twenty-centimetre

thick layer of chalky (calcareous) nodules, resting on Miopliocene. Cereals are farmed throughout the area, which is exposed to grazing despite the low levels of vegetation cover present. *Rhanterium suaveolens* is presumed to have once existed in the area, although it has disappeared from the area today.

We chose to limit the number of species we introduced, so as to make optimal use of the available water. On the whole, 'keynote' (Aronson *et al.* 1993*a* and 1993*b*) species suitable for pasture were used in the reference ecosystem (a *Rhanterium suaveolens* ecosystem). The quantity of seeds planted was calculated on the basis of the germination rate of the different species. The mix therefore comprised *Rhanterium suaveolens*, *Stispa lagascae*, *Cenchrus ciliaris* and *Plantago albicans*.

The experiment was carried out in January 1991, according to the following design:

- An external control (unfenced), unfarmed and not sown grazing area
- An internal control, fenced, worked, not sown
- Three elementary plots, fenced, worked and sown with the proposed mix. These plots were then fenced, delimiting those plots subject to grazing and those under protection

The precise conditions of this experiment are available (CCE, 1993; Le Floc'h *et al*, 1995 and 1999)

3.4 RESULTS

We present here only the results corresponding to vital attributes of the ecosystem that are important in order to assess the ecosystem's 'state of health' and to evaluate the relative success of the experiments (Aronson *et al.* 1993*a* and *b*). The attributes we discuss here relate to the vegetation present and the condition of the topsoil. (The entire body of results has already been presented in CCE 1993 and Le Floc'h *et al.* 1995, 1999.)

The attribute 'viable stock of soil seeds' was measured by the flora found when the soil was broken up by harrowing — i.e., seeds that had germinated under the experimental conditions. Table 1 presents the species found in the two samples:

- External control: 17 species (8 annuals / 9 perennials),
- Internal control: 32 species (19 annuals / 13 perennials).

The results showed that the 'keynote' species of our mixed seed supplies were not present in the soil's stock of viable seeds.

Table 1 shows that the the sown plots did not, at the time of these initial observations, present a notably higher number of plants than did the internal control (protected, farmed, unsown). However, the plants found in the control groups had little in common with that of the reference ecosystem. In the rehabilitated plots, a certain number of species died out after coming fully into flower, while young steppe species appeared. Apart from the external control, the data from the internal control, the rehabilitated plots and the reference ecosystem show they have similar annual / perennial ratios.

The third attribute revealed was the vital attribute 'vegetation cover'. The 'quadrat point' method (Goodall, 1952) was used to measure this attribute.

In this attempt to rehabilitate land by planting, the vital attribute, 'keynote' species, turns out to be a particularly important consideration. The mixture of species sown were considered as being potentially 'keynote' in terms of the functioning of the selected reference ecosystem. The results can be analysed via the density of each individual species and how this develops over time, via the overall coverage of the introduced species as a whole, or by analysing each species one-by-one. Results obtained in 1994, which are supplementary to those already presented (CCE 1993), are shown in Table 2, opposite.

Periodic monitoring of species density is an important indicator of the success of rehabilitation, and improves our understanding of the mechanisms by which young steppe formations develop. The density of the introduced species diminished progressively in the sown plot, from a peak reached during the first germination period (CCE 1993). As far as possible, the results should be interpreted in light of the density of the same species in the reference ecosystem. Floret and Pontanier (1982) found that a steppe of *Rhanterium suaveolens*, placed under protection and considered to be in good condition, should have a total density of 4.5 perennial plant species per square metre, with, for example, 3 and 0.4 plants per square metre respectively of *Rhanterium suaveolens* and *Stipa lagascae*. Our results showed the plants in the rehabilitated plots to be numerous, if small.

Measures of plant density can also be compared to the composition and the density of the planted seeds; in this case, 662 seeds per square metre of the chosen seed mix. At the time the measurements were taken, four years after the seeds had been planted, equilibrium had not yet been reached in the sown plots. However, on 15 April 1993, *Rhanterium suaveolens* was present at a density of 4.4 plants per square metre, and *Stipa lagascae* at a density of 0.2 plants per square metre. If the species that we planted do reveal themselves to be 'keynote' species, it is likely that modification of the species balance will occur progressively. The growth in terms of cover and biomass of a number of the introduced species will entrain a regression of other, less-competitive species, and, above all, of plants once they have flowered (including *Plantago albicans*).

The vital attribute 'condition of the topsoil' was also examined. For want of the possibility of easily following certain changes to do with water dynamics, we

selected a number of indicators of water functioning (infiltration, runoff, evaporation) to evaluate the condition of the topsoil at the ecosystem level (Escadafal 1981, Casenave and Valentin 1989).

If we consider the condition of the topsoil as indicative of improvements in an ecosystem's hydraulic functioning (in terms of the abundance of organic matter and sand layer), it has to be said that in our experiment the sown plots performed well. As concerns total vegetation cover, the performance of the species in the seed mix as a whole should be linked to that attained by the individual species within this seed mix that achieved the maximum coverage (in this case, *Rhanterium suaveolens*).

Discussion and Conclusions

Once a certain defence system has been established, land rehabilitation is achieved by a constant growth in the density of plant cover, by plant species of which almost all are already present in the ecosystem (Floret, 1981). Rehabilitating land by planting 'keynote species' entrains a very sudden overall growth in plant density, and a general progression in the overall vegetation cover. Following this, though, adjustments then take place in the plant balance, sometimes by a fairly brutal reduction in overall plant density, and so in the vegetation cover. Plant density may, however, evolve in a more gradual manner.

Table 1. Soil seed stock four years following commencement of the experiment on rehabilitation. (Le Floc'h *et al.* 1995).

	Control		Planted Plot	Reference Ecosystem
	Used for pasture	Not used for pasture		
Number of plants (annuals / perennials)	17 8 / 9	32 19 / 13	33 21 / 12	24 1 / 23
Plant cover, annuals %	0.1	0.4	0.2	0.15
Plant cover, perennials %	0.6	8.0	37.2	0.5

Table 2. Density (plants per square metre) of reintroduced species (Le Floc'h *et al.* 1995).

	Control Plots		Rehabilitated Plot	Reference Ecosystem
	External	Internal		
Cenchrus ciliaris	0	0	1.2	< 0.01
Plantago albicans	0	Not given	14.5	1
Stipa lagascae	0	0	0.2	0.4
Rhanterium suaveolens	0	0	4.4	3
Total	0	0	20.3	4.5

For systems that have co-evolved over time with the pressure of farmed animals, it must be recognized that these animals themselves also constitute 'keynote species', as these lands only exist in this state when they are grazed. For the site of our tests, it was observed that not only does the rehabilitated ecosystem support grazing, but that even the diverse parameters measured attest to the beneficial effects of a reasonable level of grazing (CCE 1993).

We have presented rehabilitation here in terms of measurements of some of the ecosystem's vital attributes, purposely leaving aside certain technical aspects of the experiments that were carried out (the exact composition of the seed mix, the sowing techniques used, how the land was managed). These aspects have, though, been presented elsewhere (CEC 1993, Neffati 1994). In particular, one of the interesting themes that

has not been approached here is the mode of land management applied and its effects. This involves reconstructing ecosystems that can not only support grazing but may actually benefit from a reasonable intensity and rhythm of grazing. But despite the fact that the beneficial effects of grazing have been demonstrated, no data exists on actual productivity levels.

Arid zones are rich in biodiversity, not necessarily as this is commonly understood, in terms of the number of different species present, but in terms of the numerous morpho-anatomical and physiological adaptations to drought that are represented, and to the constraints exerted by animal pressure.

Natural resources, even if they are not managed by man, are only slightly degraded over time when relatively little human or farmed animal pressure is exerted on them, and when this pressure is spread out, both temporally and spatially. Settling coupled with population growth and the legitimate search for improved living conditions has led to a sizeable increase in pressure on our natural resources, which are no longer able to spontaneously replenish themselves.

The notion of heritage is envisaged when there is a suspicion that certain plants may contain genetic material that is potentially interesting for therapeutic and pharmaceutical purposes. This should be developed, even if the interest in these species is at the local and regional level.

Extreme degradation of natural resources and ecosystems, which is sometimes referred to as 'desertification', can under certain conditions be repaired; this is the purpose of restoration ecology. The possibilities are wide-ranging and include the restoration of a certain level of biodiversity, seen as a guarantee of the stability and productivity of restored or rehabilitated ecosystems. Progress achieved in this area can only be sustainable if rational management practices are applied in restored or rehabilitated areas. It is important to remind ourselves that, for operations to have some chance of success, well-adapted plant material must be made available (high-performance ecotypes). It is vital that we ensure the conservation, or rather the preservation, of such plants in appropriate areas, such as biosphere reserves.

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8 UNESCO's Man and the Biosphere Programme (MAB): Using Biosphere Reserves to Rehabilitate Degraded Lands

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According to the United Nations Environment Programme's *World Atlas of Desertification* (UNEP, 1997), some 39 percent of the earth's surface is arid, semi-arid or dry sub-humid. If the hyper-arid areas are added, nearly half of the planet's surface, about 47 percent, consists of drylands. This large area is home to about one-fifth of the Earth's human population and therefore constitutes one of the major biogeographical regions of the world.

The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, adopted Agenda 21 as its programme of action for sustainable development. Among its forty chapters, Chapter 12 is concerned with drylands: its title 'Managing Fragile Ecosystems: Combating Desertification and Drought' sets the stage for the perception of the drylands: together with mountains (Chapter 13) and islands and coastal areas (Chapter 17), the drylands are considered as *fragile* ecosystems which need adequate management, as they contain unique features and resources that are particularly susceptible to environmental degradation and loss.

And, indeed, it is in particular in the fringing areas of the world where the impact of human activities on the environment is most pronounced and visible, generally resulting in environmental degradation, depletion of natural resources and species loss. Some scientists working in the field of environmental conservation also argue that drylands are *resilient* ecosystems. In a recent article by Ernest H. Robinson entitled 'Conservation and Management of Arid Rangelands'), the author convincingly argues that dryland ecosystems can recover in an amazing manner even after extended droughts. Plant and animal species can increase by at least tenfold and biomass by considerably more than this when the rains return. 'In these environments, plants and animals exist in the form of 'meta-populations': it is natural for these populations to undergo extinction in parts of their range, and they regenerate naturally from colonies that have survived in other parts of the range that have been unaffected' (Robinson, 2000). All people with experience of drylands know that their physiognomic aspect can change dramatically from the dry season to the rainy season.

The drylands, then, give rise to diverging views in the scientific world: are they indeed the fragile lands they are generally considered to be: unproductive if overused and whose vegetation and soil cover disappears when subjected to excessive human impact, reaching a 'point of no return' in extreme cases? Or are drylands and the life forms found within them outright champions of survival, remarkably well adapted to extreme and adverse conditions imposed by an extreme variability of precipitation, water availability and temperature change? Can degraded drylands be effectively restored from surviving plant and animal colonies in natural refuge areas?

While there are still many uncertainties with regard to dryland-ecosystem resilience, which can only be addressed through long-term ecological research spanning at least one, better still several, decades, it seems clear that the human factor has become the decisive variable in dryland fragility / stability. Increasing human pressure through demographic growth and economic expansion in the world's marginal areas has had a devastating effect on dryland equilibrium. Agricultural overuse and reduced or non-existent fallow periods deprive soils of vital nutrients such as nitrogen, phosphorous and potassium, and decrease soil fertility. Excessive grazing destroys or seriously reduces vegetation cover, leading to severe soil erosion. Logging for firewood lessens a trees' biomass above as well as below the ground. Although recurrent bush fires, a common phenomenon in dry subhumid and semi-arid zones, may provide short-term soil enrichment through carbon intake, they also expose soil to leaching and erosion. Finally, continued village / urban sprawl encroaches on agriculturally productive areas, increasing the pressure on non-inhabited lands.

In order to feed a growing human population, should agriculture be intensified (which may result in soil and water pollution in the long run, through the increased use of chemical fertilizers and pesticides) or should agriculture be extensified (which, in turn, is very land-consuming and may jeopardize remaining wilderness areas)?

The main question that we have to ask is how can we conserve the environment while at the same time providing for a sustainable natural-resource base? How can we create amenable living conditions for people in drylands without disrupting the aspirations and economic needs of future generations?

While there can be no single and simple answer to this question, UNESCO's Man and the Biosphere Programme (UNESCO-MAB) may provide some guidance on how to reconcile environmental conservation with sustainable development. Biosphere reserves have been designated to address this complex question through scientific studies on human-environment interactions. Each biosphere reserve has three broad objectives:

- to improve and encourage conservation of natural resources and the environment,
- to promote the sustainable use of natural resources based on the needs of local populations,
- to study sustainable land-use practices and share information among scientists and those involved in managing protected areas.

A zoning pattern common to all biosphere reserves addresses land use and land management in an integrated manner. Each biosphere reserve has three distinct areas: a core area, a buffer zone and a transition area.

At the heart of each biosphere reserve is the *core*, which needs to be legally established to give long-term protection to the landscapes, ecosystems and species it contains. As nature is rarely uniform and as historical land-use constraints exist in many parts of the world, there may be several cores in a single biosphere reserve, to ensure a representative coverage of the mosaic of ecological systems. In many cases, cores comprise national parks, nature reserves, game reserves and forest reserves, reflecting the need for a legal designation of this zone.

The core is surrounded by a *buffer zone*, which is clearly delineated and contiguous to the core area. Economic activities are organized here in line with the conservation objectives of the core, and help to protect the core (hence the idea of 'buffering'). For example, the buffer zone can be used as an area for experimental research: to study ways to manage natural-resource vegetation, croplands, forests, or fisheries or to enhance high-quality production while conserving natural processes and biodiversity, including soil resources, to the maximum extent possible. Similarly, experiments can be carried out in the buffer zone to explore the possibility of rehabilitating degraded areas.

Finally, the core and buffer zones are surrounded by a *transition zone*, or development area, which may include a variety of agricultural activities, human settlements and other uses of this land. It is here that local communities, conservation agencies, scientists, cultural groups, civil associations, cultural groups, private enterprises and other stakeholders must agree to work together to manage and sustainably develop the entire area's resources for the benefit of the people who live there. Given the role that biosphere reserves play in promoting sustainable management of a region's natural resources, the transition zone is of great economic and social significance for regional development.

The biosphere reserves concept has proven to be successful as a tool for environmental conservation and land-use management. As of November 2000, there are 391 biosphere reserves in 94 countries (following a decision of the MAB Programme's Intergovernmental Coordinating Council on 9 November 2000, 21 new sites were added to the World Network of Biosphere Reserves). Their locations in Africa and in Asia are shown in Figures 1 and 2.

Biosphere reserves are special sites for scientific collaboration. Their scientific infrastructure — in terms of research stations and on-going studies on the environment and land-use systems — is one criteria for acceptance into the World Network of Biosphere Reserves. An example is the UNESCO Project 'Biosphere Reserves for Biodiversity Conservation and Sustainable Development in Anglophone Africa (BRAAF)', which facilitated scientific co-operation among five African countries from June 1995 to December 1998, with studies focusing on the Amboseli Biosphere Reserve in Kenya, the Bia Biosphere Reserve in Ghana, Lake Manyara Biosphere Reserve in the United Republic of Tanzania, the Omo Biosphere Reserves in Nigeria and the Queen Elizabeth Biosphere Reserve in Uganda (see also the following article in this publication, 'Sharing Kenya's Experience in Resource Management and Rehabilitation of the Once-Degraded Amboseli Biosphere Reserve' by Joseph Masunga). The BRAAF Project identified common objectives and outlined a standardized research methodology for all five biosphere reserves. It aimed to enhance the conservation of biodiversity through income-generating schemes for local populations via a number of pilot projects, thus reducing human pressure (e.g. poaching) on the natural-resource base of the protected areas. Local people, scientists from universities and the public sector and officials in charge of the environment and nature conservation worked together to find common solutions to sustainable natural resource use.

As regards the topic of the present seminar session — land degradation and rehabilitation in drylands —

Figure 1: Biosphere Reserves in Africa

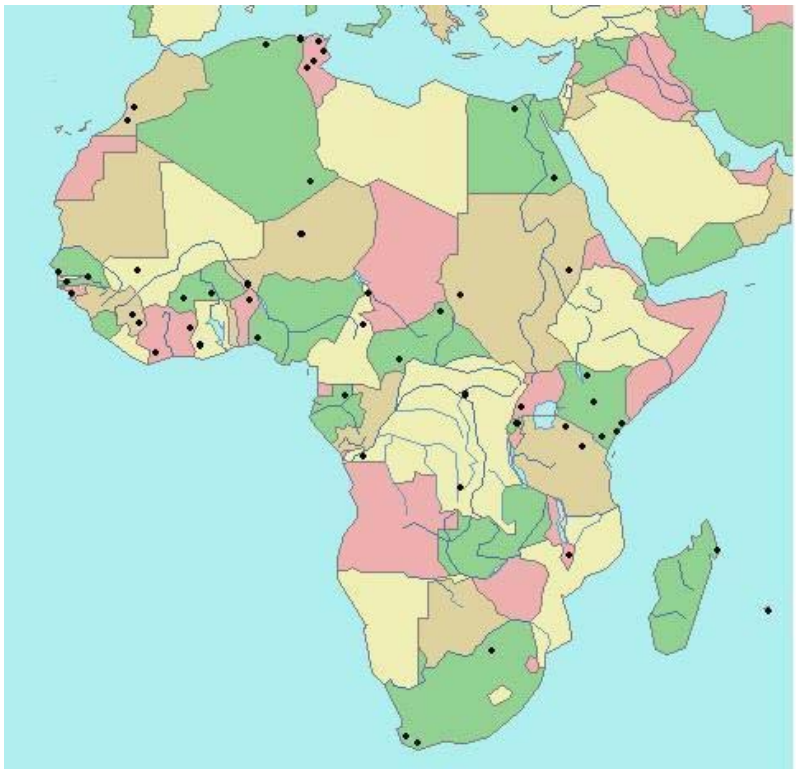
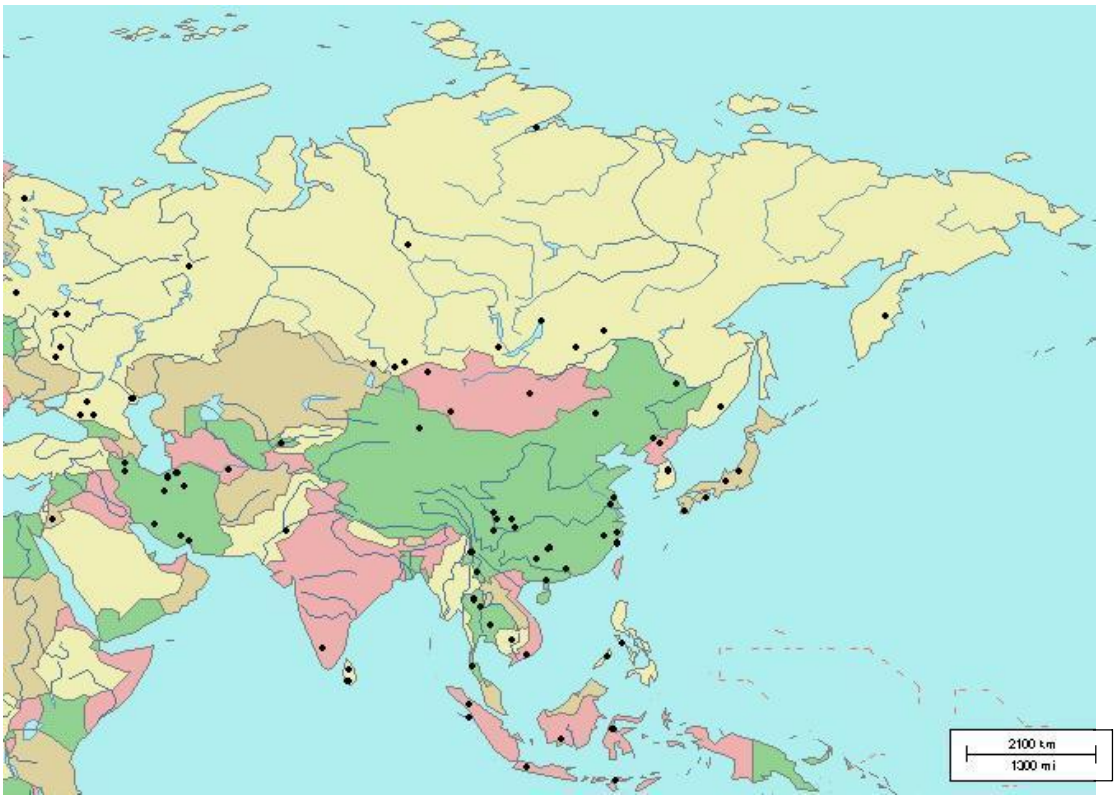


Figure 2: Biosphere Reserves in Asia



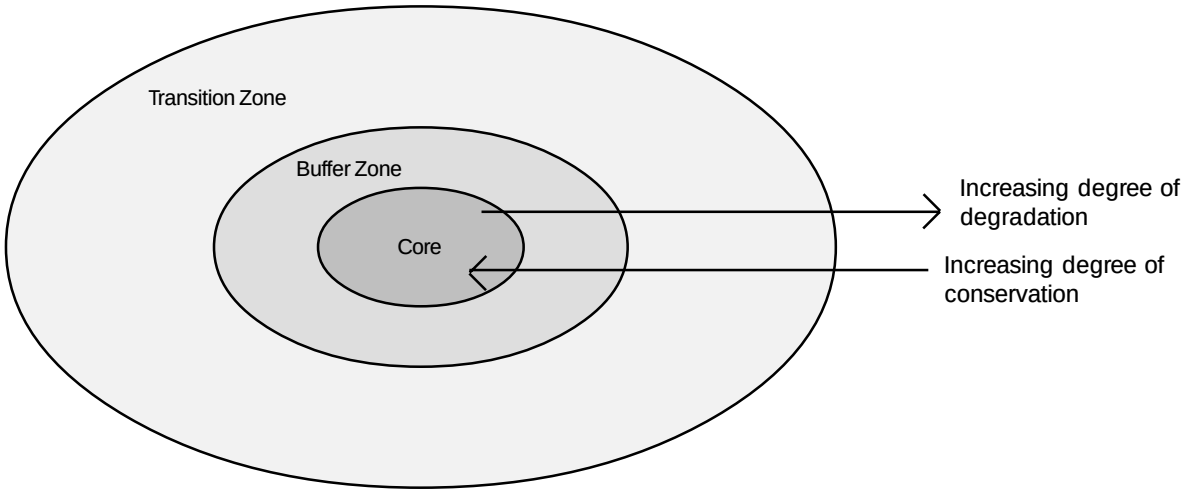
a similar joint-research initiative on dryland biosphere reserves could be envisaged. This new focus in the UNESCO-MAB Programme could encompass several biosphere reserves in dryland areas, not only in Africa, but also in the Arab States, Asia, Latin America and Mediterranean Europe, using a comparative study approach. As biosphere reserves include protected areas (with relatively undisturbed environments) in their core zones and other areas designated for economic usage and exposed to much higher degrees of environmental stress and disturbance (agriculture, pastoralism, game production, forestry etc.) in their transition zones, they can provide a good picture of the degree of environmental degradation in a relatively small area. A study of the state of the environment could be performed using a transect drawn systematically from the core area of the biosphere reserve through the buffer zone into the transition area to reveal teh state of the environment (see Figure 3).

would have to be carried out to promote the sustainable use of agricultural and pastoral lands. If we wish to contribute to the fight against land degradation, to work towards land rehabilitation, we cannot simply conserve the environment — we must offer a sound base of resources and revenue for the inhabitants of arid and semi-arid lands, by developing and promoting sustainable farming and husbandry practices.

It would be desirable for such studies to be carried in the light of the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD). The Committee on Science and Technology — Convention to Combat Desertification (CST-CCD), with its work on desertification benchmarks and indicators and on utilizing traditional knowledge to combat desertification, could provide an invaluable resource in this field.

Another UNESCO-MAB project, in northern Ghana, has obtained constructive results in the field of dryland

Figure 3: Schematic gradient of environmental degradation from the core to the transition zone



This transect would represent a gradient from a relatively intact and undisturbed environment in the core area of a biosphere reserve to an environment that is increasingly impacted by economic and other human activities, with increasing characteristics of environmental degradation. More importantly, the core zones, which are legally protected areas, could serve as reference sites of natural or near-natural environments. Natural vegetation in this area could play a role in studies on restoration ecology, while activities directed towards the rehabilitation of degraded drylands would be carried out in the buffer and transition zones. Studies could focus, for example, on the conservation of endemic plant species and characteristic plant associations; viable sizes of animal populations; or the migration of non-native species.

But these studies alone would not be sufficient to rehabilitate the natural environment. Similar studies

conservation and rehabilitation and sustainable farming practices. In the dry sub-humid climate of Ghana's northern region, sacred groves were used as indicator and reference sites to define a region's potential natural vegetation. With the consent of the local fetish-priests and chiefs, biodiversity inventories were carried out in three sacred groves. At the same time, 'buffer zones' were created around the sacred groves, providing local people (in particular women) with income-generating opportunities through cash-crop plantations (e.g. cashew nuts, mangoes) and the establishment of fodder banks. The project led to the publication of a manual on sustainable farming practices entitled 'Environmental Education and Training for Savannah Ecosystem Management', which is now widely used in Ghana for sustainable management practices in savannahs.

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9 Resource Management and Rehabilitation of the Once-Degraded Amboseli Biosphere Reserve

Joseph M. Masunga, Assistant Secretary General, Kenya National Commission For UNESCO

The Amboseli Biosphere Reserve has been used as a study site for two UNESCO pilot projects: the 'Application of the Geographic Information System to Natural-Resources Management' project, and the recently concluded 'Biosphere Reserves for Biodiversity Conservation and Sustainable Development in Anglophone Africa' (BRAAF) project.

The initial study for the BRAAF project recommended setting up a project to rehabilitate the already-degraded Amboseli Biosphere Reserve into a well-managed ecosystem that would support a broad variety of fauna and flora. Amboseli is an excellent example of how conflict between land use and wildlife conservation can be resolved, proving that it is possible to establish a harmonious coexistence between local community members (Masai pastoralists) and reserve managers: in this case the Kenya Wildlife Service.

The core area of the Amboseli Biosphere Reserve (Amboseli National Park) is above the basin of a closed hydrological drainage system. Although no major surface streams flow into this basin, melting snow and rainfall from Mount Kilimanjaro percolate through the porous volcanic soils towards the lower foothills and into the catchment basin. This water re-emerges in the Amboseli basin in the form of permanent springs scattered along the edge of the solidified lava flow. The water from these springs form swamps that attract large numbers of birds and herbivores during the dry season: 95 percent of the area's wildlife are drawn to this central basin (the 'core area' of Amboseli Biosphere Reserve) during the dry season.

An inventory of plant and animal species was prepared as part of the UNESCO projects. A long-term ecological monitoring programme has revealed that woody vegetation (trees, bushes and shrubs) is declining fast in the central area, and in the recently established Kimana wildlife sanctuary, where elephants concentrate due to the presence of perennial water sources.

Since 1991, the Kenya Wildlife Service has completely closed these degraded areas to all human activity, for the protection of the native wildlife. This decision has enabled the vegetation to regenerate.

Elephant enclosures (bordered by solar-powered electric fences) were used to monitor the regeneration of woody plant species (shrubs and trees). Water channels and earthen dams were constructed in the buffer zone to attract elephants away from the core area, to ease the pressure placed on it by the elephants. These measures have contributed to a reduction in land degradation in the core area, and have therefore contributed to the rehabilitation of the Amboseli Biosphere Reserve.

One of the major threats to biodiversity conservation in the Amboseli Biosphere Reserve is the abusive use of land for agricultural purposes in the buffer zone. Large areas within this zone are important sources of food and water for wildlife and livestock — areas such as swamps, which are increasingly converted into horticultural farms. This reduces dry-season grazing areas, thus affecting the reserve's carrying capacity for wildlife and livestock.

In Amboseli, management of indigenous flora and fauna is also practised outside the core area, with the local community actively involved in nature conservation in the buffer zone. The conservation policy in this area promotes initiatives that encourage landowner participation in flora and fauna conservation. This has seen the emergence of community sanctuaries and wildlife associations that aim to generate funds through tourism activities while protecting the natural environment. It is hoped too that these conservation trends might lead to the establishment of a number of new 'core areas' of environmental protection. This would provide protection to wildlife that have been driven from their grazing lands by increased land cultivation and settlement.

The Kenya Wildlife Service has embarked on community training in basic wildlife management skills. Community wildlife scouts have been trained to provide services to visitors, to collect entrance fees and to discourage poaching.

Similarly, the Kenya Wildlife service is assisting communities set up cultural centres and culture-orientated enterprises, with women represented in the management committees. These cultural centres are deliberately located outside the core area in order to ease tourist pressure on the park's more fragile zones — by encouraging tourists to spend more time in the buffer and transitional zones. This has reduced land degradation in the core area, and assisted the rehabilitation of the Amboseli Biosphere Reserve.

All of these measures have greatly helped to rehabilitate the once severely degraded Amboseli Biosphere Reserve. Lake Amboseli, which dried up completely some years ago, has been slowly re-emerging since the nomination and subsequent protection of the Amboseli Biosphere Reserve under UNESCO's Man and the Biosphere Programme.

I had the chance to participate in both of the UNESCO pilot projects, which provided vital research data towards the management and rehabilitation of the whole Amboseli ecosystem.

10 The World Heritage Convention — Protecting Arid-Zone Sites

Elom Agudze, UNESCO Consultant at the World Heritage Centre

Introduction

The contributors who have spoken before me have instructed us on combating desertification, freshwater resource management, rehabilitation of degraded lands in arid regions etc. Today we have the honour to touch upon another central theme of this seminar, which alludes to the protection, conservation and the valorization of natural sites. I will draw particular attention to the Convention elaborated by the UNESCO World Heritage Centre. It involves the utilization of the Convention for the protection of the world's natural and cultural heritage in the drylands.

In almost every part of the world there are treasures of irreplaceable and incalculable value. Unfortunately, many among them are experiencing degradation and destruction, and many risk disappearing forever. This damage is often attributed to human activities, although the combined effect of climatic conditions plays an important part too.

Cultural and natural heritage includes only a portion of the irreplaceable and incalculable treasures, not only for those countries that shelter them but also for the whole of humanity. The loss of one of these imminently priceless riches constitutes an impoverishment to the heritage of all the world's population, which is why they must be conserved. As certain states do not necessarily possess the means to tackle the problem alone, it seems sensible to treat the problem collectively. Of all the NGOs and international organizations that deploy their efforts to provide assistance to these states, the United Nations Educational, Scientific and Cultural Organization (UNESCO) assures their protection at the highest level on a global scale. The World Heritage Convention provides the framework and the ideal instrument for achieving such a goal. The following questions will guide our understanding:

What is the World Heritage Convention? How does it function? What can it provide in terms of the conservation of the natural environment? How does one become a member? Who can become a member?

1. The World Heritage Convention

It is understood that world heritage is the combined sum of sites and assets scattered around the world that make up the heritage of our past, of which we are beneficiaries today and have the responsibility to transmit to future generations. They represent the best possible examples of their kind, distinguished into two groups: cultural heritage and natural heritage[1]. Four groups are often distinguished that take into consideration cultural heritage, natural heritage, mixed heritage and cultural landscape. The sites are internationally renowned and selected for their authentic value and universal aesthetic, and a number are found in the drylands.

The World Heritage Convention is an agreement — a treaty — currently signed by 159 countries (of which 38 are in Africa) who are committed to contributing financially, legally and intellectually to the protection of world heritage. It defines an organized and coherent framework and legal structure. The Convention unites and engages countries around the world into active international co-operation and an effective sense of solidarity for the safeguard of world heritage. It is placed under the auspices of UNESCO, who developed and finalized the Convention with other institutions. The General Conference was adopted on 16 November 1972 and is symbolized by the World Heritage emblem.

2. Structure of the Convention

The Convention is drafted in five languages (English, French, Spanish, Russian and Arabic); it comprises a preamble followed by thirty-eight articles under eight headings. The Convention defines the type of natural or cultural sites considered for inscription to the World Heritage List as well as setting the obligations of states in the identification of potential sites and the role they play in the protection and conservation of sites. By signing the Convention, every country commits not

only to assuring the proper conservation of sites but also to protecting their natural heritage. The Convention encourages the state to integrate the protection of cultural and natural heritage within regional planning programmes, adopting measures that assign a role to the heritage sites that affect daily lives. The Convention also describes the role played by the World Heritage Committee, the election of members and their mandate, and it specifically indicates the professional specialist organizations to be consulted in the selection of sites to be eventually registered on the list. The Convention explains the use and management of World Heritage funds and the conditions and modalities of international financial assistance.

From a functional point of view, it is important to note that there are three main organs combining the conception, management, co-ordination and guiding principles of the Convention: The General Assembly (member states), the World Heritage Centre and the World Heritage Committee. The World Heritage Fund, created in 1972, is supplied by both voluntary and compulsory contributions by member states.

With a view to achieving its objective of safeguarding world heritage, the World Heritage Convention bases its work on an inventory of natural and cultural sites registered on the World Heritage List. It accords funds and support to the member states who identify and propose sites located on national territory that may potentially be included on the World Heritage List. In the case of trans-boundary sites, a joint registration is recommended. The World Heritage Committee[2] reviews proposals formulated by states, considering the precise criteria to be met. The sites chosen become common and universal property with prejudice to state sovereignty. It is this universal application that renders the notion of World Heritage an exceptional concept. Emergency measures are applied to threatened sites, which are inscribed on a separate list. Every state also produces periodic reports on the situation of listed sites.

The Convention sets down complete protection measures for these sites. This could entail international co-operation in the form of technical assistance (preparatory assistance, technical co-operation, emergency measures, training, educational and audio-visual programmes) and/or financial assistance (in the form of reduced rate or no-interest loans, or free subsidies deducted from World Heritage funds).

3. The Convention and Environment Conservation in the Drylands

The World Heritage Convention has a special function in the international combat against desertification. Its efforts in the preservation of resources in the biosphere have led to the physical and legal protection of natural sites: this also involves the protection of plant and animal species as well as the rehabilitation of geological sites. In this way, the contribution it makes to combat desertification is particularly effective.

Certain properties and sites are located in drylands, however they are ill-represented on the World Heritage List. Many people are unaware that Sahelian or desert regions possess sites of potential World Heritage interest. Furthermore, the protection of World Heritage is seen as a matter of urgency, particularly if it is threatened with degradation or destruction. In addition, property and sites in disadvantaged climatic zones should be identified, registered and protected, not least due to the incessant degradation they are subjected to.

The World Heritage Convention transforms the principle of collective responsibility for the protection of heritage into action, thanks to international solidarity. Every state signatory commits itself to the protection of its entire national heritage, whether or not it is recognized as World Heritage. The Convention thus assures a dual protective measure that is both national and international. The Convention can therefore be applied as an instrument at the service of the protection of drylands, within a particular context. The countries concerned should take stock, identify and propose property and sites so as to protect them. The onus lies with the states to take advantage of the benefits offered by the Convention.

4. Protecting the Drylands

Unfortunately, many countries of the drylands do not reap the benefits or support of the Convention, either because they are ill informed or because they do not know how best to approach it. The result is that properties and sites in the drylands are under-represented by World Heritage. To date, there are 630 sites listed, of which 480 are cultural, 128 are natural and 22 are mixed sites. However, of the 128 natural sites, only two are found in the drylands, they are Ichkeul in Tunisia and Aïr and Tenere in Niger. One other site is currently at the nomination stage: the site of Saint Catherine and South Sinaï in Egypt. In the semi-arid region, Mount Atlas in Morocco stands out among those listed. Other sites proposed by countries such as Sudan, Egypt, Morocco, Syria, Lebanon and Yemen are currently under discussion.

Very few natural sites have been proposed by arid countries with a view to protect and conserve them. In any case, drylands are under-represented on the World Heritage List. However, the drylands possess sites that could be listed. The Convention, a dynamic instrument at the service of states, is not only a list of sites and properties, but also seeks to assure different types of representative sites, and in particular, natural sites. It is for this reason that meetings are envisaged for the com-

ing year to assist Arab states to identify sites to nominate for registration on the World Heritage List and to promote the registration of cultural landscapes.

5. Challenges

It is not only forests and the large mammals of West Africa that are worth protecting and preserving. The Sahel desert region also merits conservation insofar as it is an integral part of the regional ecosystem. It is important to safeguard biodiversity[3] and all its splendour, without which World Heritage would be incomplete and impoverished. In essence, the World Heritage List draws our attention to the richness of our planet's cultural diversity and natural heritage. To this end, it aspires to be as complete as possible. The desert regions must therefore convey their differences and their specificity in terms of the wide-ranging and valuable World Heritage Convention. The countries of the drylands would benefit from the sharing of experiences, know-how and eventually from full high-level international protection of sites.

In addition to these considerations, the benefits of environmental conservation to national economies are far from negligible. International recognition of certain sites can be a determining element in establishing a tourism industry, and a conference was held in Dakar in 1996 on the tourism management of natural World Heritage sites. Tourism already represents an important part of the budget of certain arid countries, and has the potential to further enhance the economy of these and other arid countries.

It is important to point out that all member states can apply for or benefit from international assistance in the form of educational, technical or financial aid; testimony to the seriousness with which these challenges are being met.

6. Benefiting from the Support of the Convention

Countries can benefit from the Convention by studying the Convention closely, by ratifying it, by proposing sites to the World Heritage List and by working towards the protection of these irreplaceable properties.

7. Who Can Become a Member of the Convention?

All states, members or non-members of UNESCO, can adhere to the Convention.

Conclusion

The World Heritage Convention is both a movement and a legal instrument providing full protection at the highest level for universally recognized properties and sites of exceptional value. This protection extends to natural, cultural and mixed properties and sites and cultural landscapes in the world, whether found within the country or trans-boundary. The Convention could be particularly effective in the protection of the drylands. The current under-representation of natural and cultural sites and landscapes in these zones on the World Heritage List is a challenge that we should all rise to together without delay.

[1] Cultural World Heritage comprises original cultural sites and properties. It includes monuments, groups of constructions and sites of aesthetic, archaeological, scientific, ethnological or anthropological value. World Heritage comprises original natural sites and properties of outstanding physical, biological and geological importance, the zones are exceptional from a scientific or aesthetic perspective, as well as for their threatened animal and plants species. Sites made up of both of the two are classed as mixed heritage. Cultural landscapes include the combined result of man and nature, they are landscapes transformed by man during the course of economic, technological and social evolution.

[2] The World Heritage Committee is one of the three principles organs of the World Heritage Convention, the other two being the General Assembly and the World Heritage Centre. It is the Committee who decides on the sites to be listed, examines the periodic reports, and handles requests for assistance.

[3] Biodiversity is defined by the Convention on Biological Diversity as the variety and variability of living organisms and their terrestrial and aquatic ecosystems. This includes genetic, species and ecosystem diversity.

11 Using Volcanic Tuff as Mulch to Reduce Moisture Stress and Increase Soil Productivity in Arid Areas

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Introduction

Mulching techniques using a variety of organic and inorganic materials are widely used in the world and their effects on soil water conservation for crops have been observed by many scientists (Adams 1967; Benoit and Kirkham 1963; Bond and Willis 1971; Box 1981; Box and Meyer 1984; Chepil *et al.* 1963; Choriki *et al.* 1964, Corey and Kemper 1968; Epstein *et al.* 1976; Lal 1974; Mehuys *et al.* 1975; Modaish *et al.* 1985: Unger 1971*a* and *b*; Groenvelt *et al.* 1989; Dwairi 1996; Woldeab, 1994). Mulches, apart from reducing moisture losses through evaporation, can also have other positive effects on soil productivity, including:

- reducing wind and water erosion,
- reducing the mechanical impact of rain, hail and wind,
- increasing water infiltration, slowing down runoff,
- reducing soil temperature fluctuations,
- reducing weed growth,
- increasing seed germination,
- improving plant and tree seedling vigour.

However, the main reason for applying mulches is to conserve soil moisture by decreasing evaporation, in order to reduce crop losses and increase yields. The most commonly used mulching materials are of organic origin — such as crop residues, leaves, forest litter, sawdust and bark — but mulch can also be of synthetic origin (polyethylene sheeting). Also, liquid cattle manure has shown to reduce evaporation rates considerably (El-Asswad and Groenevelt 1985). Mulching experiments with naturally occurring inorganic materials like sand have been conducted by Kirhham *et al.* (1967), and Modaish *et al.* (1985) and the effectiveness of this technique as a means of reducing evaporation has been shown. Groenevelt *et al.* (1989) have shown the effectiveness of rock mulching in laboratory experiments using scoria and pumice among other materials. They also show that the effectiveness of rock mulching decreases when rocks are incorporated into the soils. Goor and Barney (1976) describe the use of gravel mulches for improving infiltration rates and reducing evaporation of tree seedlings in arid zones.

At the farming level, rock mulching is being practised at present in arid to semi-arid parts of Western China and on the Canary Islands, Spain. In some parts of Western China, the farmers cover their fields with a layer of ten centimetres or more of river gravel to reduce evaporation. The use of rock mulch is also very common in arid parts of the Canary Islands in Spain, where this technique has been applied successfully for the last few centuries (Chesworth *et al.* 1983, Frenandez Caladas and Tejdor Saguero 1987).

Unlike Western China, Canary Islands farmers mainly use rocks of volcanic origin, especially phonolites and scoria, as mulching media. In some parts of the Island of Lanzarote, the farmers also use sand as a mulching medium. Here, apart from scoria, they use sand and mulched fields to grow sweet potatoes, rock melon and watermelon (Fernandez Caldas and Tejedor Salguero 1987).

In most cases, rock-mulching techniques require large initial inputs of labour and rock materials. This initial investment is largely compensated by the low maintenance costs during the growing season and by the long-term effects of this technique. On the Canary Islands, continuous cropping on rock-mulch farms can be sustained for approximately twenty years (Fernandez Caldas and Tejedor Saluuero 1987) before a new mulch application is required.

On the Canary Islands, various rock-mulch materials and methods are used. The most common method consists of covering the relatively fertile volcanic soils, which receive their soil moisture from the sparse precipitation (and, in some areas, from dew precipitation), with a few centimetres of vesicular phonolites or scoria. The layer of volcanic rock used as mulch is up to fifteen centimetres thick, and made up of well-sorted

scoria (on the island of Lanzarote, which is one of the most arid islands of the Canaries, with annual precipitation rates of between 150 and 300 millimetres) or vesicular phonolites (on the island of Tenerife). The grain size of the volcanic materials commonly ranges from five millimetres to two centimetres. This material is transported from nearby volcanic deposits to the fields. In the past, animals performed this task, today trucks transport the material.

The crops are planted as seedlings, not into the mulching material itself but into the soil underlying the rock mulch. The mulch is removed by hand, the seedling is then planted and the area around the seedling carefully covered again. After planting, the crops require little maintenance. The mulch largely suppresses weeds. The main function of the rock mulches is to reduce evaporation from the soil by acting as a barrier. Harvesting is done carefully by hand, removing the crop without mixing the rock-mulch material or crop residues with the underlying soil. When carefully planted and harvested, the rock mulch will not mix with the soil and the system can be sustained for about twenty years (Fernandez Caldas and Tejedor Salguero 1987).

On Lanzarote, rock-mulch farming includes some twenty-three crops, among them onions (with an average yield of twelve tons per hectare), tomatoes (an average yield of nine tons per hectare) potatoes (with an average yield of six to eight tons per hectare), peas and beans. Apart from artificial mulch, there are considerable areas that are covered naturally by a deep cover of scoriaceous basalt, much of it being used for the growth of vines (Fernandez Caldas and Tejedor Salguero 1987).

The advantage of using inorganic rock material over organic crop residues is that rock mulches are relatively inert, they do not decompose, they are not attractive to termites or other small animals and, due to their higher bulk density, they are not removed by strong winds and rains. Other inorganic sources — for example, plastic mulch follies — do not biodegrade very well and are not environmentally sound.

The negative aspects of rock mulch are that they interfere with mechanical farming tools and remain in the soils for a long time without being completely degraded or weathered. When accumulated over decades they will finally reduce the rooting volume of crops.

The successful and sustainable rock-mulch technique used in the Canary Islands and Ethiopia has justified the testing of the effectiveness of this technique in Jordan, where soil productivity problems were largely related to soil-moisture stress. The basic materials for rock mulching, e.g. volcanic tuff and zeolitic tuffs, are available in large amounts in the vicinity of the problem areas.

1. Materials and Methods

1.1 VOLCANIC MULCH MATERIALS

Volcanic tuff and zeolitic tuffs were the principal materials used for mulching purposes for this experiment. Ten cubic metres of each raw material was obtained from a quarry in Tel Aritain in north-eastern Jordan. The tuff materials were prepared by screening the raw material using vibrating screens — first with a 1-centimetre wire mesh to remove larger grains, followed by a 0.2-centimetre mesh to remove smaller grains, so obtaining a grain size of between 0.2 and 1.0 centimetres.

1.2 SOIL SURVEY AND ANALYSIS

Fresh soil profiles were dug to a depth of up to half a metre at various sites in the study area. The layers of each profile were then identified, and their morphological properties were analysed and defined in accordance with the Food and Agriculture Organization (FAO) guidelines for such soil-profile descriptions. The Munsell soil colour chart was used to record the colour of the soil, both when moist and when dry. Representative soil samples, weighing about four kilograms each, were then collected from every layer for chemical and physical analysis.

1.3 LABORATORY ANALYSES

Routine physico-chemical analyses of pH, total nitrogen content, organic matter content, cation exchange capacity (CEC), exchangeable aluminium content, texture and available phosphorous and calcium carbonate were carried out at the geo-chemical laboratories in Yarmouk University, as well as gravimetric tests to determine soil moisture.

1.4 ROCK-MULCH EXPERIMENTS

Rock-mulch field experiments were conducted at the Badia Research and Development Centre's station in Safawi in north-eastern Jordan, and at the National Centre for Agricultural Research and the Transfer of Technology's station in the Ramtha area. At both locations, two types of rock (black tuff and zeolitic tuff), in layers three-, six- and nine-centimetres thick, were tested in a random complete block design on test plots four by five metres in size. Control plots were not treated with mulch. The mulch materials were spread uniformly on the surface of the plot and fertilizer rates of forty kilograms per hectare of nitrogen (urea) and ten kilograms per hectare of phosphorous (TSP) were applied to all treatments after the barley seeds were sown. The treatments were repeated three times. Soil samples for gravimetric moisture determination were collected at a depth of thirty centimetres at various times of the

growth period. The crops were harvested at maturity and the yields were determined as well as the nutrient content of the grains

2. Results

2.1 EFFECT OF ROCK MULCH ON SOIL MOISTURE

Soil moisture content was measured as percentage of moisture at different dates within the barley-growing season, at a thirty-five centimetre soil depth.

The soil-moisture data collected during the growing season of 1996 demonstrated a significant difference in soil moisture, of 9 percent and above, between the control and the mulched plot. Where, for example the control (unmulched) plot recorded 12 percent moisture, the moisture content was 22 percent in the mulched plot. These differences were sustained as the season advanced, and in some cases the difference in moisture content increased.

The rock-mulch experiments showed that considerable soil moisture was conserved, and was utilized by barley for growth. In the course of the experiment the soil moisture content of the mulched plots at Ramtha station varied from 9 to 14 percent higher than that of the control, this soil moisture was retained by the rock mulches. Comparing the two types of mulches used, zeolitic tuff seems to conserve a little more moisture than black tuff. Only a small difference was recorded between the effects of four and eight centimetres of rock mulches.

2.2 EFFECTS OF ROCK MULCH ON SOIL TEMPERATURE

Hourly soil-temperature measurements were taken at Safawi, from six AM to eight PM. They showed the differences in soil temperatures at different times of the day and with two different rock-mulch materials (black tuff and zeolitic tuff) applied at thicknesses of four and six centimetres.

The temperature differences between mulched and unmulched plots were considerable. At topsoil level there were particularly clear differences in temperature between the various treatments.

2.3 EFFECT OF VOLCANIC MULCH ON SEED GERMINATION

The seed germination and early growth was much better on the mulched plots than on the control plots. Approximately 55 percent seed emergence was observed at ten days on the black tuff and zeolitic tuff plots compared to 0 percent on day ten on the control plots. The second observation of seed emergence was made twenty-five days after planting. All the plots except the control had germination rates well over 80 percent and gaps were beginning to be filled. Further observations at 55 percent tasseling, at silking and at maturity showed that these growth stages followed the moisture-availability trend. In all mulch plots there was a difference in seed sprouting of nine to eleven days when compared with that of unmulched plots.

2.4 EFFECT OF ROCK MULCH ON WEED AND PEST SUPPRESSION

Weeds and pests are major problems in Jordan. In areas where barley is grown, weeds can bring substantial losses if not controlled properly. Also, loss of crops due to termite damage can be considerable. Rock mulch significantly suppressed weed growth at all test sites, the mulched plots were clear while the control plots were weedy. The rock-mulched plots were practically termite free.

2.5 EFFECT OF ROCK MULCH ON BARLEY YIELD

The rock mulch had a major effect on grain yield. At the Ramtha station, grain yield on the control plots ranged from 1,980 kg/ha to 2,100 kg/ha during the year 1994. The mulched fields with a layer of three centimetres of zeolitic tuff saw grain yields ranging from 3,800 to 4,260 kg/ha, more than double that of the control.

2.6 EFFECT OF ROCK MULCH ON NUTRIENT UPTAKE

Mulching significantly enhanced the total uptake of the major soil nutrients, nitrogen, phosphorous and potassium (NPK) by the grain. The favourable soil moisture conditions created as a result of mulching intensified the uptake of the major nutrients, NPK. This is probably due to the fact that adequate moisture in the soil has increased plant growth. The total NPK accumulated in the grain was highest when the soil was mulched with black tuff or zeolitic tuff, and lowest for the control plot. This clearly indicates that creating better moisture conditions is a positive soil fertility management technique, to be used along with the use of fertilizers or manure and the introduction of legumes.

Conclusions

Rock mulching, a water-conservation technique successfully applied over centuries in other arid and semi arid regions of the world, has been tested successfully in arid and semi-arid areas in Jordan where suitable rock-mulch resources are abundant. Rock mulching with locally available black tuff and zeolitic tuff materials proved to be very beneficial to crop production in the two test areas (Safawi and Ramtha). Improved yields of barely were obtained by the application of tuff and zeolitic tuff mulches. This increase in yield was probably the results of the combined effects of various parameters, among them improved soil moisture levels, a reduction in temperature fluctuations, reduced competition with weeds and better nutrient uptake.

Rock-mulching experiments carried out in Jordan provided the following results:

- Soil moisture was conserved
- Weed growth was reduced
- The seed germination rate was increased
- Soil temperature fluctuations were reduced
- Crop yield was increased, due to the combined effect of various parameters

The application of rock mulch was found to be an economic, efficient and intensive land-use technique.

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12 Land Degradation and Rehabilitation in the Arid Zones of Benin

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1. A General Introduction to Benin

The Republic of Benin is located in West Africa, lying between 6° 10' and 12° 25' north latitudes and between longitudes 0° 45' and 3° 55' east. It covers a surface of 114, 763 square kilometres, bordered by the Republic of Burkina Faso to the northwest, the Republic of Niger to the north, the Republic of Togo to the west, the Federal Republic of Nigeria to the east and by the Atlantic Ocean to the south. The only elevated area is the Atacora range in the northwest of the country.

Benin is relatively dry in the south, and the coastal area has a warm climate with high humidity and little variation in temperature. The annual rainfall in different regions of the country varies from 1,400 millimetres in Sème, in the east, to 1,050 millimetres in Grand-Popo in the west, with around 1,200 millimetres annually in the sub littoral region. The rains fall in two periods, with 60 to 70 percent falling in the first wet season, which lasts from mid-March to mid-July and is known as the Great Rain season, and 15 to 25 percent falling in the second period, from September to mid-November. Between these two rainy seasons are the dry seasons: the Great Dry season, from November to March, and the Small Dry season, which is a mere reprieve from the rain mid-winter, from mid-July to September.

The Republic of Benin has a significant hydrographic network including 3,048 kilometres of rivers and 333 kilometres of lakes and lagoons. This network feeds three aquifer basins: the Niger Basin, the Pendjari Basin and the Coastal Basin.

Soils in Benin are characterised by great variability, as much in their nature and fertility as in their geographical distribution. Although 62.5 percent of the land surface is cultivable, only 20 percent only of the cultivable surfaces are actually exploited: or 12.24 percent of the national territory. Five principal types of soils can be distinguished: tropical ferruginous soil (found in 70 percent of Benin), ferralitic soil (found in up to 10 percent of the country), hydromorphic soil (found in up to 8 percent of the country), vertisols and soils with vertic qualities (found in 5 percent of Benin), and mineral and poorly evolved soils (found in 5 percent of Benin).

Benin is not a forested country, in spite of its apparently favourable geographical position. The areas of Grand-Popo and Ouidah have an annual rainfall of less than 900 millimetres.

According to the results of the Second General Census of Population and Housing (census carried out February 1992), Benin had a population of 4.9 million people in 1992, estimated to reach 5.5 million in 1996 and approaching 6 million inhabitants in 1998. This population is unevenly distributed, and is concentrated in the southernmost part of Benin, where 53.2 percent of the population lives in one tenth of the country. It is estimated that 48.6 percent of the population are under fifteen years old, and only 6 percent are over the age of 60.

2. Land Degradation in Benin

Land degradation can be divided into three categories: chemical degradation, physical degradation and salinization. The first is the loss of soil fertility. This phenomenon, a consequence of agricultural production, affects all cultivated land in Benin. The second category, physical degradation, is manifested primarily through hydrous erosion and wind erosion.

2.1 DEGREES OF LAND DEGRADATION

According to the state of deterioration of the vegetative cover and the degree of productivity of the land, we can differentiate among four degrees of land degradation:

Severely Degraded Land

An estimated 1,240 square kilometers of severely degraded lands have been identified in the areas of Boukoumbé and Ouaké, where the minimal vegetation cover has caused hydrous erosion and wind erosion.

Highly Degraded Land

Highly degraded lands are found within the Sudano-Sahel region of Benin's extreme north: in the areas of Matéri and Natitingou, and in certain parts of Ouaké; making up 16 percent of this zone. Highly degraded areas are also found in Banikoara and Kandi in the east-central and northwest Sudan zone — making up 4,880 square kilometres. Almost the entire Sudan zone in the north and the northeast, in the region of Malanville, Karimama and Guéné, is highly degraded, covering approximately 5,390 square kilometres.

On the slopes of catchment basins in the Sudano-Guinean transition zone, 3,150 square kilometres of land is highly degraded, comprising lands that are heavily farmed or are at a medium incline. There is around 3,750 square kilometres of highly degraded land on plateau slopes in the Sudano-Guinean zone.

Moderately Degraded Land

A total of 8,600 square kilometres of land in the Sudano-Sahel region in the extreme north of Benin is moderately degraded, localised around agglomerations such as Kotopounga, Kouandé, Péhunco, Copargo and Djougou, with similarly moderately degraded lands covering 24 percent of the Sudan region of the north-west and centre-east, in the areas of Ségbana, Gogounou, Kérou, Péhunco, Sinendé, Bembéréké, Kalalé, Nikki, Dali and Parakou. There is a strip of moderately degraded land along the department of Alibori in the northern / north-eastern region, representing 16 percent of the region.

In the Sudano-Guinean plateau '*terre de barre*' region — characterized by iron clay cut with marshy dips — moderately degraded land can be found in the areas of Sakété, Kétou, Pobè and Porto-Novo in the department of Ouémé; Zakpota in the department of Zou; Allada, Tori-Bossito and Zè in the Atlantic department; and Lonkli, Lokossa and Comè in the department of Mono: totalling approximately 6,750 square kilometres of moderately degraded land.

Finally, in the sandy littoral and fluvial-lakes region, moderately degraded lands are to be found north of Cotonou, west of Comé and in the area between Lokossa and Djakotomey.

Slightly Degraded land

Approximately 2,170 square kilometres of slightly degraded lands are found along the coastal strip between Cotonou and Grand-Popo in the littoral and fluvial-lake sandy region of Benin. In the Sudano-Guinean region, almost the entire Lama Depression is characterized by slightly degraded vertisols. In the Sudano-Guinean transition zone, slightly degraded land can be seen between Bantè and Doumè, between Tchetti and Doumè and between Ouèssè and Tchaourou, accounting for 10 percent of the region's land surface.

There are pockets of slightly degraded land throughout the Sudan region in the centre east and northwest of Benin, totalling approximately 29,127 square kilometres. In the Sudano-Sahel region of the extreme north, slightly degraded lands have been identified between Toucountouna and the Mékrou River, between Bassila and Patargo and east of Parakou-Pèrèrè-Nikki road; a total of 14,045 square kilometres of land.

2.2 EXPANSION OF DEGRADED LANDS

An estimated 100,000 hectares of land in Benin is cleared each year to create new fields. Fishing and salt-production industries have destroyed forests of mangroves and other hydrophilic species in the coastal region. The area covered by dense natural forest in the Lama Depression shrank from 11,000 hectares in 1946 to 2,300 hectares in 1986. The development of the cotton industry in the centre and the north of Benin has considerably reduced the density of the area's natural vegetation (trees, bushes and scrub), while existing fields are deteriorating through intensive yam farming. Overall, Benin's forests, which in 1949 covered 20 percent of the country, have been reduced to a total area of less than 12 percent of the country. Removal of wood and the illicit use of forests for agricultural purposes have increased considerably since the 1970s.

The entire region of Boukoumbé, Cobly, Matéri and Tanguiéta is semi-arid and on a steep incline. Poor agricultural practices have caused intense erosion in this area, resulting in a very stony and fragile topsoil. Water runoff strips the land of its nutrients, and the region has become almost entirely desertified. Crops are negligible and trees rare. The Ouaké, Djougou and Copargo region is less steep, but very poor agricultural practices, in which meter-high hillocks have been constructed and the natural watercourses have been ploughed, have caused severe erosion and the filling-in of watercourses.

The area encompassing Karimama, Malanville, Kandi, Banikoara and Ségbana is contiguous with the Sahel zone. It has a long dry season with occasional sandstorms, and cattle herds from Niger and Nigeria pass through seasonally. Pressure on the natural resources of this zone is explained primarily by the poverty of the rural population.

3. Factors of Land Degradation in Benin

Both human and natural factors contribute to land degradation and desertification.

3.1 NATURAL FACTORS

Relief

Mountainous and hilly areas such as are found in parts of the northern departments and the department of Collines, are exposed to the phenomenon of desertification.

Climate and Hydrography

For some decades, the climate of Benin has been marked by great pluviometric variations, a general reduction in annual rainfall and a precocity of the seasons. The reduction in the quantity of rain is particularly marked in the northern departments, where rainfall has decreased by more than 20 percent in the areas of Tchaourou, Bembéréké, Karimama, Ségbana, Tanguiéta, Boukoumbé and Cobly. In addition, analysis of water run-off at hydrometric stations shows that river flows have decreased since the 1970s, as has the replenishment of aquifers — which has diminished by as much as 60 percent in the Collines, Zou, Alibori and Borgou departments. Many of Benin's rivers are seasonal, and the rainy season causes significant flooding, yet most of this water drains off and does not benefit the soil.

The northern part of the country receives the least rainfall and suffers from overgrazing and transhumance. Although the slightly ferric clays of the plateaux of south Benin (the '*terre de barre'* region) have a good agricultural potential, the land in this region is very threatened as well. Representing approximately 5 percent of the country, around half of Benin's population lives in this region; that is to say, approximately 2,750,000 people in 1996. Almost all of the land here has been damaged by the combined effects of physical factors, such as hydrous erosion and wind erosion, and human factors, such as the destruction of vegetation and the widespread use of poor agricultural techniques.

3.2 HUMAN FACTORS

Farming Methods

The principal economic activity in Benin is agriculture. However, the combination of traditional farming methods (itinerant culture, slash-and-burn farming) and overpopulation has led to over-exploitation and exhaustion of much of the land. In a sixteen-year period, 348,328 hectares of land was cleared, which corresponds to an average rate of 21,770.5 hectares cleared per year, or 0.3 percent of the country's cultivable surface annually. In general, over-exploited lands eventually become unproductive, sterile belts of land, a precursor to desertification.

Benin's two northern departments are particularly threatened by desertification, yet one of these departments alone accounts for more than two-thirds of the country's cotton production. Along with the yam industry, the cotton industry, in its current form, plays a great part in the land's degradation. Cotton represents more than 80 percent of Benin's GDP, and in this northern region it is a provider of security and prosperity: it ensures a solid income every season.

In spite of a significant use of chemicals, traditional cultivation methods are still used in Benin. Artificial fertilizers being expensive, they are rarely used in the cotton industry: once production drops significantly, the cotton producer moves on, burning new plots to gain cultivable land. Once cotton fields have stripped the land of its nutrient, the abandoned fields rapidly become barren soils, which are then exposed to various other forms of erosion. Vast areas of land thus become degraded.

Yam tubers asphyxiate young trees, growing around their trunks as if they were simply supporting stakes. Moreover, yam farming necessitates a large quantity of water, which impoverishes the soil and leads to hydrous erosion.

Utilization of Forest Resources

Forested areas in Benin have been unlawfully used to plant crops, and excessive amounts of wood and tree products are regularly taken from forests. These practices have led to the destruction of vast areas of forest: Benin's forests cover less than 12 percent of the territory, compared to 29 percent in 1949.

Fishing Techniques

Fishing is also a significant activity on Benin's lakes and lagoons, although still practiced on a small scale by individual fishermen. The technique of constructing *acadja* enclosures, or traps, from branches that are placed in water at a depth of one metre, is becoming increasingly common. The *acadja* technique contributes to the deforestation of wooded banks: a phenomenon that is especially manifest around Lake Ahémé.

Transhumance

Transhumance is perceived as destructive for the environment, owing to the fact that it reduces pastoral resources and causes massive displacements of livestock in the search for pastures and water points.

In Benin, livestock migration takes place primarily in a north-south direction. Cattle are concentrated in the northern departments, in particular in Borgou, Alibori, Atacora and Donga, which together account for 85 percent of Benin's almost 1,200,000 head of cattle. Since the 1970s and 1980s drought years, the numbers of livestock coming into Benin from the bordering countries of Niger, Nigeria and Burkina-Faso have risen dramatically: nearly 200,000 cattle and 17,000 sheep entered the country during the dry season of 1994–1995.

However, the agro-pastoral and pastoral systems of production established in these areas favorize transhumance. Cattle-raising methods are characterized by grazing during the day and a combination of two types of cattle migration: short migrations during the wet season and a longer migration during the dry season, for a duration of approximately six months.

The classified forests of these zones are used by cattle herders, the great majority of whom are Fulani. The vegetation cover has been destroyed along broad tracts of land within these forests, from the repeated trampling of the ground by cattle and by the animals systematically eating any new growth. This phenomenon creates conflict situations between farmers and stockbreeders.

Controlled Bushfires

A significant part of Benin (106,990 kilometres) is regularly subjected to controlled burning. The departments in the north and the centre especially suffer great damage from this practice, which is used to prepare fields for crops, to generate new growth for cattle grazing, or to hunt animals. This burning exposes the soil to erosion and transforms the organic mulch of the forest floor into ash, which is carried away by the first winds or rain, removing the soil's vital nutritive elements. Repeated burning so damages the vegetation to such an extent that year-by-year the composition of species alters markedly, with plants that are more resistant to burning becoming predominant, and with large areas that were once forested becoming completely barren.

4. Property Title

Two property systems exist in Benin: the customary system is based on secular rules and practices, but its lack of security leads to frequent conflicts; the system of land title is the only system that provides legal security, as set out in the law No. 65-25 of August 14, 1965. However, this law is of very limited use, as less than 1 percent of Benin is currently covered by property tenure.

This dualism explains the problems Benin faces in its system of property tenure, which lacks coherence and is ill-adapted to the needs of economic and social development. This leads to a number of practices that are harmful to the environment.

Itinerant crop farming, in combination with slash-and-burn techniques, reduces the land's vegetation cover and diminishes soil fertility. Fallow periods are severely reduced, if not non-existent. All of these factors lead to desertification.

Frequent conflicts related to the exploitation of land and water in the wetlands has caused numerous water resources to be appropriated by private groups; counter to the principle of water as a public resource.

5. Consequences of Land Degradation

Desertification results in a reduction in rainfall, a reduction in the size of water tables, the drying up of water courses and wells, climatic disturbances (the Harmatten is prolonged), destruction of forests, soil deterioration, sand deposits in streams and rivers, a loss of trees and bushes (sources of wood for fuel and construction), the diminution of land that is fertile enough to be used for agricultural purposes, and the loss of certain plant and animal species.

5.1 ECOLOGICAL CONSEQUENCES

The reduction in annual rainfall has had a negative effect on agriculture, the growth of natural vegetation and the condition of water resources, and has raised serious questions over how land is distributed among different activities. High demographic growth and soaring rates of urbanization have harmed the ecological balance, exerting increased pressure on already weakened natural resources.

5.2 SOCIO-ECONOMIC CONSEQUENCES

The impoverishment and deterioration of the soil, the reduction of vegetation along watercourses and the loss of sources of wood progressively impoverish the rural and semi-rural population. In the countryside, rural migration deprives the agricultural industry of its workforce.

For reasons of both survival and social convention (weddings, funeral, etc), rural people often sell their produce before it is harvested, or even their small land holdings, thus depriving themselves definitively of their principal source of income. This situation is likely to worsen, as cities and neighbouring countries no longer welcome new immigrants. A complete review of Benin's laws governing property ownership is vital.

6. Rehabilitating Degraded Lands in Benin

In accordance with Article 18 of the Convention, the parties agree, in accordance with national legislation and policies, to promote the acquisition, the adoption and the development of ecologically rational, economically viable and socially acceptable technologies to fight desertification and to mitigate the effects of drought, and to contribute to sustainable development in the drylands.

To this end, various means have been provided to rural communities to fight against land deterioration. Methods and tools that encourage a participatory approach have been developed, enabling the rural people themselves to play a greater role in the research / action process, taking the sociological problems of the areas concerned into account. These methods and tools include:

1) "Mucuna" technology to improve soil fertility and control weeds
2) Measures to control erosion by planting vegetation along contour lines
3) Plantation of vegetation to provide supplementary fodder

4) Production and use of organic fertilizers, in particular farm manure
5) Improved housing
6) Expanded use of bio-gas technology
7) Methods to farm honey without the use of fire
8) Expanded use of solar energy

An understanding of the need to protect the environment through sustainable development is not new to Benin. Land-usage rights, rules and codes were traditionally developed corresponding to the country's different ecosystems. Certain communities today employ land-management techniques that work towards conserving biological diversity. These technological and sociocultural skills have often been given religious endorsement to guarantee their approval. In the cultures of the Aja-Tado and Yoruba people, for example, four fundamental elements give and govern life: water, fire, air and earth. Life itself is seen as resulting from the harmonious combination of these elements, which guarantee the material, physical, moral and psychological well-being of every member of society. The people of north of the country share this perception of nature, and their beliefs and myths correspond to it.

Traditional communities are thus largely aware that nature constitutes the backbone of their lifestyle and of their beliefs. Fire, earth, air and water are sacred — they are each identified with a god and are feared by all; for their partial or total disappearance or simply their deterioration can threaten life. Farming techniques and regulations governing natural resources have been developed on the basis of these traditional principles, through which it has been possible to preserve the balance of certain ecosystems.

The technique of terrace farming used by the people of the mountainous areas of the north-west is a striking example of this, as is the technique used by the Lokpa of planting associated crops on large hillocks — a form of intensive management of the lower slopes and vales. Strict rules surrounding the cutting of certain plant species for well-defined uses, which is characteristic of some communities, is a way of conserving diversity and protecting the soil. Sacred forests, used only for particular social and religious functions, have proven to be another effective means of environmental conservation and protection.

To achieve our general objective of restoring and rehabilitating degraded lands we must carry out activities in a number of areas: developing and managing water resources, securing energy requirement, securing food sources, conserving and protecting natural resources, land use, reinforcing the capacities of those involved in land rehabilitation at various levels, fighting poverty and establishing property ownership laws.

An example illustrates the efforts made in the fight against desertification in Benin: the areas struck most heavily by land degradation are in regions in which the system of leaving land to periodically lie fallow has disappeared. Cultivable land, once believed to be available in unlimited quantities, has today become rare, as farmers find themselves in competition for land with people from the towns, working in businesses or the public sector, who see cotton production as a way to gain additional income. Year-by-year, new cotton producers appear.

It would be idealistic and perhaps impossible to abandon the cotton trade, which brings money into the country and a substantial income to many households. Convinced of the cotton industry's negative impact on soils, biodiversity and natural resources, the Government of Benin, through the Ministry of the Environment, has undertaken a vast tree-planting promotion program.

The tree-planting project is a direct response to environmental concerns. Cashew trees have been planted widely throughout these regions, and have been offered free of charge to local communities, with the aim of diversifying agricultural production. The one criterion is that the area to be rehabilitated must be clearly determined and defined from the outset. Weeding, planting and care of the seedlings and trees, and protecting them against transhumant agricultural and pastoral practices and bushfires are the responsibility of the local communities. Also, cashew trees bring vegetation cover, provide an income and protect land against all forms of deterioration. Cashew plantations tolerate being planted in conjunction with other crops, such as grains or oil-producing plants.

This type of agricultural venture does not lead rural people into debt through the acquisition of chemical products, and does not expose them to the anguish that a poor harvest of a crop ill-adapted to the area's climatic hazards brings.

Conclusion

Land rehabilitation today requires us to learn from the experiences of the past. This is why, within the framework of the participatory process of the National Action Programme (NAP), we must take account of, and respect the value of, endogenous knowledge expressed by local communities, and respect the needs of these people.

The cost of new agricultural ventures, the difficulty in controlling agricultural practices and the absence of any practical application of agronomic research will remain the greatest obstacles to the sustainable development of the economies of countries in the process of development for some time. For these reasons, it is necessary to insist upon the importance of indigenous knowledge in rehabilitating degraded land.

13 Degradation and Rehabilitation of Drylands: The Nigerian Experience

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Introduction

All terrestrial life depends on the fragile, friable crust of soil that covers the continents. More than a hundred and ten countries have drylands that are potentially at risk from desertification. The United Nations Environment Programme (UNEP) estimated that desertification, a major form of land degradation, could cost the world forty-two billion dollars a year in lost productivity. The social cost may be even higher and harder to quantify. Many dryland populations have been or are in danger of being driven from their land with the effect of increasing migration to urban areas and / or to other countries. The lack of control over land by the majority of people and the breakdown of rural societies in affected areas contribute to poverty, social and ethnic conflicts, political instability and worsening environmental degradation.

1. Nigeria's Physical Environment

Nigeria, located between 4° and 14° north latitude and between longitude 2° 2' and 14° 30' east, has a surface area of approximately 923,770 kilometres. About 35 percent of this land mass is believed to be arable, while 15 percent is used for pasture, 10 percent as forest reserves, 10 percent for human settlements and the remaining 30 percent is considered unfit for cultivation.

By virtue of its size, the country encompasses various climatic regimes and geographical units: representing a wide variety of ecological zones such as rainforest, Guinea savannah, Sudan savannah and Sahelian vegetation. The semi-arid Sudano–Sahelian area is, by its nature and characteristics, susceptible to the desertification process. This zone is most vulnerable to climatic and human pressures arising from rapidly increasing population and intensive economic activities.

2. The Drylands of Nigeria

According to the Food and Agriculture Organization of the United Nations (FAO), drylands are defined as arid and semi-arid areas that average less than 1,500 millimetres of rainfall per year, depending on altitude and latitude. Nigeria's drylands are in the Sudano–Sahelian area. The area of the continent that is most prone to droughts and desertification, the Sudano–Sahelian area extends across sixteen of Africa's thirty-six states and territories, although environmental conditions are harsher in the north than they are in the more humid southern areas. The evapo-transpiration (Et) potential in these areas is much higher than the annual rainfall, which leads to a water-balance deficit of about 230 millimetres in the southern part to about 1,309 millimetres at the northern edge of the region.

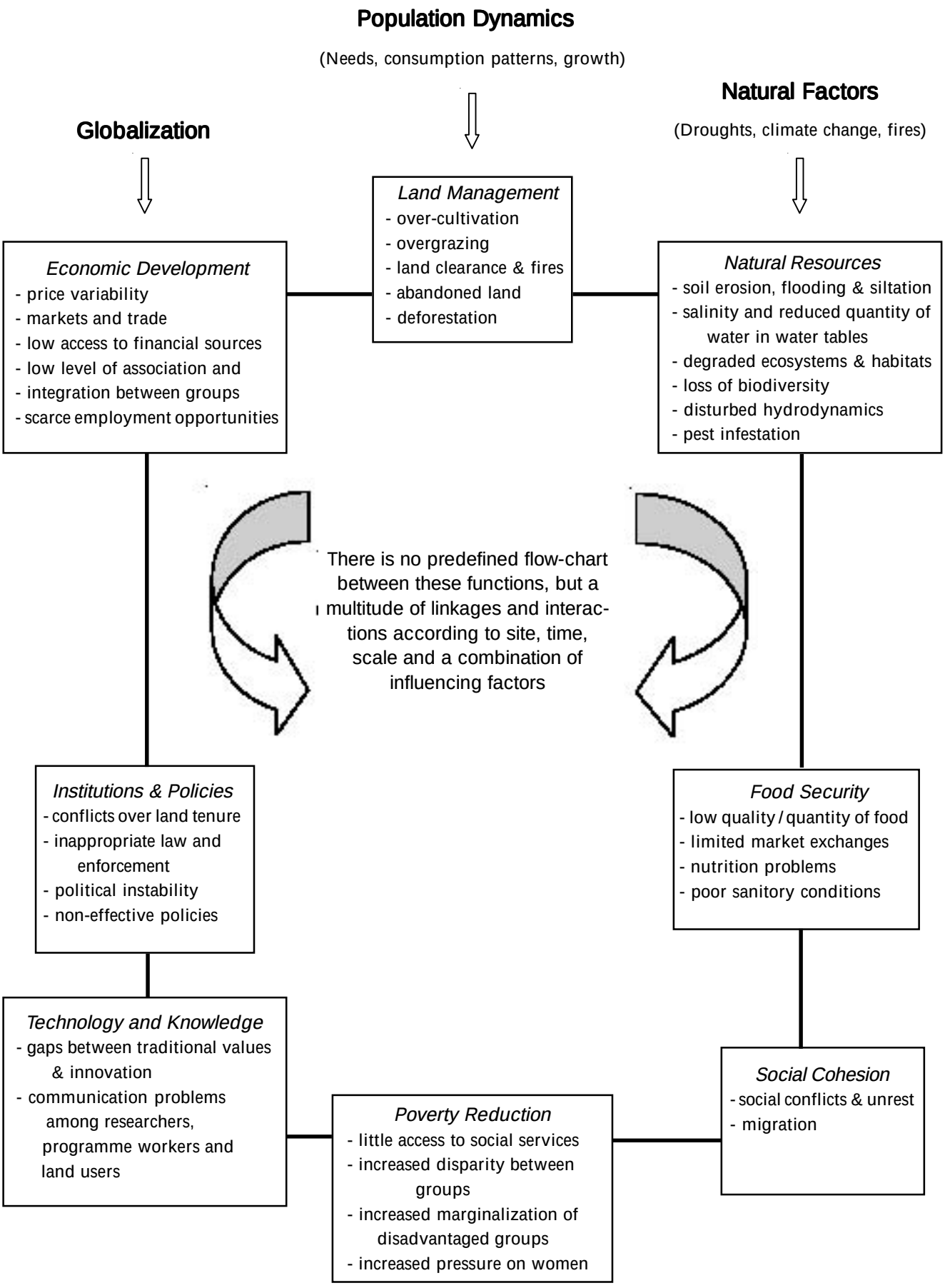
The high water deficit associated with this region has compelled local, state and federal governments to explore and exploit groundwater resources. Currently, the extraction of groundwater through boreholes and hand-dug wells is tapping one or more of the aquifers underlying the area, which results in over-exploitation. For example, a decline of 1.5 metres was recently recorded in the dynamic level from boreholes in Maiduguri, in northeastern Nigeria. Currently, the situation is probably worse in most parts of the drylands.

The soils in most parts of the drylands, though well drained, are sandy, low in organic matter and characterized by low water-holding capacity. The only exception is *fadama* soil, which is fine-textured with a higher organic-matter content and a relatively higher water-holding capacity. It is also a region in which farmers have encroached on grazing reserves and climatically marginal areas, leading to an increase in pastoralist-farmer conflict and exacerbating the desertification process.

3. Desertification in Nigeria

The climatic characteristics of the region make Nigeria one of the most vulnerable areas to desertification in the world. It has a long dry season lasting from October to May and a relatively short wet season from June

Figure 1: Land Degradation Process in Drylands (FAO, 1999)



to September. Rainfall is both sparse in volume and erratic in distribution. Furthermore, the rainfall pattern is characterized by spatial and temporal variations in distribution that often entail a drastic reduction in the growing season; giving rise to low yields, malnutrition or even famine. The area is therefore fraught with high risk and uncertainty, which makes agriculture and other economic pursuits very precarious.

4. The Extent and Severity of Desertification in Nigeria

The actual extent and magnitude of desertification in Nigeria is still being established. However, it is known that desertification, which is affecting the country's eleven northern states, is considered Nigeria's most pressing environmental problem, and accounts for about 73 percent of the US$5.11 billion that the World Bank has estimated Nigeria loses annually due to environmental degradation. It is also estimated that the country is currently losing about 351,000 hectares of its landmass annually to desert and desert-like conditions. Such conditions are advancing southwards at the rate of approximately 0.6 kilometres per year.

The most visible sign of this phenomenon is the gradual shift in vegetation in these areas. The original vegetation of grasses, bushes and occasional trees gives way to a vegetation composed entirely of grasses and bushes, then, in the final stages, to expansive areas of desert-like sand. Research has indicated that between 50 percent and 75 percent of Nigeria's eleven northern states are affected by desertification. These states, with a population of about thirty million people, account for about 40 percent of the country's total land area. Vulnerable as the area is, it supports about 90 percent of Nigeria's cattle population, two-thirds of its goats and sheep and almost all of the donkeys, camels and horses found in the country.

5. Causes of Desertification in Nigeria

In Nigeria, as in other dry areas of the world, the process of desertification is a result of the interaction of several factors, both natural and human — anthropogenic.

The causes of desertification that are most commonly identified include poor physical conditions in terms of soils, vegetation, topography and inherent extreme variability of climate as manifested in frequent drought, and anthropogenic disruption in the ecological balance caused by poor land use and ever-increasing demands being made on the available resources by the expanding population and socio-economic systems of the affected areas:

- over-cultivation,
- over-grazing,
- deforestation,
- inappropriate irrigation practices and
- improper land-use practices and poor land management.

Table 1, below, summarizes the major causes of desertification in Nigeria:

Table 1: Issues Relating to Desertification in the Drylands of Nigeria

Issues	Causes
Over-cultivation / cultivation of marginal lands	* Population pressure resulting in elimination of fallow period. * Declining soil fertility which forces farmers into cultivating marginal lands.
Overgrazing	* Increasing livestock population. * Concentration of livestock in range lands and watering points beyond the carrying capacity of the land. * Increasing migration of livestock from neighbouring countries such as Chad, Niger, Cameroon.
Salinity	* Poor irrigation design, management and monitoring.
Deforestation	* Excessive fuel wood extraction. * Extraction of wood for building. * Bush burning. * Uncontrolled land clearing for agricultural purposes.
Crop losses	* Pest and disease invasion. * Drought.
Poverty	* Unfavourable government economic policies. * Land degradation resulting in poor harvests. * Inadequate opportunities for off-farm income-generating activities. * Lack of access to credit facilities.

6. Impact of Land Degradation and Desertification

The impacts of land degradation in Nigeria include, among others:

6.1 SOCIO-ECONOMIC IMPACTS

Desertification and land degradation have socio-economic impacts in the form of low agricultural productivity and disruption of societal structure. Studies have shown that the most usual, though probably not the least traumatic, response to the hazards of drought and desertification is migration. Most movements in this area are directed to the urban centres in the northern and southern states. The other pattern of migration is rural–rural, particularly directed to the *fadamas* and river / lake basins for grazing, the cultivation of cowpeas and maize and also for fishing. A survey of migrants conducted on the floor of Lake Chad in 1989 showed that migrants were mainly from the frontline states of Bauchi, Gombe, Kano, Jigawa and Sokoto, Zamfara and Kebbi.

6.2 RESOURCE USE CONFLICTS

Desertification and land degradation are known to engender economic problems and social strife. It has been reported that conflicts over land resources in the drylands are likely to focus on areas of high productivity, especially if these areas provide a critical seasonal resource.

The most valuable and productive resource in the dry region is the wetland (*fadama*). The competitive uses of the *fadama* are a source of potential conflicts among the various rural land users. These include conflicts among settled farmers, between farmers and pastoralists, between farmers and fishermen and between fishermen and pastoralists. This is often accentuated by a lack of proper natural resource planning and management, rapid population increases and a diminishing environmental-resource base.

6.3 DESTRUCTION OF HABITAT AND LOSS OF BIO-DIVERSITY

The flora and fauna of the Sudano-Sahelian region has been badly depleted as a result of climatic change and human mismanagement and / or over-exploitation of the environment. Some fauna species such as the antelope, cheetah and lion are now almost extinct, while others like giraffe and elephants are endangered. Among other endangered species are the crowned crane, the bustard, the ostrich and the tree duck. With regard to the flora, most of the indigenous plant species identified some decades ago are now hard to find, especially those with medicinal or edible value, such as *Acacia senegalensis* and *Adansonia digitata*.

7. Efforts at Combating Desertification in Nigeria

Nigeria's federal government has in recent years taken bold steps towards protecting the environment, with a view to facilitate sustainable development. It is therefore pertinent to review some of the government's major efforts, with the aim of identifying new initiatives that are considered desirable.

7.1 POLICIES, PLANS AND STRATEGIES

The government has recognized the multi-sectoral problems of desertification and has established a number of policies and plans in spheres ranging from agriculture to energy: the National Policy on the Environment, the National Agricultural Policy, individual state environmental action plans, the National Forestry Action Plan, the National Conservation Strategy, the Natural Resources Conservation Action Plan, the National Water Resources Master Plan, the National Biodiversity Strategy and Action Plan, the Green Agenda of the Vision 2010 Report and National Agenda 21.

7.2 LEGAL AND INSTITUTIONAL FRAMEWORK

Even before the United Nations Convention to Combat Desertification (UNCCD) was established, a number of Nigerian national and state laws and regulations relating directly or indirectly to desertification control were already in force. Many of these laws contain provisions that directly address the causes of desertification; such as deforestation, the over–exploitation of natural resources, inappropriate agricultural practices, bush burning, etc.

The establishment of the Federal Ministry of Environment is the most far-reaching initiative undertaken by the Government to address the multifarious environmental problems. The Ministry is charged with the responsibility of environmental protection, biodiversity and natural resources conservation, including policy matters relating to desertification control, and is also in charge of the implementation of the UNCCD.

As part of the implementation strategies of the UNCCD, a National Co-coordinating Committee on Desertification Control was established to advise and co-ordinate implementation activities, as an apex technical advisory committee. This Committee comprises representatives of federal and state ministries as well as representatives of agencies, relevant research institutes, and non-governmental organizations (NGOS). Other Nigerian initiatives include the establishment of the National Parks Service Board and enactment of legislation protecting natural resources: including the Endangered Species Act (Control of International Trade and Traffic in Fauna and Flora), the National Water Resources Decree and Environmental Impact Assessment (EIA).

7.3 MANAGEMENT OF WATER RESOURCES

The United Nations Water Conference held in 1977 called for socially, economically and environmentally sound planning, development and management of water resources as among the measures that should be taken to combat desertification. Nigeria's River Basin Development Authorities (RBDAS), under the supervision of the Federal Ministry of Water Resources, are actively involved in the development of water resources particularly for irrigation in the drylands. These efforts include the damming and diversion of rivers, and in some areas the exploitation of underground water. The RBDAS are also involved in the improvement of community water supplies and provision of watering points in rangelands.

In the same vein, Nigeria's government, in collaboration with World Bank Assistance, initiated the National Fadama Development Project, supervised by the Agricultural Development Programmes (ADPS) of the states, for the purpose of optimally utilizing the water resources of the wetlands for small-scale irrigation. This project enhanced food production capability in the affected states, thereby increasing family income and alleviating poverty. The project also provides gainful employment for the rural populace during the dry season, thereby cutting down on the number of rural people who engage in off-season trade in firewood.

7.4 FORESTRY PROGRAMMES

An Arid Zone Afforestation Project (AZAP) was instituted by the Federal Government in 1976 to tackle the problems of desertification through the establishment of wood lots, shelterbelts and windbreaks. Over ten million seedlings were raised annually between 1978 and 1984. Approximately 150 kilometres of shelterbelts and 3,680 hectares of wood lots were established, as well as 24 boreholes and 70 tree nurseries.

The European Community has financed a pilot project in Katsina State covering a total area of 1.6 million hectares, involving the establishment of shelterbelts, windbreaks, wood lots and trees on farmlands. In addition, the World Bank is also financing a similar project in another five arid-zone states. The emphasis is on farmer participation and extension. Areas of focus include land-use and energy policies, a sylvo-pastoral system, sand-dune fixation, a tree-planting campaign and the prevention of bush fires.

7.5 DRYLAND AGRICULTURAL DEVELOPMENT PROGRAMME

Nigeria's Federal Government, in collaboration with World Bank assistance, has expended enormous resources to establish Agricultural Development Programmes (ADPS) in all thirty-six states and the Federal Capital Territory. The ADPS operate Training and Visit (T and V) systems as part of the unified extension system covering the areas of crop production and protection, livestock production and animal health, fisheries, agro-forestry and gender-related issues in agriculture, popularly referred to as '*Women-In-Agriculture*'. This unified extension system is employed for the dissemination of proven agricultural technologies (aimed at ensuring sustainable development) to small-scale farmers who are responsible for well over 90 percent of the national food production.

7.6 ALTERNATIVE ENERGY SOURCES PROGRAMME

Although Nigeria is blessed with abundant renewable energy resources, there is currently a heavy reliance on fuel wood and fossil fuels. Sourcing of fuel wood for domestic and commercial uses is a major cause of desertification in the arid-zone states. The Energy Commission of Nigeria (ECN) has put in place many programmes for the purpose of promoting optimal utilization of renewable energy resources, with a view to reducing the deforestation associated with fuel wood sourcing. A number of completed and on-going projects facilitated by the ECN include training programmes on renewable energy technology and biogas and biomass utilization projects.

7.7 POVERTY-ALLEVIATION PROGRAMMES

The Nigerian government has realized that poverty alleviation is a major weapon for combating desertification. Consequently, a number of poverty alleviation programmes have been established. Notably among them are the Northeast Arid Zone Development Programme (NEAZDP), the Model Village Programme, the Sokoto Environmental Protection Programme (SEPP) and the Katsina State Agricultural and Community Development Project (KSACDP).

The government has also been embarking upon economic-empowerment programmes such as the Family Support Programme, the Peoples' Bank and community banks to enable the rural poor access to credit facilities. Under the present administration, these have now been brought under one umbrella — the National Agricultural, Co-operative and Rural Development Bank. Furthermore, the government has fashioned out a comprehensive Poverty Alleviation Programme as one of its top-priority programmes.

8. Past Experiences and Constraints

Several of the sectoral programmes discussed have had limited success, largely due to a number of constraints. These include a top-down approach to environmental-resource management, a lack of proper co-ordination and monitoring, frequent policy shifts, inappropriate technology and the neglect of indigenous technology in the development process.

8.1 TOP-DOWN APPROACH

Environmental conservation strategies in Nigeria have until now been top-down, without consultation among conservationists, planners, policy-makers and stakeholders, thus tending to be inconsistent with the basic needs of the people. This results in a lack of co-ordination, and the overlapping or duplication of efforts.

8.2 FREQUENT POLICY SHIFTS

Environmental conservation efforts have been adversely affected by frequent shifts in the government's policy positions. Such policy shifts have been as frequent as the change in leaders —the country's economic fortune or misfortune usually dictates such shifts.

8.3 THE NEED TO PLAN FROM THE BOTTOM UP

Arguments in favour of the participatory approach to development in general, and to combating desertification and mitigating drought effects in particular, are based partly on the failure of previous top-down approaches to development. This requires decentralization, transferring authority to a lower level of government or institution.

8.4 USE OF INAPPROPRIATE TECHNOLOGY

The Government's response to the droughts of 1972–74 and 1983–85 and the accompanying ecological and human disasters was technological. However, technological innovation as the human response to environmental hazards has exacerbated rather than ameliorated the hazards of desertification in Nigeria. Furthermore, technological manipulation of the environment in the form of inappropriate irrigation schemes often produce new hazards such as salinity, water-borne disease and weed infestation, while accentuating animal, human and plant disease. Construction of upstream dams has meant the loss of the productive base — and so of productivity — of those downstream.

8.5 NEGLECT OF INDIGENOUS TECHNICAL KNOWLEDGE (ITK)

A concomitant effect of inappropriate technology is the neglect of indigenous technical knowledge, which is a major bane of environmental conservation strategies in Nigeria. It has been reported that indigenous technical knowledge (ITK) is the single largest knowledge resource not yet mobilized in development strategies.

9. The Way Forward

9.1 PARTICIPATORY AND BOTTOM-UP APPROACH

The UNCCD sees desertification and drought as development problems, and therefore calls for an integrated approach to combat desertification and to mitigate the effects of drought. This approach is not only multi-sectoral but also multi-disciplinary and participatory. Nigeria has already adopted this approach in the following ways:

- Making better decisions that take greater account of local circumstances
- Giving greater autonomy to the local level, to make the system more adaptable
- Establishing more effective resource management and use
- Encouraging effective local participation in the decision-making process, including planning and implementation of resource use
- Developing and implementing a National Action Programme (NAP) to combat desertification

Nigeria's NAP, currently being published, attempts to identify the factors contributing to desertification, and evokes the practical measures necessary to combat them, as well as specifying the roles of government, local communities and land users.

9.2 STANDARDIZATION AND RATIONALIZATION OF EFFORTS

The recent establishment of the Federal Ministry of Environment has brought together all relevant departments and units whose mandates relate to combating desertification and land degradation in general. Furthermore, the Nigerian government has adopted a bottom-up, collaborative and partnership-based approach, as advocated by the UNCCD and the Climate Change and Biodiversity Conventions, as well as other relevant environmental Conventions ratified by Nigeria. These provisions now serve as the guiding principles of government activities relating to environment protection and management.

9.3 PRIORITY PROJECTS AND THEIR IMPLEMENTATION

To further strengthen government efforts to combat land degradation, a number of priority projects have been identified for implementation in the short term. The outputs of these projects are expected to provide the necessary information for future plans, as the country battles with the implementation of the UNCCD and other relevant Conventions. Some of the priority programmes identified include:

- Assessing the extent and intensity of drought and desertification nationwide
- Alleviating poverty
- Establishing greenbelts, wood lots and shelterbelts in affected areas
- Researching and implementing alternative energy sources

- Ensuring sustainable agricultural development in the drylands
- Afforestation and biodiversity conservation
- Research and development in appropriate technology
- Providing and promoting environmental education and information and improving public awareness
- Sub-regional programmes on trans-boundary management of natural resources, sustainable water resources utilization and livestock and market development

Conclusion

More than ever before, Nigeria is determined to tackle its serious environmental problems, and particularly land degradation, industrial and domestic waste and biodiversity loss. With our new political position, the situation is now conducive to effective collaboration with the international community, United Nations agencies and NGOS in achieving the country's dream of a healthy environment for sustainable development.

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14 Land Degradation and Rehabilitation in the Drylands of Mali

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1. Introduction: Land Degradation

Land degradation is generally manifested by land erosion. Often a result of the over-exploitation or poor use of land — through farming practices such as monoculture, short fallow periods or over-grazing — land erosion is the attrition, the transport and the deposit of soil and rock particles from the soil surface. While the principle causes of erosion are physical phenomena, chemical phenomena also play a part.

The vulnerability of a plot of land to erosion depends on several parameters:

- The intensity of the weather conditions it is subjected to (essentially the force of the wind and violent rains);
- The presence of vegetation cover, or the nature of the vegetation that is present;
- The soil type and its surface structure;
- The incline and length of the slope over which water runoff flows.

The Sudan–Sahel region is particularly vulnerable to erosion:

- The climate is characterized by very irregular rain patterns with rains that are particularly intense;
- Storm fronts are preceded by very violent winds that may last for hours;
- Bush fires and the majority of farming techniques leave the soil bare for many months;
- The soil is predominantly sandy (in agricultural regions at least) and is therefore unable to bind and poor in organic matter and clay, which would help increase binding;
- Climate conditions induce crust formation on the soil surface, which seriously affects the permeability of the topsoil.

Erosion is also caused by wind:

- The northwest Harmattan wind is dry and regular and continues for several days during the dry season, desiccating the soil and transporting very fine sand;
- Storm fronts during the rainy season generally come from the southwest.

These brief, irregular storms (lasting from several minutes to one hour) are very violent. The winds transport large quantities of sand before the rain starts to fall. These water and wind phenomena work towards soil degradation.

2. Rehabilitating Drylands

Land rehabilitation in the drylands is attained by fighting erosion and by restoring soil to render agricultural land fertile. The list of techniques, often age old, used to fight erosion the world over is long. However, in West Africa, their implementation is recent and timely. A lot of research still needs to be undertaken and a lot of experiences need to be consolidated if we are to face up to situations that are as much human as ecological.

Agro-forestry plantations would consolidate the techniques described in this paper, wherever possible, reinforcing their effects.

2.1. MULCHING OF LAND PLOTS

To prevent topsoil erosion, the topsoil can be covered with vegetation waste: crop residues, straw and various stalks and branches. Spreading a layer of mulch on the soil surface after harvesting:

- Traps soil particles that would otherwise be carried off by the wind;
- Limits the impact force of heavy rainfall;
- Creates a surface-level microclimate that conserves humidity and improves the soil structure (this results in better water infiltration and less runoff);
- Provides feed for termites that transport digested organic matter into the soil.

This technique is practised locally with millet stalks on harvested fields and with branches on pastoral routes. The major inconvenience of this land conservation technique is the difficulty that is encountered the following winter in working land cluttered with plant waste.

Before the mulched fields can be replanted, the mulching residue is raked into long piles laid out along the length of the land's contour lines. As well as clearing the land for sowing (and to facilitate weeding), this maintains reserves of organic matter (mulch) and acts as an obstacle to water erosion.

2.2. LIVE FENCES USED IN CONJUNCTION WITH GRASS STRIPS

The use of a combination of live fences and strips of grassland is a land-rehabilitation technique that aims to trap wind-born silt particles within a short distance of them being lifted from the topsoil, and before they leave the field itself. As such fences are an obstacle to the formation of small watercourses by runoff, a strip of perennial grasses is planted alongside them, following the land's natural contour lines and guiding runoff flow.

The live fence is laid out with a distance of twenty-five centimetres to one metre between each plant. The grass strip is composed of tufted grasses with perennial root systems — the tufts act as a filter at the soil surface. Suitable grass species include *Andropogon gayanus* and *Pannicum maximum*, already used by villagers to border fields.

2.3. FASCINES

Fascines are used as barriers to prevent runoff from flowing into gullies. Fascines are barriers constructed from tightly entwined sticks and branches, between which supplementary branches can be added. They are less than one metre high and about the same width. Fascines are constructed in two to four parallel rows, only one or two metres apart.

2.4 STONE RIDGES

Stone ridges, usually less than fifteen centimetres across, are similarly constructed in two to four parallel rows, following the land's natural contour lines. They have the same anti-erosion objective as shelterbelts edged with a grass strip.

Stone ridges are filtering dykes; they allow surplus water to pass through, to prevent an excess of water from accumulating above them and to facilitate slow drainage towards the fields located below. The ridges are twenty to forty centimetres high and twenty to fifty centimetres metres wide. On fields at an incline of less than three percent, the ridges are constructed with an average density of one every twenty-five to fifty metres — or two hundred to four hundred linear metres of ridges per hectare.

The ends of each ridge turn upslope slightly, to hold the water in and prevent it from flowing around and out of the ridge. Stone ridges can withstand water runoff on slopes at an incline of 3 percent to 12 percent — or more, if the mounds are constructed more closely together and are reinforced.

2.5 EARTH CONTOUR BUNDS

Earthen contour bunds are long mounds constructed along the land's natural contour lines from packed and dampened clay. The work is achieved manually with shovels, spades and picks.

Contour bunds are not filtering dams; they retain overland flow and any silt transported with it. During periods of heavy rainfall, contour bunds risk being damaged. The following conditions are necessary for their construction:

- Low-gradient slopes, of less than 3 percent incline, or better still, less than 1 percent;
- Large stones should be placed at either end of each bund to prevent damage from water overflow;
- Small stone spillways should be incorporated at regular intervals along the longer bunds (with a one-meter stone spillway every fifty metres, for instance);
- The upper side of the bunds should be reinforced with stones wherever possible;
- Once the upper bank has been dammed, perennial grasses should be planted along the top and on the lower side of the bunds.

Each individual earth contour bund should be 0.3 to 0.4 metres high and 0.4 to 1.0 metres wide. On a slope with a gradient of less than 1 percent, they would be spaced 50 to 100 metres apart. The length of the contour bunds depends on the size of the fields to be restored (from fifty to two hundred metres). Each bund is constructed from earth dug either upslope (bunds with upslope trench), or downslope (bunds with downslope trench).

The principal inconvenience of earthen dikes is that they erode easily.

2.6 DRY-ROCK DAMS

Dry-rock dams are a series of low bund walls less than two metres in height, made of dry rocks and stones. As the rocks and stones are neither cemented together nor blocked by gabion baskets, their height is limited to a maximum of one metre.

Dry-rock dams, also known as 'filtering floodwater spreaders', stop land from eroding into gullies and spread floodwaters across valley floors, reversing the formation of already-developing gullies. They are

positioned across the valley floor, anchored at the base and the sides. A build up of silt forms behind the bund over each wet season.

Depending on the initial state of the valley floor, permeable rock dams can:

- Efface small gullies in one wet season, recovering cultivable land;
- Gradually fill in larger gullies, through successive wet seasons.

To build each rock wall, or bund, a trench twenty centimetres deep and forty centimetres wide is dug across the valley floor and along the sides of the valley. Large stones (fifteen to thirty centimetres across) are fitted firmly together to form the casing of the wall, with smaller stones then tightly packed between them (a mallet or stone is used to hammer the smaller stones in place). An apron of rocks extends on the downstream side of the wall for two to three metres, to temper the erosive force of the overflow — this is essential to maintaining the wall, as otherwise the gully could enlarge and the wall collapse.

There are three essential rules to follow in building the rock bunds:

- It is always better to construct several small successive bunds, rather than one large stone wall;
- It is best to start at the top of the valley, as the objective is to stop the gully from extending back towards the direction of the floodwaters;
- The stone walls should be built at such a distance that the base of each wall is at the same level as the top of the one below it.

2.7. SEMI-CIRCULAR BUNDS

Semi-circular bunds are used on flat land or land with only a slight incline, to rehabilitate degraded arid and semi-arid areas for rangeland and, eventually, crops. Their aim:

- To establish rain-fed agricultural production in a region with insufficient water, by increasing the quantity of rainfall that the land receives
- To recuperate land for pasture (fodder crops) or forestry (tree plantations)

2.8. *TASSA* OR *ZAÏ* PLANTING PITS

Tassa and *zaï* are local terms used in Niger (*tassa*) and Burkina Faso (*zaï*) for small planting pits. They are usually dug on land with a slight incline only, and return to cultivation once they have been refilled.

The *tassa* or *zaï* is prepared during the dry season and is classed as a field-preparation technique. The size of the pit determines the amount of water it can collect and store. The technique can be supplemented by adding manure to the pit.

This very simple traditional technique protects young plants from the effects of wind and, by virtue of the humidity of the deeper soil, enables seedlings to survive a certain level of drought conditions. However, the work involved is substantial (several hundred hours per hectare) and digging the pits is sometimes difficult to achieve. The use of a pickaxe is strongly recommended.

15 The Day Forest, Djibouti

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1. The Republic of Djibouti

1.1 PHYSICAL ENVIRONMENT

The Republic of Djibouti is situated between longitude 40 and 43° east and from 11° to 12° 40' north latitude. The country's total surface area is 23,000 square kilometres. Temperatures reach an average daily maximum of 25.6°C in January and 35.6°C in July, with an average rainfall of 100 to 200 millimetres annually, depending on the ecological regions (with a monsoon region to the east and a climate of hot, wet summers to the west). Rainfall is irregular and there is an absence of continual watercourses. A dense hydrological network of *wadis* covers the country — watercourses that are dry except for during the rainy season, and which flow from two to eight times a year depending on the region.

- Hygrometry: up to 70 percent (particularly in coastal areas), lower in the interior.
- Evapo-transpiration (ETP): intense (in the order of 2800 millimetres a year)
- Soils: mountainous relief composed of volcanic rock with a few collapsed pits filled with alluvial deposits — quaternary colluviums, the only ones fit for agricultural purposes.

1.2 SOCIO-ECONOMIC PARAMETERS

According to the census of 1993, Djibouti's population at the time was 650,000, with a population growth rate of 3 percent. An estimated 52 percent of the population are under twenty years old.

The economy is dominated by the tertiary sector (72 percent of GDP); the primary (3 percent of GDP) and secondary (25 percent of GDP) sectors are still at an early phase of development. The sub-sectors of agriculture and fisheries are under-developed, notably due to unfavourable agro-climatic conditions and the absence of an agricultural tradition in general, as Djibouti's people are traditionally nomadic pastoral. Also, the country imports the quasi-totality of its alimentation needs. Apart from meat and fish products (which remain under-developed but are very promising), dependence on food imports is great, especially as concerns fruit, vegetables and cereals — of which national production barely covers 8 percent of the population's needs over the six to seven productive months of the year.

2. The Day Forest

The Republic of Djibouti's severe physical and climatic conditions cause it to be particularly exposed to the phenomenon of desertification. Its forests, which are principally located in the north, on the slopes of Mount Goda (1,783 metres) and Mount Mabla (1,370 metres), are already in an advanced state of degradation.

There are two types of forest in Djibouti:

- The dense dry conifer forests of *Juniperus procera* on the Goda massif (the Day Forest covers the upper slopes of the massif, from between 1,000 and 1,783 metres, with a total area of 900 hectares).
- The dense dry *feuillus* forests of the Goda and Mabla massifs. *Terminalia brownii* is predominant at lower levels, covering an area of approximately 2,000 hectares. These two forests are less dense than the Day Forest, and in certain parts present a physiognomy of dense arboreal steppes.

2.1 FLORA

The higher altitudes provide these areas with lower temperatures and relatively abundant precipitation, in the form of rain, fog, condensation and mists, and have led to forests combining Mediterranean and Ethiopian plants. According to a study of forest flora distribution undertaken by Audru *et al*. (1987), *Juniperus procera* occupies the superior stratum, the arboreal stratum is essentially dominated by *Buxus hildebrandtii*, followed by *Olea africana* as well as an ephemeral presence of *Monotheca buxifolia* and *Clutia abyssinica*. The herbaceous

stratum, which is practically continuous through the rainy season, comprises numerous species, many of which are annuals. Edaphic factors play an important role, privileging the proliferation of dominant species. According to the study, the dominant *Bidens schimpéri* species has been observed in forest openings as well as in degraded areas of *Juniperus procera*.

2.2 EVOLUTION OF THE FOREST

A vestige of ancient times when the climate was less severe and not as dry, the Day Forest is in constant regression. According to Blot (1987), two centuries ago, the forest covered 7,500 hectares; by 1949 this had been reduced to 2,300 hectares. This regression is illustrated by isolated and scattered vestiges of *Juniperus* across mounts Goda and Mabla, principally in the areas of Mitrida and Alomay.

The *Juniperus procera* forest is formed by climatic action in that its structure is closely attributed to climatic factors and the nature of the soil. Currently, this formation is strongly regressing — a result of the high mortality and lack of regeneration of junipers, from the combined effects of logging and over-grazing, the damaging effects of the fungus *Armillara species* and unfavourable climatic changes.

2.3 PASTORAL INTEREST OF *JUNIPERUS PROCERA* POPULATIONS

Despite the fact that *Juniperus procera* is not used as fodder, it still plays an essential bio-climatic role in the area. It is, in fact, the sole species capable of capturing moisture from cloud cover, which contributes to the development of herbaceous vegetation, conducive to pasture. During the drier months (periods of over six months without rain are not uncommon), perennial and ligneous plants, some of which are used by pastoralists, contribute to maintaining the ecological balance. Apart from climatic and human factors, over-grazing in the forest during prolonged dry periods seems to be responsible for serious changes in the composition of herbaceous flora (as is witnessed by the regression of *graminae*, overtaken by *Bidens schimperi*).

An illustration of the gravity of the situation affecting adult *Juniperus procera* and *Olea africana* trees was demonstrated in October 1988. In a quadrat study of two 0.25-hectare (50 m x 50 m) areas on the Adonta plateau, both at an altitude of 1300 metres, and one similarly-sized area on the Dawdawya plateau, at an altitude of 1200 metres, the following results were found:

- For the three areas, 56 percent of junipers and 13 percent of *Olea* had died;
- Tree degradation amounted to 36 percent and 68 percent respectively for *Juniperus* and for *Olea*, with outward signs of stress characterized by a large number of dead branches. Only 8 percent of the *Juniperus* and 19 percent of the *Olea* species were judged to be in a satisfactory state of health (the majority of young shoots or trees did not exceed a height of two metres);
- In the first quadrat, it was noted that thirty-eight *Juniperus* and five *Olea* — of which 88 percent exceeded two metres in height and 46 percent were dead trees — cohabited with fifty-nine *Acacia etbaica* and twenty-three *Acacia seyal* — of which all were in good health, although 73 percent did not exceed two metres.

This degradation suggests an ultra-rapid ecological transition (Baragoîta Saîd, 1999).

2.4 THE HUMAN CAUSES OF DEGRADATION

The regression observed in the Day Forest over the past twenty-five years can be attributed to several factors, the most important of which are the effects of climatic conditions and human activities. Due to the relative abundance of plant resources (compared to the surrounding area), the forest has for a long time been a refuge for pastoralists in the area. In the past, local customs regulated pastoralists' use of the forest for domestic needs. These customs have come to be disregarded, however, due to increased human and animal population pressure. For instance, a customary law once prohibited small ruminants from grazing in the forest, which was reserved for bovines. Today, sheep routinely destroy forest vegetation, preventing regeneration.

As in other developing countries, forest grazing is a common practice — a practice exacerbated by chronic drought periods. The nomadic pastoralists lead their herds into the forest undergrowth and do not hesitate to cut down trees. As regards wood, it seems that the young trees are cut for commercial reasons (which was banned by the customary code), notably for the construction of dwellings and tourist centres. Given the slow growth rate of junipers, which have a life span of one thousand years, it is rare to find trees greater than a height of two metres, the majority of which are already dead or dying. The changing attitudes of the population have prejudiced any moves to regenerate the forest, and it seems that junipers and *Olea* in Djibouti risk disappearing altogether. The forest is thus condemned to disappear if the pastoralists' animals continue to graze — damaging young shoots and thus paralysing the regeneration of vegetation cover. Trees already weakened by the unfavourable climatic conditions are also subject to attacks by parasites.

2.5 FOREST RESTORATION PROJECTS

Under the supervision of ISERST (Djibouti's *Institut Supérieur d'Etudes et de Recherches Scientifiques et Techniques;*

'National Institute of Higher Scientific and Technology Research'), research projects were carried out in the Day Forest over a seven-year period from 1980 to 1987. These studies have enabled us to better understand the dynamics and the regressive evolution of the forest. However more up-to-date data is needed if we are to understand this ecosystem, which is rapidly changing for the worse.

A programme of forest restoration and integrated forest planning was drawn up by ISERST and Djibouti's Ministry of Agriculture in 1989/90. Unfortunately, the programme was interrupted early in the preliminary phase (CES pilot projects, creation of income-generating activities for the on-site population; such as craft work for the tourist industry, bee-keeping, etc.) by armed conflict in the north of the country (1992–1994).

Recommendations

The local population of the area must be consulted and encouraged to participate in any projects aimed at protecting the Day Forest. It is only by satisfying their basic needs that we can protect what is left of this unique forest type. It is only by creating non-destructive income-generating activities that we can obtain the support of the population whose very survival depends on forest resources. For instance, it could be possible to teach cattle-herders agricultural practices (promoting an association between agriculture and herding by cultivating plants used for cattle fodder), chicken farming or modern bee-keeping techniques (the region is renowned for its traditionally made honey). As water availability is the limiting factor, it would be necessary to mobilize the collection of surface water.

One could equally direct efforts towards promoting natural regeneration to assure the renewal of the forest — as the introduction of non-native plant species jeopardizes the areas' genetic heritage (de Framond, 1990). Human activities should be limited while the juniper trees are in seed, and sheep should be controlled in wooded areas by installing temporary barriers. By establishing grazing areas that could be used for three to six months of the year, the forest's flora would be able to regenerate and degradation could be brought to a halt.

Nomadic cattle-herders should be taught the essential principles of rational use of the forest, particularly in terms of cutting branches and trees to protect regeneration.

The forest must be respected for the services it renders to the community: providing food for cattle and wood for construction and fuel. It is also a biodiversity reserve of national, if not global, importance. The Day region is home to a number of animal and bird species including the Day Francolin (*Francolinus ochropeduis*), an endemic partridge that is threatened with extinction and is included on the World Conservation Union's 'Red List' of endangered species. Numerous endemic floral species are found in the Mount Goda region, including the Giant Palm (*Livistonia cariensis),* also threatened with extinction.

Session III: Desertification Benchmarks and Indicators and the UNCCD

16 Keynote Address: Impact Indicators and Monitoring-Evaluation for Action Programmes to Combat Desertification: The Sahara and Sahel Observatory (OSS) Experience

Mr. Youssef Brahimi, Advisor, OSS

Introduction

One of the important lessons gleaned from past experiences in the field of combating desertification is the importance of monitoring-evaluation of the impacts of actions undertaken: the absence of such monitoring-evaluation has been found to be one of the reasons for the failure of certain programmes. Post-project or post-programme evaluation is often too late to enable any corrective measures to be taken. This is made all the more obvious when projects are carried out without the participation of those directly benefiting from the project, i.e. the local population.

The absence of permanent and participatory monitoring-evaluation mechanisms hinders the advancement of acquired experiences, to the detriment of a programme's relevance and performance. It is for this reason that the United Nations Convention to Combat Desertification (UNCCD) incorporates this issue as a vital part of any programme to combat desertification, according monitoring-evaluation aspects as much importance as the action in the field itself. The Sahara and Sahel Observatory (OSS), whose principal mission is to contribute to African countries' management of information valuable to combating desertification, is entirely party to the process advocated by the UNCCD to reinforce, with its African and international partners, national capacities to combat desertification.

1. Obstacles

African countries are confronted with many obstacles in the implementation of a national system of impact monitoring-evaluation, which could be used as an instrument contributing to decision-making.

1.1 INSUFFICIENT KNOWLEDGE OF EXISTING TOOLS AND PRODUCTS

The majority of the available monitoring-evaluation systems — Geographic Information Systems (GIS) and Environmental Information Systems (EIS) — are established within the context of development projects and respond only to the needs of these projects. The methods by which monitoring-evaluation is approached often differ greatly according to the project at hand, which seriously impedes the possibility of information and data exchange at the national as well as the regional level.

1.2 COMPARTMENTALISATION AMONG DIFFERENT PROVIDERS OF INFORMATION

For many years, significant efforts have been directed towards combating desertification, in terms of scientific and technical research as well as the development of context-specific projects. However, compartmentalisation between the different actors often renders data and information inaccessible to other users, and not sufficiently useful in the decision-making process as far as combating desertification and environmental monitoring are concerned. The loss of information capital is a factor leading to redundancy, time loss and the wastage of resources.

1.3 AN ABSENCE OF DIALOGUE BETWEEN PROVIDERS AND USERS OF DATA

Mechanisms of dialogue between providers and users of data are often minimal, if not inexistent. Moreover, the UNCCD has taken this situation, prejudicial for the sustainable management of natural resources, into consideration, by asking each country to implement or design a National Coordinating Body (NCB) to play a role as a catalyst in the development, implementation and evaluation of its National Action Programme (Article 9 of the Africa annexe of the UNCCD). The multiplicity of actors involved in the process to combat desertification, and the lack of co-operation among these actors, aggravates the situation. Difficulties in introducing permanent dialogue between the different categories of actors involved in the process to combat desertification are reflected in the lack of a participatory approach and the weak capacity of

organizations to negotiate at a grassroots level (to recognize and express their needs).

The multiplicity of actors involved, from local to national levels, without excluding development partners, renders the establishment of a dialogue to achieve consensual objectives even more indispensable.

1.4 LOW SCIENTIFIC AND TECHNICAL POTENTIAL

The establishment of national schemes for impact monitoring-evaluation necessitates a union of human and material resources that is beyond the capacities of the majority of African nations. Action programmes to combat desertification are understood primarily as local development programmes in areas affected by drought and desertification.

As such, they are characterised notably by a diversity of actions, which cannot simply be reduced to actions to preserve natural resources. These actions must henceforth include all factors that contribute both to the sustainable management of natural resources and to poverty alleviation in the regions concerned.

Monitoring-evaluation poses a problem in terms of scientific and technical skills and expertise in the collection, treatment and dissemination of information. A coherent vision is needed among local actors and scientists responsible for observation and monitoring-evaluation activities.

A great conceptual effort remains to be made to establish a general harmonised and validated reference structure. National Action Programmes (NAPS) operate within a wide-ranging national context, notably integrating other environmental conventions (Climate Change, Biological Diversity) and activities linked to sustainable development. These different groups maintain close relationships among themselves, particularly as concerns their respective fields of action, which often overlap. National Action Programmes, with a view to identifying impact indicators, should take into consideration the different indicators that may have been developed in this context.

It is for this reason that impact monitoring-evaluation of actions to combat desertification and the effects of drought, and the indicators that ensue from this monitoring-evaluation, constitute a priority from the UNCCD perspective. This requirement has in fact already been incorporated into Agenda 21, and is found in the environmental conventions developed from the Rio Summit.

2. Setting Up Monitoring-Evaluation Systems

Since 1998, the OSS and the CILSS (the Permanent Inter-State Committee for Drought Control in the Sahel) have lead a regional project associating five North and West African countries in the establishment of national systems of monitoring-evaluation action programmes. The following approach was decided upon, benefiting from work previously undertaken by the CILSS and the OSS, and notably work undertaken within the ad-hoc groups of the Committee on Science and Technology — Convention to Combat Desertification (CST-CCD).

2.1 SELECTING TARGET GROUPS

At the national level of these countries, the principal targeted groups are the National Coordinating Bodies (NCB). The pertinence of the choice of the NCBs lies in their composition and their strategic functions in leading the implementation process of the NAP.

Other than their co-ordination/dialogue function, NCBs are directly implicated in monitoring-evaluation. In the words of Article 9 of the Africa annexe of the UNCCD, NCBs are to establish 'pertinent, quantifiable and easily verifiable criteria to ensure the analysis and evaluation of national action programmes, comprising short-, medium- and long-term measures, and their implementation; and to prepare substantive reports on the progress of national action programmes' (Article 9, §D and §E of the Africa annexe of the UNCCD).

It is for this reason that each NCB is required to bring together the different categories of actors involved in the process of implementing the UNCCD. These include the central administration bodies of the different sectors; scientific and technical institutions; representatives of civil society (for example, NGOS) and, possibly, representatives of development projects.

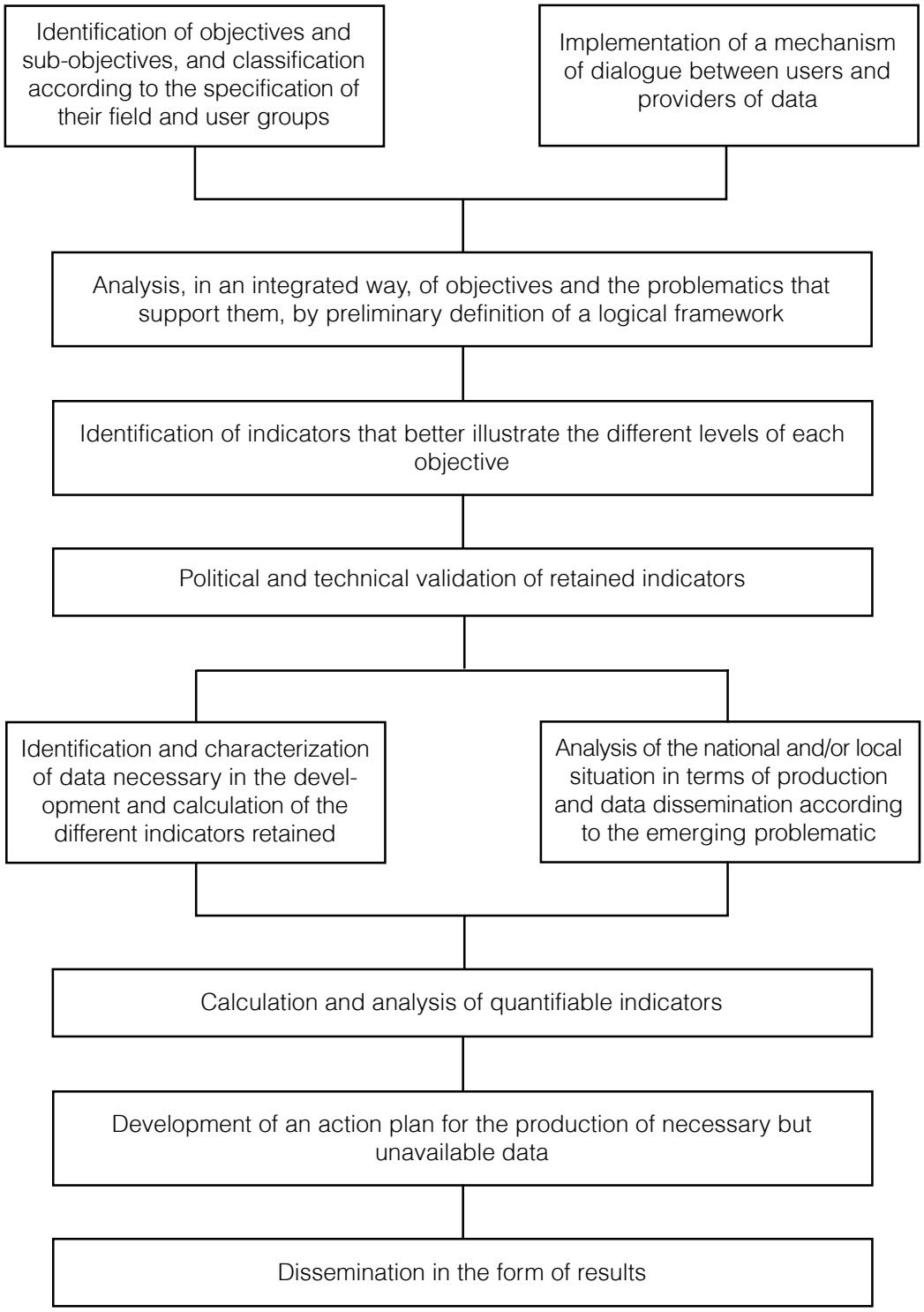
2.2 OBJECTIVES

The core objective of the project is to help partner countries set up operational systems of monitoring-evaluation of the impact of action programmes to combat desertification at the national and regional level.

The project will rely on principles of synergy and coherence between the national and regional levels. Its aims are:

- To ensure connections among long-term environmental impact evaluation systems;
- To promote the use of environmental impact evaluation, drawing on the national monitoring-evaluation systems already in place;
- To forge partnerships between countries, and at regional and international levels;
- To establish impact indicators coherent with sustainable development indicators;
- To set up a permanent network of exchange of information and experiences among countries and partners, benefiting from relevant experiences
- To eventually contribute to the development of a sub-regional action plan to combat desertification.

Figure 1: The development and dissemination of impact indicators



2.3 PRINCIPLES OF ACTION

The project is based on a global approach that is progressive, iterative and participatory, taking into consideration national capacities within the field and aiming to reinforce them to develop a comprehensive understanding of the national process of impact monitoring-evaluation actions to combat desertification.

Implementation of the project relies on the following basic principles, guiding the assembly of partners. Primary responsibility for the national monitoring-evaluation process rests with national actors, and in particularly the NCBS. The OSS and other external partners provide scientific and technical support, an exchange of experiences, training and the reinforcement of national capacities. This subsidiary role is accompanied by an iterative and progressive approach to the appropriation by national actors of instruments for the collection, treatment and dissemination of information:

- Establish a functional system of permanent dialogue;
- Adapt projects to the specific situation of countries;
- Draw on existing systems.

The methodological approach used is outlined below:

- Develop dialogue between providers and users of information;
- Analyse and study avenues that could be used to monitor desertification and the effects of combating desertification, within the context of NAPS;
- Identify, elaborate or select indicators according to the domain, level and key priority actors;
- Test the selected indicators, the developed products and the mode of dissemination;
- Ascertain the best way for key actors to present products;
- Develop co-operation between project partners in order to accelerate and support the harmonisation of the process;
- Draw lessons in order to extend the approach to neighbouring countries.

Figure 1 on the preceding page (page 85) presents the application of this approach to developing impact indicators.

Table 1: Common base indicators selected

Objective	Base Indicators Selected
Poverty elimination	Percentage of population living below the poverty level Female/male income ratio Rural exodus Nutritional condition of children less than 5 years old
Natural-resource management	Soil occupation Soil vulnerability Rainfall (temporal and spatial) Evapo-transpiration Geographic distribution of mobilised water resources (quantity and quality) Exploitation index of usable water resources Evolution of vegetation cover Evolution of plant biomass Agricultural resources Animal biodiversity

2.4 CIRCULATION OF INFORMATION ON DESERTIFICATION AND THE ENVIRONMENT THROUGH A NETWORK OF SYSTEMS

The functional organization of activities within the project will be established in the form of a network of impact indicators. This will be created in both of the countries under the responsibility of the NCB. It will comprise the principal categories of actors involved in the production and utilisation of indicators: sectoral administrations, scientific institutions, development projects, NGOs, etc. The exact composition of the national network will be defined at the start of the project, after the opening workshop.

3. Indicators

Two large complementary groups of indicators have been determined.

3.1 BASIC INDICATORS

The basic indicators consist of a minimum set of indicators common to all the partner countries, and which constitute, from their perspective, the minimum indispensable information-base required to ascertain the progression of the combat against desertification. These indicators should help to standardize monitoring instruments that combat desertification and allow comparisons to be made on the progress of action programmes of different countries. The matrix of base indicators in the table below was developed with two fundamental objectives of the UNCCD in mind: poverty alleviation and the sustainable management of natural resources. (See Table 1.)

3.2 IMPACT INDICATORS SPECIFIC TO NATIONAL ACTION PROGRAMMES

Impact indictors specific to each NAP are directly deduced from the real objectives and priorities of each country concerned (Morocco, Tunisia, Senegal, Niger and Burkina Faso). As an example, Table 2 presents the NAP indicators specific to combating desertification in Senegal.

Each country has already identified its specific impact indictors, and is engaged in establishing inventories of existing data and in calculating certain of the selected indicators.

Table 2: NAP indicators specific to combating desertification in Senegal

Strategic Objective of NAP to Combat Desertification		Impact Indicator Selected
SO1	Combating soil degradation	Rate of recuperated surface area compared to degraded surface area = $\frac{\text{Recuperated surface area}}{\text{Degraded surface area}}$
		Soil productivity
SO2	Regeneration of degraded natural formations	Regeneration rate
		Rise in biological diversity
SO3	Improvement in food security and contribution to meet domestic energy needs	Coverage rate of food needs = $\frac{\text{Production}}{\text{Energy and food needs}}$
		Importance and accessibility to different energy sources
SO4	Improvement in water access	Improvement in the coverage rate of needs
		Percentage of the population with access to potable water
SO5	Combating bush fires	Number of cases (frequency)
		Burned surface area

4. Future Steps

Lessons have been learned from this first step taken by the OSS, the CILSS and their partners to reinforce efforts already undertaken. The next step will bear on the principal directions outlined below:

- The establishment of scientific teams and the core 'monitoring-evaluation' units at the National Coordinating Body (NCB) level, or in close collaboration with them
- Reinforcement of the scientific aspects of the project, notably by improving methods of calculating the selected indicators and standards of production and treatment of necessary data
- Reinforcement of national capacities in terms of collection, treatment and dissemination of information, notably by the way of targeted training modules
- Evaluating the costs of producing hitherto unavailable data
- Reinforcement of the international support network for national groups, through the OSS, the CILSS and the Arab Maghreb Union (AMU)

The results achieved during the realization of this project are available at the OSS web site: http://www.UNESCO.org/oss

17 Aquifers of the Large Sedimentary Basins in the Southern Sahara — A Strategic Approach

Bassirou Diagana, Hydro-geologist, expert in water resources and the environment

Introduction

The area covered by the aquifers of the large sedimentary basins of the southern Sahara corresponds to the Sahara-Sahelian countries of the Sahara fringe. This area alone covers five million square kilometres and comprises, from the west to the east, Senegal, Mauritania, Mali, Niger and Chad. Guinea-Bissau and Gambia, although located further south and having a Guinean climate, constitute a privileged area in terms of rainfall, favourable to supplying the Senegal-Mauritanian aquifer basin.

The aquifer basins of Senegal, Taoudenit, Uillemenden and Chad correspond to the hydrographic basins of the large watercourses of west and central Africa (Senegal, Niger, Chari et Logone). Large-scale facilities that are operated on the watercourses that drain these basins have an impact on the aquifers, and appropriate studies are needed to limit the problem.

Although the use of these underwater reserves does not as yet pose a threat, studies need to be carried out to increase the knowledge base of their function and behaviour, which should be a state priority. Contrary to countries north of the Sahara, the southern aquifers are relatively poorly exploited.

At the moment, the knowledge we have is based on assessments of numerous village hydraulic programmes undertaken in the context of the International Drinking Water Supply and Sanitation Decade (IDWSSD: 1981–1989). These programmes, implemented for villages that had been subjected to the damaging effects of drought, constitute an important source of information for any study of aquifers. As specific research studies are expensive and are not considered by governments to be a priority when compared with the need to supply villages with equipment such as boreholes, they have been little developed.

Despite this, the general characteristics of aquifers of the large sedimentary basins are already known. In 1976, the Sudano–Sahelian area was the object of studies undertaken by the Inter-African Committee of Hydraulic Studies (ICHS). Since then, certain countries have undertaken periodic but essential regional studies to augment our knowledge of these basins.

Strategies to improve our understanding of these aquifers have already been taken by the OSS. Regional workshops have been held for almost a decade, bringing together representatives of the countries concerned and scientific partners, and constituting an effective structure to promote co-operation and the OSS concept of 'basin awareness'.

The present study was undertaken by the Sahara and Sahel Observatory (OSS) in 1997. A programme of deep-aquifer study was initiated in southern Sahara in 1992 by OSS, in partnership with ICHS, which produced the first analytical report of the level of knowledge of aquifers; published in 1994. It was presented at a workshop on the subject held in Niamey in 1996.

The final aim of this study is based on what is termed 'Basin awareness'; to create a collaborative context for the sharing of common resources, and to recognize the necessity of working together in the utilization of these resources. This 'Basin awareness' should, for each basin, be organized through the exchange of information and data.

1. Geographic Context

1.1 IDENTIFICATION OF DEEP AQUIFERS IN THE SOUTHERN SAHARA

The sedimentary aquifer basins of the southern Sahara are located to the west and the east: in Mauritania, Senegal, Mali, Niger and Chad. These water tables spread into other countries that have remained largely unaffected by the damaging effects of the Sahel droughts of the 1970s, such as Guinea-Bissau. All the aquifers of these basins are trans-boundary, although referred to by the names of the countries they have been identified with.

1.2 BASIN EXTENSIONS

All the aquifer basins of the southern Sahara are transboundary. This imposes a joint effort on the part of the countries concerned, with a view to undertaking common actions to improve their knowledge.

2.2 GROUNDWATER

Although catchment basins have not yet lead to disputes between countries sharing an aquifer basin, groundwater constitutes an essential resource for the northern regions of all of the countries concerned. They make up the only alternative water source in these areas, and large-scale demands have been made of them since the 1970s, within the context of the International Drinking Water Supply and Sanitation Decade (IDWSSD — 1981–1989). Since then, programmes to harness water have been put into operation by both governments and private organizations, with the sole aim of providing water to the population and to their cattle.

The state of knowledge of the characteristics of aquifers in the different sedimentary basins is summarized in Tables 1, 2 and 3.

Table 1: Sub-Saharan Aquifer Basins

Aquifer Basin	Countries concerned	Size of basin
Senegalo-Mauritanian	Mauritania, Senegal, Gambia, Guinea-Bissau	240,000 km^2
Toudéni	Mauritania, Mali, Algeria	500,000 km^2
Iullemenden	Mali, Niger, Algeria, Nigeria	200,000 km^2
Chad	Chad, Niger, Nigeria, Cameroon	350,000 km^2
Total		1,290,000 km^2

2. Water Resources Knowledge Base

2.1 SURFACE WATER

Despite their geographic situation and climate, the great watercourses of West Africa, which are fed almost entirely from the Foutajallon Mountains in Guinea, play a vital role in the water cycle of the countries concerned.

The catchment basins that supply the great aquifers of the sedimentary basins of the southern Sahara are presented in Table 2.

With regard to their cycle and the areas traversed, the watercourses of these basins constitute an essential renewable source of water in the region.

Table 2: Sub-Saharan Catchment Basins

Catchment basin	Countries concerned	Size of catchment basin
Senegal	Guinea, Mali, Senegal, Mauritania	34,000 km^2
Gambia	Guinea, Senegal, Mauritania	80,000 km^2
Niger	Guinea, Senegal, Gambia, Guinea-Bissau	200,000 km^2
Chad	Cameroon, Niger, Nigeria, RCA, Chad	2,500,000 km^2

2.3 CURRENT USE

The current use of groundwater reserves in the southern Sahara region is almost exclusively for human needs. Industrial and agricultural needs remain relatively unimportant, and their part of the total volume used can seem insignificant, in spite of the increasing number of industries in the region.

Furthermore, development programmes very often mask questions of the volume of water that is available and whether this is appropriate to satisfy local needs. Also, the management of natural resources is constrained by ineffective regulations and laws (determining the role of different organizations in the water sector, or ensuring better water policing).

Table 3: Usage of Aquifer Resources

		Senegal	Niger
Needs	Domestic Industrial Agriculture	1,103,106 m^3/day 62,430 m^3/day 5,331,106 m^3/day	7107-0,107 m^3/day 2,107 m^3/day 108 m^3/day
Utilization	Domestic Industrial Agriculture	463,220 m^3/day 52,020 m^3/day 130,109 m^3/day	25 L/h/day 2,106 m^3/day 5,108 m^3/day
Satisfaction rate	Domestic Industrial Agriculture	51% 40% 42%	59% covered covered

3. State of Scientific Research

Scientific research in groundwater is still not a priority for governments, who focus more on equipping villages with boreholes.

However, despite a limited budget, and in association with European research institutes, universities are undertaking very encouraging activities aimed at improving knowledge of aquifers. Research has been carried out in areas such as geo-physics (sometimes linked to oil exploration) and piezometry, and the modelling of certain aquifers has been undertaken in the Senegalese basin.

Piezometers — designed to measure fluid pressures, such as ground water elevations — have permitted us to evaluate and estimate the river supply feeding the aquifers of the Senegalo-Mauritanian basin. Unfortunately, over the past seven years, the Mauritania aquifer system has not benefited from a follow up.

The most significant models, those leading to a better understanding of aquifers, have been those established from the Idini caption tanks which feed into Nouakchott and Boulanouar, supplying Nouadhibou, and the models realized in Senegal.

4. Usage Constraints

The fact that the major priority for governments tends to be the supply of water to the population, rather than improving knowledge of underground water systems, somewhat handicaps regulation of aquifer usage, which is a component of aquifer studies.

As water is the base of all sustainable socio-economic development, it should be taken into account by all programmes covering all sectors (an example is the development of cattle-farming across transhumance areas). In addition to the legislative aspect, one of the major constraints lies in the low level of co-ordination among the different groups involved, and the lack of any significant information flow and information collation among them.

The essential parameters to collect in order to implement a surveillance network are:

Strategic level — flow input
Dynamic level — flow output
Effluence — quality

However, there is currently no common methodology, either at the national or the regional level, for the collection of this data — data that is essential if we are to fully understand aquifer functioning.

5. Improving Our Understanding of Aquifers

The approach that has already been taken by the OSS constitutes the only alternative, within a sub-regional framework, if we are to progress towards a better knowledge of aquifers.

The OSS is made up of two zones, the countries to the north of the Sahara and those to the south. The countries to the south of the Sahara contain four great

catchment basins. After a workshop to initiate the project, a document was put together synthesizing the state of knowledge of these aquifers. Specific workshops were then held for each aquifer basin. The first workshop, on the Iullenden basin took place in July 1999. It was followed by a training session on mathematical modelling last July.

This initiative should be pursued to the benefit of the other basins:

- The Senegalo-Mauritanian basin
- The Taoudenni basin
- The Chad basin

6. Conclusions and Recommendations

The state of knowledge of freshwater resources in Africa is not at the same level in sub-Saharan countries as it is in Africa's northern states; with regard both to aquifers in general and to discontinuous water reserves. Equally, these two issues are often not given equal weighting. But regardless of the causes for this situation, measures must be taken to improve the state of knowledge of our freshwater resources, which already constitute a limiting factor that is central to all sustainable development actions. It is within this perspective that the OSS has undertaken, for almost ten years now, the 'Basin Awareness' approach — based essentially on the capacities of states — and has promoted collaboration and the exchange of information, and organized training sessions, workshops and seminars.

18 The Impact of Drought on the Availability of Water Resources for Human Needs: The Case of North-Eastern Côte d'Ivoire

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Introduction

CLIMATE

The Côte d'Ivoire is characterized by a hot and humid transition climate in the south and a dry tropical climate in the north. The climatic characteristics are defined by the confluence of two different air mass types:

- Northeastern boreal trade winds, which blow dry, hot air that is often charged with dust.
- Southern monsoons, which bring with them hot and humid air.

Depending on whether they are affected by one or both of these phenomena, four climatic regions can be distinguished in the Côte d'Ivoire. (See Table l.)

HYDRAULIC NETWORK

Côte d'Ivoire's hydraulic network comprises four large watercourses: the Bandama; the Comoé; the Sassandra and the Cavally. All of these watercourses flow from north to south before entering the ocean.

1.Water Resource Management in Cote d'Ivoire (the Water Code)

Côte d'Ivoire's new water resource management policy, based on integrated resources management, was developed after criticism that existing practices lacked a cohesive structure. The following were identified as being obstacles to a rational management of water resources:

- The diversity of actors, the fragmentation of programmes and a lack of co-ordination and dialogue that led to conflicts of interest. *Without any co-ordination, the government gave direct and indirect responsibilities in the administration, guardianship and exploitation of activities with regard to planning, utilization and conservation of water resources to several different ministries at once*;
- The irresponsibility of the sector in failing to take the economic value of water into account;

Table 1: Principal climatic zones of Côte d'Ivoire

	North-east	Centre	South	West
Rainy season	June–September (maximum rainfall in August)	April–October (two maxima, in June and in September, but not clearly demarcated)	April–July (long season); September–November	April–October (wetter than other places at the same latitude)
Dry season	October–May	November–March	December–March; August (short season)	November–March

- The non-existence of a water police unit;
- The anarchic use of water resources;
- The failure to prioritize activities due to a misunderstanding of the water needs of different sectors (agriculture, drinking water, industrial needs, etc.) and of the resources available, and a lack of consultation in decision-making;
- Poor knowledge of water resources;
- Not taking the environmental aspect into account. *Degradation of the environment diminishes water quality, which results in a reduction of the volume of water available for practical purposes and exacerbates the very real and imminent threat that lies on the horizon, illustrated by the climatic changes of the last few decades. Visible consequences have been a fall in productivity and a rise in the need for the country to encourage socio-economic development.*

Moreover, after two decades of the National Hydraulic Programme, the community hydraulic sector found itself confronted by serious financial difficulties. Funds set up to finance sectors such as community hydraulics and sanitization were found to be inadequate — a result of insufficient mobilization of national resources, ineffective fund management, inappropriate tariffs and a number of unexpected complications. In the field of agricultural hydraulics, the state bodies in charge of implementing agricultural programmes were unable to take into account the large hydraulic potential that the hydraulic network offered by developing clear policies appreciating the value of water resources.

As a result of these observations, in January 1996 the Côte d' Ivoire government created a High Commission of Hydraulics (HCH), to be responsible for defining a new water resources management policy that would rely on, among other aspects:

- Appropriate institutional reform
- Prime importance awarded to basins as resources to be managed judiciously
- A new financial policy responding to the real constraints
- The orientation of all actions towards an integrated management of water resources
- More thorough planning
- Feasible, adaptible and realistic sub-sectoral approaches
- Increased sub-regional and international co-operation
- Education and training

The first result was the introduction of Law 98-755, voted on by the National Assembly of Côte d'Ivoire on 23 December 1998, which saw the instigation of the Water Code. The President of the Republic announced the law in 1999.

1.1 OBJECTIVES OF THE WATER CODE

The Water Code aims to establish an integrated management of water resources, waterworks and water distribution. This management aims to assure:

- The preservation of aquatic ecosystems and humid sites and zones
- The protection of surface water, underground water and sea water within territorial waters against all forms of pollution, and the restoration of polluted waters
- The protection, mobilization and management of water resources
- The development and protection of waterworks
- A coherent planning of water resource use at the hydrological catchment basin scale as well as on a national scale
- The improvement of living conditions of the different sectors of the population, respect the equilibrium of the surrounding environment
- The establishment of conditions for the rational and sustainable use of water resources for present and future generations
- The setting up of an institutional structure characterized by the redefinition of the role of the actors concerned
- An appreciation of the value of water as an economic resource
- The distribution of water so as to satisfy or to conciliate, with regard to different uses, activities or works, the requirements of:

  1) The supply of potable water to the population;
  2) Hygiene, public-health and civil protection;
  3) The conservation and free flow of water resources and protection against floods;
  4) Agriculture, ocean fishing and marine culture, freshwater fishing, energy production, transport, tourism, recreation and nautical sports, as well as other legally exercised human activities.

1.2 APPLICATION OF THE WATER CODE

The Water Code defines the fundamental principles applicable to:

- A judicial system for water resources, amenities and hydraulic works
- The protection of water, amenities and hydraulic works
- The management of water, amenities and hydraulic works

It highlights the general rules:

- For the preservation and distribution of water

- For the preservation and quality of amenities and hydraulic works
- For the sensitive use of sacred water
- Water police, penalties and sanctions

Water as defined in the Water Code comprises continental waters and territorial sea waters. From the Water Code, it is envisaged that a new National Hydraulic Programme will be developed: this programme is not yet available.

2. Drought and Availability of Water Resources for Human Consumption in Northeast Côte d'Ivoire

2.1 GENERAL DATA ON THE NORTHEAST

Climate

The Northeast of Côte d' Ivoire is characterized by a dry tropical climate with a rainy season from June to September and a dry season from October to May.

Rainfall

In an average year, precipitation in the northeast is around 950 millimetres (the lowest levels of rainfall in Côte d'Ivoire). It is tempting to say that this region is wetter compared to other regions in Africa, but for some years now this region has suffered from an unstable climate — accentuated by rampant desertification that is still poorly controlled, the consequence of the combined effects of traditional farming methods, recurrent bush fires and global climatic change.

Hydraulic Network

The northeast of Côte d'Ivoire is not crossed by any large watercourses, although the Comoé River, one of the four large rivers in the country, borders it to the west. The region is supplied only by effluents of the Comoé and the Black Volta; effluents that seasonal rather than perennial.

2.2 COMMUNITY DRINKING-WATER DISTRIBUTION SYSTEMS

Village Hydraulics (VH)

Village hydraulics is the responsibility of the state, represented by the Direction of Hydraulics (Ministry of Infrastructure). It consists of supplying village communities with modern water points, wells or boreholes equipped with a hand-action pump. To meet the criteria, any agglomeration with greater than one hundred inhabitants benefits from a water point. An extra water point is provided for every additional four hundred inhabitants.

Improved Village Hydraulics (IVH)

Many villages, taking into account their relatively high population, benefit from several water points (three to five, sometimes more). In this case, not only can waterworks management pose problems, even when the village has established a good management system, but also the cost of such an investment is high with regard to the level of service offered to the population.

Villages with a population of between one thousand and four thousand people cannot reasonably benefit from a complete network of Potable Water Conveyance (PWC), due to the high cost of such an extensive system in these villages (its profitability is hypothetical).

To respond to the legitimate demand of these villages, which for the most part benefit from community infrastructures encouraging their development, and to provide them with an enhanced system using hand-action water pumps, the Direction of Hydraulics has initiated and tested a basic PWC system named Improved Village Hydraulics (IVH). Such a system essentially addresses well-organized and well-structured villages.

The IVH is a network system that is intermediate between the system of establishing a complete PWC network and the system of installing hand-action water pumps at water points. This system will be developed further in future programmes.

Table 2: Examples

Number of Inhabitants	Number of Works
100 to 400	1
400 to 800	2
800 to 1,200	3
1,200 to 1,600	4

Improved Village Hydraulics systems include:

- a water tower;
- a basic water network;
- boreholes equipped with an underground pump;
- well-constructed, tapped, water points, judiciously distributed throughout the village.

The management of these installations is entirely assured by the village community, assisted for a certain initial time period by the Direction of Hydraulics.

It is important to emphasize that the IVH system will only be set up in well-organized villages that can show they are sufficiently motivated to have such a system — notably by making a 20-percent financial contribution to the investment.

Urban Hydraulics (UH)

The Urban Hydraulics sector is essentially interested in cities and villages equipped with a complete PWC system. The *Société de distribution d'eau de Côte d'Ivoire* (SODECI — 'the Society of Water Distribution in Côte d' Ivoire') is a public-sector service that has been privatized. Their contract stipulates that the state, represented by the Direction of Hydraulics, assures the initial financing of water installations (planning and construction costs), while the SODECI is responsible for managing the waterworks.

2.3 THE IMPACT OF DROUGHT ON RESOURCES

Village Hydraulics

The northeast region has a total of 1,475 water points (221 wells and 1,254 boreholes). Of these, 1,192 are in good condition and 283 have been abandoned for diverse reasons (water quality: 15; depletion: 171; intermittent supply: 80). The intermittent works are those wells that are only exploitable during the rainy season (they are completely depleted during the dry season). These figures show that 17 percent of the water points in the northeast region have been abandoned due to drought. This phenomenon will intensify with desertification encroaching on land in this part of the country (due to the combined effects of bush fires and a marked reduction in rainfall).

To combat the problem of the depletion of water points, the Direction of Hydraulics stopped digging new wells in the 1980s; it now is progressively replacing existing wells. The average depth of a well is twenty metres; the average depth of a borehole is fifty-five metres.

Improved Village Hydraulics

At the moment, only three locations have Improved Village Hydraulics systems. The equipment was provided in 1994 and 1995 but problems have already arisen at the boreholes.

Urban Hydraulics

There are thirteen centres of potable water production in the northeast region, supplying twenty-seven localities. The water at these thirteen production centres is drawn from boreholes. Six of the production centres have boreholes whose level drops during the dry season; occasional falls in the water level results in a production deficit that leads to water shortage in certain localities. It is important to note that most of the six problem centres are now using their second or third borehole, the first having been abandoned due to depletion.

Conclusion

It can be said that, compared to certain other areas of Africa, overall, Côte d' Ivoire benefits from good quantities of rainfall. However, the northeast region of the country suffers from low levels of rainfall, which has an effect on the water resources available for human consumption. Those of us responsible for this region have encountered enormous difficulties assuring the supply of water to rural as well as urban populations during the dry season.

19 Mitigating the Effects of Drought in Guinea-Bissau

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Introduction

Given its climatic conditions and regular rainfall patterns, Guinea-Bissau is not, strictly speaking, confronted with the problem of desertification (unlike Mauritania, Niger, Burkina Faso or even Senegal). However, it is exposed to various processes of natural ecosystem degradation affecting its agricultural, pasture, fishing and forest resources. While desertification is only a threat in certain eroded areas in the Boé region and in areas of high population density, the speed at which productive natural resources are degrading remains alarming. The compatibility of increasing agricultural production and conserving the country's natural riches must be questioned.

The United Nations Convention to Combat Desertification (UNCCD) enables an assessment to be made of environmental conservation and protection actions that have been carried out by different groups — the Guinea-Bissau government and local government bodies, international associations and projects, NGOs and the private sector — with respect to the Convention. The Convention is an important aid in mitigating the effects of drought in Guinea-Bissau.

Few large-scale actions have been concretely established in Guinea-Bissau since the ratification of the Convention in March 1995. The multiplicity of the structures involved in environmental management issues is a serious impediment to the process of developing a National Action Plan. Indeed, nobody is entirely sure who is ultimately responsible for co-ordinating and implementing the Convention: the Department for the Environment or the National Committee of the Permanent Inter-State Committee for Drought Control in the Sahel (CONACILSS).

Recently, however, several guidelines have been constructed (and many seminars held) with the co-operative support of international organizations such as the United Nations Development Programme (UNDP), the World Conservation Union (IUCN) and the World Health Organization (WHO), among others. A number of plans, too, are in the final stages of development; among these are action plans in the areas of tourism, the environment and agriculture. These actions are in addition to the guidelines on combating degradation of the natural environment established in 1984 and revised in 1988, which were presented as a national report at the Earth Summit in Rio in 1992.

1. Achievements and Activities in Guinea-Bissau in the Combat Against Desertification.

Elaborate forms of land use have always been practised in Guinea-Bissau. The main areas that organizations and projects involved in combating desertification — such as the Cantanhez Initiative, the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), IUCN, RADI/TESSITO — have focused on have been reforestation, the protection of natural vegetation and regeneration, studies of the sylvo-pastoral and agro-forestry systems and catchment-basin management, and the creation of national parks. These programmes share an aim to support government efforts to implement concrete actions in conformity with provisions laid out in Agenda 21 and the Convention to Combat Desertification.

Establishment of the institutional and organizational context necessary to build a true partnership for the co-ordination and follow-up of the National Action plan' implies:

- Promoting wider awareness and a better understanding of the provisions and spirit of the Convention to Combat Desertification at the national level.
- Organizing field trips to gather information on programmes and other activities.
- Holding seminars or briefings with the principal groups involved, focusing in particular on the most disadvantaged target groups.

A series of activities has already been developed in Guinea-Bissau (others are in progress) that can be integrated in Guinea-Bissau's National Action Plan, to be developed in accordance with the Convention to Combat Desertification.

2. Conservation of Fragile Mangrove Ecosystems

From an environmental point of view, the mangrove ecosystem plays a large and beneficial role as a 'buffer' zone in coastal regions. Apart from its role of protecting shorelines against coastal erosion, the mangrove constitutes a very rich biotope for manatees, fish species, shellfish and molluscs, to which it provides both a habitat and abundant food.

In Guinea-Bissau, the rivers and its tributaries, bays and channels form a dense network in which the influence of the tide can be felt up to 150 kilometres inland. The surface area of mangrove forests in Guinea-Bissau is estimated to be in the order of 2,484 square kilometres, stretching along 350 kilometres of coastline — that is to say, mangrove forests cover approximately 6 percent of the surface area of the country, a noticable reduction from 8 percent in 1976.

Clearing mangroves for rice cultivation has accelerated over the past few decades, increasing from 20 square kilometres per year between 1953 and 1976 to 38.3 square kilometres per year between 1976 and 1990. Rain-fed rice has been cultivated in mangrove regions ('*bolanha*') by the Balantes for centuries, but in northern Guinea-Bissau, more than 50 percent of the plots have been abandoned. In several cases, these abandoned fields have remained sterile, due to soil acidity and hypersalinity. However, in certain areas a slow recolonisation of the region with *Avicennia germinans* has been observed.

3. Classification of the Bijagos Archipelago as a UNESCO World Heritage Area

The first animal reserves were established in Guinea-Bissau in 1980, in theory protecting animal communities. Areas to be protected (halieutic fields, dense dry forests, clear forest, mangrove forests etc.) are proposed through studies undertaken by various organizations. As a result, twenty sites have been created: six natural monuments, five forest reserves, two fauna reserves, five national parks, one integral reserve and the Corubal valley conservation zone (an area of controlled exploitation). These account for 12 percent of the nation's territory. The biosphere reserve encompasses the Bijagos archipelago and was instituted and classified as a World Heritage Area under the patronage of UNESCO in 1995.

On the biological level, the Bijagos archipelago enjoys high productivity; explained mainly by its location at the convergence of two principal coastal marine currents and the Rio Géba and Rio Grande of the Buba estuary. This archipelago is often considered by marine biologists as one of the principal nurseries on the West-African coast for many commercial fishing species. The archipelago is also a significant feeding-station for migratory birds. Studies have been undertaken to finalise proposals to protect the following natural areas as national parks:

- The Rio Cacheu mangroves (540 km^2)
- The Orango islands of the Bijagos archipelago (680 km^2)
- The Cufada lagoons (990 km^2)
- The Cantanhez forest (650 km^2)
- The clear forests of Dulombi (1.770 km^2), an area of high vertebrate diversity.

These areas total 12 percent of the country, of which totally protected reserves make up almost 3 percent.

4. The Cacheu and Orango Islands National Parks

National parks play a significant role in the conservation of genetic resources, and thus constitute a species reservoir for the selection of useful and drought-resistant varieties.

The two protected areas in which the IUCN is involved today are the natural Cacheu mangrove reserve in the northern part of the country and the Orango islands National Park in the Bijagós archipelago. For several years, and in partnership with several NGOs and country authorities, a consultative process with local populations has enabled protected areas to be established in accordance with the economic, social, cultural and ecological realities of each area. The institutionalization of these two National Parks was approved by the Council of Ministers on 22 December 1997.

Cacheu National Park is one of the most important areas of mangroves on the continent. Populations of hippopotamus and well-preserved dry forests can still be observed here, as well as unique cultural characteristics, important for the whole country from a sociological viewpoint. The Orango National Park is part of the Bolama-Bijagós Biosphere Reserve, and is an area with one of the highest biodiversity indices in the archipelago (it is a breeding area for fish and shrimp, and a major phytoplankton production area). The park has significant populations of hippopotamus, crocodiles and manatees, with both dune and mangrove forest ecosystems.

The designated protected areas also play a significant international role. They contribute to the sub-Sahelian network of wooded areas, which provide a

barrier against the devastating effects of chronic drought, by providing an indispensable source of evapo-transpiration that is crucial to maintaining hygroscopic balance and replenishing groundwater.

5. Protecting the Dense Cantanhez Forests

The southwest part of the country harbours the last strips of primary sub humid forest. This very special environment, which harbours a diverse range of plants and animals, is threatened and is subjected to increasing pressure from sedentary and migratory farmers. The Cantanhez Initiative is a project that is being carried out in the Cubucaré sector by three national NGOs (Tininguena and Alternag), with support from the Netherlands and within the framework of the IUCN program. This grouping of NGOs managed to persuade the region's elders and traditional leaders to classify a large part of the forests within their territories. These forests are traditionally sacred areas, or *matus malgos*.

To consolidate this success, local populations need to be supported in establishing alternative agricultural activities that will compensate for any loss in immediate earnings caused by the voluntary classification of protected areas — thus guaranteeing their sustainability. The Cantanhez Initiative set up a series of activities in the fields of fishing, bee-keeping, social communication and the rehabilitation of rice plantations within mangrove forests (these had been abandoned because of labour shortages, in favour of slash-and-burn rice farming methods that pose a serious threat to the forest's survival).

6. Promoting Agro-Forestry and Reforestation

The conditions necessary for agro-forestry are quite clear: hedges and windbreaks must be established, crop rotation and the planting of fruit and other trees with practical usages needs to be encouraged, fallow fields must be supported by planting nitrogen fixing trees (these can be isolated or planted in rows or in small clusters). Today, the integration of trees is centred on fruit-tree and cashew plantations. We have also seen the creation of greenbelts, the introduction of agro-sylvo-pastoral species such as *Acacia albida*, *Leucaena leucocephala* in fields within close proximity to villages, and preventive burning of natural vegetation.

Farmers are progressively creating strips of natural vegetation, from ten to fifteen metres wide, between plots of land that are eighty to one hundred metres wide. These form natural windbreaks and allow the natural vegetation to reconstitute itself in the event of the farmland being abandoned. The farmer, now also a forester, also benefits from biological advantages (for example: tree root systems bringing minerals up toward the topsoil, symbiotic fixing, increased activity on the part of edaphic fauna, which improves soil structure) and mechanical advantages (the soil is protected against erosion and rain infiltration is improved).

More recently, certain projects have introduced different species or techniques. Since 1986, intercalated plantations containing *Leucaena leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus*, and *Acacia albida* have been proposed. Live fences of *Jatropha curcas* or *Moringa oleifera* are becoming more widespread. Around Bafata and Gabu, PASP has introduced several useful local species (for example, *Acacia albida*). The Famandinga project, which concentrates on breeding small animals and tree cultivation, has also planted a variety of species, in particular *Gliricidia sepium*.

Reforestation is one of the more effective methods of restoring degraded land. Guinea-Bissau's Forestry Commission has declared July 'the month of the tree', in which reforestation activities are carried out by both local communities and other groups. However, significant shortcomings hamper this initiative: particularly the absence of a national seed centre to provide high-quality seeds in sufficient quantities.

7. Dynamic Plantations Based on the Cashew Tree

Cashew plantations have developed strongly these last few years, primarily for reasons of land ownership (land occupation) but also because cashews are a profitable crop. Cashew trees are generally planted after clearing patches in the forest belt. Rain-fed rice is another common rural crop: crop rotation is commonly practised, with two or three years of rice crops followed by millet or sorghum the following year. The wood collected from cleared patches is generally used as firewood or transformed into charcoal.

According to Vayssié and Camara (1996), by 1995, cashew plantations covered 103,000 hectares of land: 88,000 hectares, or 85 percent, belonged to traditional farmers, while 15,000 hectares, or 15 percent, belonged to modern farmers — *'ponteiros'*. For the country as a whole, 67 percent of traditional farms and 97 percent of large holdings had one or more orchards of cashew trees.

8. Developing Participatory Community Forestry

The past ten years has seen the emergence of a number of NGOs who have contributed to supporting populations in the sustainable management of forest resources. In the northern region, NGOs such as RADI and ICAP have developed activities in the field of forestry

that give priority to reforestation and the protection and conservation of forests, and have promoted public-awareness campaigns. They also support local populations in their organization of groups. In the southern part of the country, activities have been undertaken within the framework of the Cantanhez Initiative, whereby three national NGOs brought together the inhabitants and local authorities to promote protective measures on a community basis to safeguard the country's remaining humid primary forests.

Certain associations are currently involved in forest protection and forest-resource management (the Baransam Association of Cuntima, Farim and Tchurbric, Cacheu, Bachil, Cacheu etc.). Activities include:

- The production of plants in nurseries;
- The planting of local native plants (*Acacia albida*) in fallow fields;
- Forest fire prevention through the construction of firebreaks, early preventive burning, clearing of planted fields and clearing around the villages;
- The creation of nature conservation committees.

As well as being involved in conservation activities and forest-resource management, the rural population sometimes participate in the commercialization of certain products (charcoal, firewood, wild fruits, medicinal plants etc.).

9. Environmental Education

Palmeirinha: Written in simple language corresponding to the level of literacy of children in their fifth and sixth year at school, this newspaper tackles subjects relevant to the children's immediate environment. The objective of this newspaper is to awaken the children's curiosity and to show them that everything has its place in nature. *Palmeirinha* is distributed free of charge in public educational establishments with the aid of financial support from the IUCN. Today, *Palmeirinha* is at its 11th edition, with 12,000 copies produced per trimester. The number of readers has increased considerably: 16,400 from a network of 34 collaborating teachers in 24 schools.

The celebration of June 17. June 17 has been declared the International Day to Combat Desertification, and is commemorated each year by various activities, terminating with a round-table gathering made up representatives of various groups concerned with environmental issues.

10. Better Stoves

One of first studies carried out on wood as a source of energy was undertaken by G. Madon and S. Strasfogel in 1982, and gave rise to the development of two projects. One project involved the promotion of better wood and coal stoves, while the other project focused on training coal-makers to use better techniques.

The first of these projects was set up with financial assistance and co-operation from the *Association Bois de Feu* (ABF: "the Firewood Association") and the *Association Française des Volontaires du Progrès* (AFVP: "the French Association of Volunteers for Progress"). This project has now ended, but teams continue their public-awareness activities with regard to better stoves. The construction and mini-distribution of improved stoves enabled two types of stoves to be developed and tested, adapted to the different needs and profiles of the inhabitants of Bissau and Gabu. They included a three-stone improved banco oven, a metallic wood-burning stove, a multi-pot coal-burning metal oven called a *sakkhanal* and wood and coal-burning ceramic ovens.

11. Butane Gas

Guinea-Bissau was to take part in the Regional Program for the promotion of butane gas (PRG) for the member states of CILSS, financed by the European Development Fund (EDF). According to Marie Oj Demante (1992), the annual consumption of gas, available in twelve-kilogram bottles, had reached 600 tons in 1989. Initially, the objective of the program was to increase consumption to 1,200 tons in 1992. However, no concrete results were obtained.

The national component of PRG has not made it possible to introduce gas stoves with three- or six-kilogram tanks onto the market. These models, widespread in certain countries of the CILSS, and in particular in Senegal, are *a priori* well adapted to middle-class and working-class households. However, the lack of purchasing power of these households is probably a significant impediment to the development of gas energy for domestic use. Gas's image in Guinea-Bissau adds to the trepidation of these households; at all socio-economic levels, gas is perceived as dangerous. Finally, gas distribution networks are as yet poorly developed and limited mainly to the capital, and they suffer frequent stock shortages.

Overall, the results of these activities demonstrate a relative level of success, notably as regards the improvement of stoves, the fight against erosion, the protection of natural forests and water management. But there are also areas that have not seen much success — such as reforestation, with selective over-exploitation of wood resources and restrictive regulations. It should be noted that, even if their impact is minor, some commendable results have been achieved in the combat against desertification, notably:

- In training and providing technical assistance to rural populations;

- In improving the state of resource knowledge;
- In improving infrastructures and amenities;
- In promoting new technologies;
- In encouraging the rural population to become more involved in environmental issues and to take more responsibility in combating desertification.

Conclusion

Government plans in Guinea-Bissau include taking measures and considering proposals in the field of environmental policy and the management of natural resources, including forests, as well as the formulation of priority projects. Although the principal problems and eventual solutions have been identified, these plans do not, unfortunately, rely on a dynamic participatory process and an active partnership for development, involving all levels of the community in Guinea-Bissau.

As a general rule, the current strategy for preventing and combating desertification relies primarily on the action and projects of community groups, associations and NGOs — notably in the areas of public awareness, the development of agro-forestry and sylvo-pastoral systems, the protection of catchment basins and irrigated perimeters and the conservation of protected areas and forests.

The various constraints identified must be tackled so as to improve production and environment protection, making better use of the positive aspects of land and water conservation that make it possible to maintain environmental stability. A sound plan against desertification demands more institutional support than that which exists currently, and the reinforcement of certain essential means of action.

For physical, economical and social reasons, development strategies must aim at promoting 'total production' by firstly encouraging the horizontal integration of production systems (of agro-sylvo-pastoral systems), followed by the vertical integration of primary products into the transformation and commercialization process.

For this reason, it is useful to recall that combating drought and desertification must principally be undertaken within the framework of a global programme aimed at appreciating the value of natural resources. It is through the application of farming and production methods that are both effective and restore the exploited resource that we will assure the productive capacity of soils, meadows, forests and *bolanhas* (mangrove rice fields), rather than through setting up defence systems or repairing damage after the fact.

This approach, a basic criterion in our recommendations, integrates perfectly with the underlying principles of the UNCCD action plan, namely the carrying-out and co-ordination of action programmes; the collection, analysis and exchange of information; research and development; the transfer and development of technology; capacity-building; education and public awareness; the mobilization of financial resources and the creation of financial mechanisms.

From this perspective, the fundamental recommendations that we formulated hinge on the following principles:

- To support the integration of the various systems of production, land and resource use and transformation into a coherent plan of participatory resource management and land and town planning
- To develop techniques and resource-conservation methods that correspond to local needs, with the help of surveys, studies and applied research
- To formulate policies aiming at reinforcing the administration charged with forestry and the promotion of education, training and public awareness with regard to natural-resources management, by defining a strategy to finance these activities.

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20 The Sub-Regional Action Programme to Combat Desertification in West Africa and Chad

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Introduction

In Africa, particularly in West Africa, drought and desertification constitute major constraints to economic and social development. Aware of this situation, leaders and the African people have taken the initiative to negotiate with the International community a Convention to combat desertification and the effects of drought. As a result, and in conformity with decisions taken at the Rio Conference (1992), the United Nations Convention to Combat Desertification in countries seriously affected by droughty and/or desertification was adopted in 17 June 1994 in Paris, and was ready for signing in October of the same year. The Convention entered into force on 26 December 1996. By 2 March 1998, all the West African countries had ratified the Convention.

The Convention envisages that countries affected by desertification and Parties to the Convention consult together and co-operate in order to develop appropriate sub-regional action programmes with a view to standardize and complete national programmes and render them more effective (Article 11 of the Convention).

Conforming to the plan of action and under the auspices of the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), the member states of the CILSS and the Economic Community of Western African States (ECOWAS) took the decision in July 1995 in Dakar to co-operate in the development and implementation of a sub-regional action programme for West Africa and Chad. The countries concerned are: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea-Bissau, Guinea (Conakry), Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra-Leone, Togo and Chad.

The Sub-Regional Action Programme (SRAP) document is the result of many discussions and meetings, bringing together representatives of concerned groups.

In December 1994 in Bamako, sub-regional experts assembled to define the most suitable methodology with which to develop a functional SRAP; appropriate to the region and respecting the principles of participation and partnership.

In July 1995 in Dakar, a sub-regional conference brought together representatives of the UNCCD, of NGOs and IGOs and of development partners. The meeting, which was an important step in the process of preparing the SRAP, enabled:

1) the general direction of the SRAP to be agreed upon, along with the eligibility criteria to apply when selecting appropriate projects.
2) the designation of the CILSS and the ECOWAS, conforming to Article 10 of the African Annex of the Convention, as liaison centres in charge of directing the development process and implementation of the SRAP in West Africa. The CILSS was selected for its experience and technical competence in combating desertification, and the ECOWAS because of its political influence and its broader geographic cover.

In February 1996 in Lomé, IGOs, in accordance with Paragraph 2 of Article 10 of the African Annex of the Convention, assembled together to agree on the precise roles of the parties to the process, according to the mandate and experience of each institution.

In July 1997 in Niamey, a forum was held to identify sub-regional priorities. It was concerned with defining the structure of the SRAP, priority areas and directions for its actions, and the modalities of its operation.

As a result of the meeting in Niamey, the Sub-Regional Co-ordination Committee (SRCC) was established. This sub-regional committee met together twice:

In December 1997 in Accra, the SRCC validated texts governing the functioning of the co-coordinating bodies; the direction of the SRAP process; the budget for the

preparation process; and proposals for the organization and co-ordination of specialized, thematic, groups — notably as concerns the selection of group leaders.

In September 1998 in Cotonou, the SRCC examined the SRAP draft and formulated observations and recommendations for its finalization.

In January 1998 and in March 1998 in Ouagadougou, meetings of the thematic groups enabled them to:

1) agree on practical organizational methods for their activities;
2) comprehensively analyze the situation collectively and reach consensus on all aspects of it;
3) formulate and propose actions and common measures to engage upon.

The SRAP is the product of long and collective deliberation on the challenges faced and on sub-regional priorities. It constitutes a reference framework for the direction, arbitration and standardization of action plans to combat desertification and the damaging effects of drought.

1. Goals, Objectives and Content

1.1 GOALS AND OBJECTIVES OF THE SRAP

The SRAP is closely linked to the spirit of the Convention. It aims to achieve the global objectives of the UNCCD — to combat desertification and mitigate the effects of drought in countries seriously affected by drought and desertification, particularly in Africa. This is to be achieved through effective measures at every level, supported by international co-operation and partnership agreements, within the framework of an integrated approach compatible with Agenda 21 and with a view to contributing to the sustainable development of the drylands.

1.2 PRIORITY AREAS

The SRAP has outlined eight priority areas:

1) the sustainable development of shared hydraulic resources;
2) the sustainable development of shared or transboundary plant and animal resources;
3) scientific and technical co-operation;
4) rational management and development of energy resources;
5) the need to combat factors damaging to crops, forest resources and animals;
6) the need to recognize early warning signs and to mitigate the effects of drought;
7) information/training/communication;
8) co-ordination of commercialization schemes and the implementation of common infrastructures.

These eight priority areas are based on an analysis of the causes, manifestations and effects of desertification, on examination of valuable experiences and expertise, and appreciation of the obstacles to be overcome.

1.3 GUIDING PRINCIPALS OF THE SRAP

Parties to the SRAP have agreed on the following principals to guide their actions:

- to guarantee the participation of all interested parties and members of the community, notably woman and young people, in developing and implementing the SRAP;
- to assure solidarity, partnership and co-ordination of all those involved in the combat against desertification in the sub-region, so as to maximize resources and to rationalize and reinforce institutions concerned with combating desertification and the effects of drought;
- to implement the SRAP by placing a priority on sub-regional resources (outside assistance and support should be considered as supplementary);
- to build upon existing structures. The application of the SRAP will be more effective by involving existing institutions that are well-anchored in the geographic context, and by taking on-going and proposed projects and programmes into consideration. Members can and should contribute greatly to it by integrating and encapsulating the concepts of the SRAP in their own programmes and projects;
- to make SRAP an evolving and continual programme;
- to seek and assure synergies in the application of the Conventions emanating from Rio and other appropriate Conventions concerned with environmental management;
- to reinforce co-operation with other sub-regions and world regions.

2. Mechanisms for Co-ordinating and Administering the SRAP

The following organizations and groups provide co-ordination mechanisms to assure the implementation and follow-up of SRAP activities:

The Conference of the Heads of State and Governments of ECOWAS, *enlarged to include Chad*. This forms the sovereign decision-making authority of the SRAP. Meetings are prepared by the Ministries in charge of environmental issues in countries of the ECOWAS and the CILSS.

The Sub-Regional Forum. With representatives from each and every level of actors, the Sub-Regional Forum meets together every three years. It evaluates the implementation of SRAP, proposes reforms necessary for its orientation and defines the major direction of its activities.

The Sub-Regional Committee of Co-ordination (SRCC). Presided over by the ECOWAS, the SRCC meets together at least once a year. Made up of representatives of the seventeen countries that are parties to the programme, of the two liaison centres — CILSS and the ECOWAS — of leaders of thematic groups, of the principal sub-regional organizations of civil society and of representatives of development partners, it defines the priorities of the SRAP, arbitrates in choosing between potential SRAP projects and validates various documents and projects.

The SRAP Technical Secretariat. Placed under the authority of CILSS, the Technical Secretariat prepares the meetings of the SRCC and the Sub-Regional Forum, supervises the actions of the SRAP and evaluates these actions.

Specialized Groups. Specialized groups have been formed on the basis of the SRAP's eight priority areas. Each group is composed of sub-regional actors participating in or having relevant skills in the field concerned. They are a setting for scientific and technical thought and for discussion and co-ordination. These groups aim to identify and propose actions that will contribute to resolving the problems and constraints linked to their respective fields.

3. Application and Funding

The SRAP plays three essential roles:

1) *It influences the politics, strategies and practices of the combat against desertification at the sub-regional and national level*. The directions defined in the SRAP and the mechanisms identified for their implementation (thematic groups, the SRCC, sub-regional forums) should help to refine concepts and judge their effectiveness, and should encourage a better cross-fertilization of knowledge and skills among concerned parties, and a continued improvement in terms of strategies and actions;
2) *It rationalizes sub-regional operations (inter-governmental organizations, etc.).* Eventually, it should be possible to reveal duplications and convergences in the efforts of IGOs and other sub-regional actors and to contribute to the development of complementarities and synergies. This would lead to the establishment of common objectives and resources and to a reasonable reduction in the number of IGOs. Furthermore, on the basis of strategies defined by the groups concerned, and favouring concerted efforts (notably through the specialized groups), organizations operating programmes in isolation that are of cross-border interest may agree to combine their efforts — to initiate and implement actions that combat desertification.
3) *It complements and reinforces actions already in progress,* by identifying and instigating new actions to be submitted to sub-regional financial systems. Actions are defined collaboratively, in accordance with the priorities and capacities of the countries and organizations concerned.

A significant mobilization of resources — both human and financial — would be required for the SRAP to be fully successful. To this effect, a substantial commitment is expected on the part of all parties involved (states, IGOs, civil society, private operators). All of these groups should provide financial, technical and material contributions towards the establishment of the SRAP, notably towards the financing and functioning of the bodies involved, and in the implementation of common priority actions.

SRAP

GOALS

To develop sub-regional co-operation towards the rational management of shared natural resources and to contribute to sustainable development in Chad and the countries of Western Africa.

STRATEGIC OBJECTIVES

To assure:

- Food security
- Energy security
- The sustainability and quality of economic growth

OPERATIONAL OBJECTIVES

- To harmonize and supplement National Action Progrmmes and to render them more effective.
- To define and implement long-term sub-regional strategies to combat desertification more effectively and to mitigate the effects of drought.
- To support sub-regional actors in their efforts to manage shared resources
- To develop joint programmes decided upon by common accord and in partnership with sub-regional actors.

21 Environmental Education as an Instrument to Combat Desertification and Promote Sustainable Development in the Lake Chad Basin

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Introduction

Humanity finds itself at a pivotal point in its history. Misery, hunger, illiteracy and bloody conflicts continue to worsen. The ecosystem on which our food security depends is degrading daily, with ever-increasing inequalities between rich and poor.

According to recent United Nations' estimates, approximately 150 million people (one-third of the population of the African continent) will be forced to abandon their land between now and 2015, to migrate to more productive land. We have already witnessed the displacement of nomadic herders from the Sahelian zone, who migrate towards still-fertile southern regions, sparking occasional conflicts with farmers.

Tackling the problem of desertification and integrated management of natural resources such as water and land in the Lake Chad Basin region cannot be left to luck or trial and error. Finding solutions to these questions calls for active solidarity among all countries in the context of North-South co-operation as cited in Agenda 21. It is for this reason that this seminar intends to seek a common and united perspective to respond to this call.

Many severe conflicts that destabilize our societies arise from economic and social injustices related to the unequal sharing of common heritage. Only by eliminating the abuse of such natural resources as food, land and fresh water (to cite only the most vital of human needs) by instituting fair and equitable management of these common resources, can these problems be resolved. Satisfying these basic needs will lead to an improvement in living standards and to the protection of ecosystems.

1. The Lake Chad Basin

Located in the heart of Africa, the Lake Chad Basin is characterized as both a geographic and a conventional entity. The geographic Chad basin encompasses Chad (1.28 million km²), Nigeria (925,000 km²), the Central African Republic (623,000 km²) and Cameroon (475,000 km²). The persistent droughts of the 1970s and 1980s have resulted in dramatic changes to the Lake Chad basin environment. The desiccation of the lake, desert encroachment and the decline of agriculture, herding and fishing threaten the social and economic well-being of about nine million of the region's inhabitants, in three climatic zones: the Sahara desert (north of Niger and Chad), the Sahel and the savannah.

The total surface areas of the hydraulic and conventional basin of Lake Chad are respectively 25,000 km² and 427,300 km². The conventional basin is shared between four member states, established as follows:

Cameroon	37,500 km²
Niger	121,500 km²
Nigeria	90,000 km²
Chad	178,300 km²

The population of the conventional basin is divided as follows:

Cameroon	2.13 million people
Niger	425,000 people
Nigeria	4.17 million people
Chad	1.79 million people

Population growth is at 2.6 percent; 52 percent of the population are under twenty years old, and population density varies greatly, with the lowest density, of 0.1 inhabitants per square kilometre, found in the mountainous area of Mora in Cameroon.

With a population growth of 2.6 percent, the population of the conventional basin was estimated to reach 11.4 million inhabitants by the year 2000.

The principal socio-economic activities of the Lake Chad basin are agriculture, herding and fishing (the majority of practices are traditional).

1.1 SOCIO-ECONOMIC OUTLOOK

Classified as one of the most under-developed regions in Africa, since 1973 the Lake Chad Basin area has

been confronted by a crisis prompting massive migratory movements. Its rural population amounts to 86 percent of the total population and the illiteracy rate is at 90 percent. The average annual population growth rate is 2.7 percent. Life expectancy at birth is 52 years, and the population density is 34.6 inhabitants per square kilometre.

Many rural areas within the region remain disadvantaged, despite co-ordinated efforts by the basin states in the last few years to assure minimum social well-being for all sectors of the population. The Lake Chad Basin states have thus found it necessary to support interest groups, such as associations, in rural development projects. Several feasibility studies have found in favour of community development projects in this region, highlighting the needs of the rural population.

The principal objectives of the Regional Centre for Environmental Education and Training to Fight Desertification in the Chad Basin (CREFELD) are to create a synergy based on education and the reinforcement of socio-economic infrastructures to promote sustainable and truly endogenous human development.

To accomplish this, CREFELD relies on the support of local community organizations and national technical competence to reinforce the socio-economic infrastructure and to provide the population with basic human needs so that they can assume the responsibility to undertake other community development actions themselves.

1.2 WOMEN AND CHILDREN

Women live in a patriarchal society. The majority of women living in rural communities are very poor; they have limited means of production and little or no responsibility in the management of the family income, despite their remarkable participation in domestic activities and the formidable task of child-bearing.

The situation for children is even more precarious. According to regional surveys carried out in 1992, 42.7 percent of children between one and four years old, 27 percent of children between the ages of five and ten years and 39 percent of babies under one year old suffer from protein/calorie malnutrition (measured in terms of height/weight ratio), of which 1.6 percent show signs of severe malnutrition. Fifteen percent of children born in maternity clinics weigh less than 2.9 kg at birth. Infant mortality (of babies and children under six years old) is very high.

1.3 LITERACY

Illiteracy still affects the majority of the population, despite efforts deployed to combat this. There is an obvious predominance of illiterate girls, as families are still reluctant to send girls to school — girls are expected to become wives and mothers, roles which are not considered as requiring an education. Furthermore, it is not uncommon for girls to provide valuable help to their mothers by carrying out multiple household chores or for them to supplement the family income by working for small enterprises.

Schools are often inadequately equipped — lacking potable water, teaching materials, toilets, waste disposal systems, and first-aid materials — which severely affects the quality of the teaching and the health of the children.

The schooling rate in the region is one of the lowest on the African continent, with two obvious disparities in schooling opportunities:

- urban areas — where infrastructures are concentrated — are advantaged over rural areas;
- boys have better opportunities than girls.

1.4 ECONOMY

The economy of the Lake Chad Basin region is based on agriculture and cattle-rearing. These are affected by natural constraints (irregular rainfall distribution and intermittent rains, poor soils, lack of grazing areas) which add to economic difficulties (inadequate equipment, insufficient financial resources and underdeveloped technology) to hamper a production that has become precarious and dependant on outside markets. The ratio of exports to imports is still small even though it has improved in the last few years.

1.5 ACCESS TO NATURAL RESOURCES

In certain villages water access is limited, due to an insufficiency of wells and their inadequate distribution. Some women walk for three or four kilometres before waiting for up to three hours in a queue to fetch drinking water for their families. Despite all these handicaps, the dynamism of the local population has been the source of many collective development projects via the creation of co-operative groups made up of both men and women. These groups vary from thirty to one hundred individuals and are involved in a variety of activities: including agriculture, craftwork, cattle-raising and fishing.

Craftwork is a well-developed industry in the region (painting, pottery, weaving and sewing), and wood remains the principal source of energy.

2. Activity Programme

The essential aim of the programme is to test the active participation of the local population through a pilot programme set up by an operational unit for educational research to explore innovative approaches to non-formal environmental education, particularly among the predominant rural population, with a view to maintaining a prosperous and sustainable environment. This should conclude with the creation of a network of multipliers

stemming from the socio-professional sector, qualified to identify factors that promote changes in behaviour at the heart of their community or workplace.

Multipliers who distinguish themselves by a real commitment to defending the environment will be chosen to participate in a training workshop on environmental pedagogy, after which they will receive a certificate of participation.

The seminar programme should reflect its inter-disciplinary and participatory character, and qualified specialists from experienced institutions will be solicited to make a contribution.

2.1 METHODOLOGICAL APPROACH

It is important to recognize and understand the initiatives and organizations that operate in the field of environmental protection. To do so, we must ask the following questions:

- What groups are working to combat desertification? Which of these groups have planned or instigated reforestation campaigns?
- What plant extracts can be or are being farmed, and for what purposes? (Plant extract are used for plant oils, anti-erosives, etc.)
- What local establishments are interested in renewable energies?
- What educational materials are needed? (Photographs, models, sketches and other images, atlases, pluviometric data etc.)
- What economic promoters sponsor environmental education?
- What type of dialogue is there between the diverse sectors of society on the environmental theme?
- How can environmental education be integrated into society?

2.2 WATER

Water is essential to life, and management of water resources is of vital concern to any environmental programme. The questions to consider here are:

- How are we to render water available to everyone?
- How can organizations work together for practical solutions to water problems?
- How can authorities be made aware of the need for an equitable water policy?

2.3 ENERGY SOURCES

A number of different sources of energy are available for different purposes:

- Combustible energy sources, including firewood, cow manure, straw and branches
- Conventional energy sources, including gas, petrol (gasoline), diesel, electricity
- Renewable energy sources, including wind power, solar energy, biogas

2.4 ORGANIZATION OF AGRO-PASTORAL ACTIVITIES

In planning and organizing agricultural and pastoral activities, the following aspects should be considered:

- Overgrazing and its consequences
- Intensification of fishing and its effects
- Hunting and its effects on fauna
- Wild and domestic fruit picking and their effects
- Agricultural dynamism and its diverse implications

2.5 STRATEGY

Community environmental programmes to combat desertification are based on:

- Training multipliers, who will be responsible for gathering and researching educational environmental information, to be presented in a public environmental education bulletin.
- Film screenings of environmental educational films; excursions and camping trips promoting environmental education; guided training and educational visits.

This programme should integrate practices and theories by establishing Ecological Initiative Groups among people of the same profession, neighbourhood, village, or religious group.

Action groups of environmental education promoters should be established at the community level to monitor learning groups on the protection of the environment and its resources.

2.6 ACTIVITIES

Programme activities should include:

- Periodic seminars on training nature guides
- The development of environmental education programmes for all educational levels
- Open-air ecological walks, in zoos, parks or reserves, along riverbanks and in forests
- Short courses for pre-school and primary school educators to introduce them to the preliminary elements of environmental education
- Excursions to provide practical training in environmental protection
- Ecological and reforestation camps
- Refresher courses on fauna and flora with traditional African botanists
- Public demonstrations on the use of solar and biogas ovens
- Environmental training courses offered via Internet or email for teachers and other interested parties
- Conferences, debates and round-table discussions on environmental education

22 Chad's Experience in Combating Desertification

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Introduction

Drought and desertification have both become common words in the Chadian vocabulary. In Chad, it is normally accepted that drought is endemic — along with its chronic effects, among which famine is the most well documented. Drought has both human and environmental victims. It affects ecosystems and hydro-systems, such as that found in the Lake Chad Basin.

If drought is attributed to climatic change leading to a degradation of ecosystems, man has also exacerbated this natural phenomenon by provoking what we can call the formation of a spiral of degradation that leads to damaging consequences, accelerating the production of causes characteristic of desertification. Bush fires, mechanical ploughing, over-exploitation of land and overfishing, insufficient crop-rotation, over-grazing and poor irrigation techniques make up the poor practices that aggravate desertification and increase the level of poverty in Chad, exacerbated by poor educational standards and high illiteracy levels. This leads us to the conclusion that the major constraints to desertification are based on socio-economic issues rather than technical limitations.

1. Drought and Desertification in Chad

1.1 FACTORS LEADING TO DEGRADATION

Natural Fragility of Chad's Ecosystems

Continentality

Stretching over 1,760 kilometres north from 8° north longitude in the Tropic of Cancer and over 1,100 kilometres from Lake Chad to Sudan, Chad is one of the world's most land-locked countries. The capital is 1,000 kilometres from the Benin Gulf, 2,000 kilometres from the Mediterranean and 2,500 kilometres from the Red Sea.

This distance from the maritime coastline results in a quasi-absence of dense vegetation formations. The entire country is under the influence of a dry tropical climate with only one rainy season. The northern half of Chad has become a desert. Apart from the extreme southwest, the rest of the territory features sparse vegetation, with scant wood and dominated by spiny scrub. These Sudanese and Sahelian savannahs are ecosystems that are naturally prone to the propagation of bush fires.

Proximity of the Sahara anticyclone

In Chad, wind and rain patterns are conditioned by inter-tropical front movements formed by the combination of dry continental air (*harmattan*) and humid maritime air (monsoon). The *harmattan* is centred on the Sahara anticyclone, while the monsoon is formed by the Saint Helen anticyclone situated in the Gulf of Guinea.

These conditions lead to a long dry season during which a continental mass of Saharan air stretches from Libya and the Sahara, blowing across a large portion of Chad (northern, central and sometimes even to the south). Sandstorms are commonplace. As a result, sand encroachment and wind erosion are growing problems.

A short rainy season, including the transit of the inter-tropical front over Chad, leads to:

- Sandy winds and short spells of rain to the north (Saharan region)
- Passing, sporadic and whirling rain in central Chad (Sahelian region)
- Frequent but often stormy rain to the south (Sudanese region)

Socio-Economic Factors

Natural resources are relied upon heavily by a largely rural population, which accounts for the ever-increasing environmental degradation. The farming systems employed and the use of natural resources are closely dependent on agro-climatic characteristics. The distinct regional climates help to delineate Saharan, Sahelian and Sudanese production systems. They are characterized by the strong pressures exerted on agrarian lands, which, coupled with reduced fallow periods, lead to land degradation.

Saharan region

Production systems in the Saharan region are characterized by an agro-forestry system that centres on the *wadis* and palms. Date cultivation, irrigated subsistence farming, sedentary rearing of small ruminants and nomadic camel rearing are all practised.

Sahelian region

Production systems in the Sahelian region are a combination of diversified systems dominated by pastoral agro-forestry. Agricultural practices range from traditional irrigated subsistence farming to a more viable extensive farming of oilseeds and legumes. Although vegetation in the south includes trees and forests, the north is more steppe-like. Forests are exploited essentially for ligneous products for domestic energy needs and economically profitable ligneous sub-products, in particular gum arabic. Animal rearing is transhumant.

Sudano region

Production systems in the Sudano region are very diversified. Vegetation consists of dry dense forests and savannah. These lands are used for cattle-rearing and cereal, oilseed, tuber, legume and cotton production.

Demography and Population Movements

The impact of climate degradation on Chad's ecosystems is accentuated by the pressure exerted on the environment by Chad's strong demographic growth (2.5 percent per year). Degradation is caused by over-exploitation of natural resources to satisfy daily food and energy requirements. Food production systems and the removal of wood for fuel are issues that must be addressed.

Migratory movements that occur under the combined effects of war and drought have, moreover, profoundly modified the socio-economic equilibrium:

- The social structure of herder-farmers has been disturbed
- The presence and sometimes settlement of rearer-herders in certain areas has brought about tensions with farmers
- Encouraging rearer-herders to shift to farming activities has not been achieved without social problems as new agricultural lands need to be found for these people

1.2 COMBATING DESERTIFICATION IN CHAD

Political and Strategic Considerations

Because of political instability and subsequent clashes, which have occurred at the same time as periods of drought, Chad has been unable to implement a real strategy to combat desertification to the extent of other Sahelian countries. Although activities have been undertaken within the general framework of combating desertification, they tended to be aimed at improving the environment (the green belt of N'djamena) or promoting agricultural production (*Acacia albida*, *Karité*) or forest production (*Acacia senegal*). In all cases, these projects were instigated by the forestry service, or under its auspices, and their objectives were essentially sectoral. Furthermore, these actions were too limited in terms of both their time frames and the affected land areas to have any significant impact on the desertification process. In a significant number of cases, they did not achieve their sectoral objectives.

Because of this, it became apparent that, if Chad was to be successful in fighting desertification, there was a need to implement a rational and consistent strategy; drawing on accumulated experience and a more objective analysis of the situation.

It was determined that this strategy should be inspired by the regional structure outlined in the Nouakchott strategy (CILSS, 1984), and should be translated at the national level by a General Plan to Combat Desertification (*Plan directeur de lutte contre la désertification*, or PDLCD). The PDLCD would need to analyse the process of desertification, define directions in line with development options, put forward a strategy and, finally, propose an action programme. In brief, it would guide actions, in view of proposing solutions better adapted to the specific problems of desertification in Chad.

The Chadian government elaborated and adopted the PDLCD in 1989. The strategic orientations of the PDLCD hinge on the following four major axes:

- Transferring responsibilities for the management of natural resources to the rural community: this must be translated at the juridicial level, notably as concerns tax laws, by a thorough reform of government's hitherto centralized approach. The sectoral session of 1994 thus announced that rural communities would be involved in the management of natural resources, in particular through a ' decentralization of responsibilities ' within the framework of village land management.
- Promoting public awareness by disseminating information and providing training is the principal means of involving the population.
- Promoting use of production systems that do not consume natural resources. This involves choosing appropriate, cost-efficient regions in which to operate the careful selection of resources, while monitoring natural resources and increasing public understanding of them.
- Establishing an organizational structure that promotes inter-sectorality and the integration of rural/environment development and is centred on adapting existing structures and projects rather than on introducing specific environmental structures.

Legislative Context

The Constitution of 31 March 1996 is a landmark legal document expressing the strong determination of Chad to assure environmental protection. The National High Committee for the Environment has as its mission to standardize, supervise and implement environmental policy and strategy with a view to sustainable development. Its specific tasks are:

- To ensure the effective implementation of the recommendations of the National Sovereign Conference on the environment and development;
- To ensure the application of Agenda 21 of the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992;
- To ensure the effective integration of environment and development issues; to oversee sustainable development policies and ensure their concrete implementation;
- To act as an arbitrator in case of incompatibilities or conflicting interests between development priorities and environmental protection;
- To define the structure and functioning of a National Fund for the Environment in order to promote actions that favour the environment, and notably actions to combat desertification;
- To mobilize institutional and social partners in order to promote the protection and improvement of the environment.

If there is one constant in Chad's bureaucratic system, it is that a good number of statutes are so outdated that their application in today's changed socio-political environment poses serious problems. Regulations relating to the environment have been poorly adapted, mostly because they are fragmentary and obsolete. Among efforts to combat desertification before Chad's independence was a declaration that led to the following initiatives:

- National Tree Week, instigated in 1972;
- The adoption of the General Plan to Combat Desertification in 1989;
- A seminar on the environment and combating desertification, held in November 1994;
- The creation of the National High Committee for the Environment in 1995;
- The adoption, signature and ratification of the United Nations Convention to Combat Desertification (UNCCD) in June and October 1994 and August 1996 respectively.

During this period, the Chadian government and partner institutions initiated and implemented several projects. Among these were:

- The Gommerais Development Project, financed by the European Development Fund (EDF);
- The Massaguet community forest reserve project, financed by the EDF;
- The Forest Activities Development Project, financed by the United Nations Development Programme (UNDP);
- The Rural Forest Management for the Production of Firewood Project, financed by the Netherlands;
- A pilot project for the management of village lands, financed by the Netherlands;
- The Management of Natural Resources Project, financed by the CEE.

A number of NGOs — including AFRICARE; WORLD VISION; SECADEV (*Secours Catholique pour le Développement*, or the Catholic Relief Fund) and CARE INTERNATIONAL — have also contributed to specific projects. Unfortunately, none of these projects were ultimately successful. However, the approach recommended by the UNCCD, which centres on involving and raising the awareness of the local population, may well prove to be the solution.

2. Case Study: Combating Sand Encroachment in Kanem

Today, the phenomenon of desertification affects the entire country of Chad. However, the most affected areas are located between 12° and 22° north latitude, covering an area of 1,091,420 square kilometres — approximately 85 percent of the country. The area concerned by this study, the Kanem, covers 115,000 square kilometres and has a population of 280,000 people.

Sand encroachment in Kanem is the most spectacular of the causes of desertification in the region. Currently, sand encroachment affects 64 percent of the land and threatens the livelihood of 14 percent of the population of Chad. Primarily caused by human activities, other natural factors, such as drought, compound its effects. The considerable scale of the phenomenon is such that the means mobilized by the population have not proven sufficient to protect the region's important infrastructures (inhabited villages, farmed and grazing areas, wells). It has largely been due to government mobilization and the assistance of NGOs that a number of villages (such as Tarfey, Rig-Rig and Barra) and certain *wadis* (Miou, Barkadroussou, Moto) have been saved from being engulfed by sand. The successful actions implemented by the pilot Kanem Agro-Forestry Pastoral Development Project can be used as a model for future interventions against sand encroachment in arid and semi-arid zones.

2.1 DESERTIFICATION AND SAND ENCROACHMENT

As have other Sahara and Sahel regions, the natural environment of Kanem has suffered degradation in the past few decades, due to the prolonged drought periods

that have ruthlessly affected the country since the 1960s, and continue to affect it.

The principal causes are the following: persistent drought, overgrazing, cattle tramping, deforestation and relentless tree logging (evaluated at 250,000 tonnes in 1988), and farming on sand dunes (rendering the dune surface vulnerable to the erosive effects of the wind).

In fact, 219 villages, 324 *wadis* and numerous boreholes and grazing areas are increasingly becoming so threatened by sand encroachment as to be potentially life threatening for the local population in Kanem.

2.2 STRATEGY USED TO FIGHT DESERTIFICATION IN KANEM

The combat strategy adopted hinges on the following four imperatives:

- The protection of threatened sites and the regeneration of ecological resources
- The improvement of production systems
- The reinforcement of institutional capacities
- The development of a national scheme of land planning

It is within the framework of this combat strategy that the agro-forestry pastoral development project in operation in Kanem from 1993 to 1998 contributed to saving certain villages, *wadis*, schools and clinics from the catastrophe of sand encroachment. Both structural and biological methods were used to halt sand encroachment.

Structural Methods of Inhibiting Sand Encroachment

Brush Fences

Fencing consists of setting up a barrier (using date palms, *Leptadenia* branches, thorny twigs and millet thatch) between the source of the sand and the threatened area. As sand accumulates along this barrier, it forms an artificial dune, which itself acts as a further obstacle. The fence is placed two hundred to three hundred metres from the site to be protected, orientated perpendicular to the dominant wind direction.

The following characteristics are required for the success of this approach:

- The fence must have a certain permeability, to prevent the wind from destroying it. The only criteria used is the quantity of material used: an average of twenty to twenty-five palms or four to six branches of *Leptadenia* is used per metre;
- Taking into account sand distribution along the fence according to wind flux, the ideal height of the fence is between 1.5 metres and 1.8 metres;
- Resistance: the greater the height of the fence, the lower its resistance. In building the fence, a trench at least thirty centimetres deep is needed to firmly sink the supporting elements of the fence. Similarly, these fence elements should be firmly tied together between at two or more levels along the length of the fence to increase its resistance.

This fencing technique has been shown to be very effective in Kanem, especially as the wind is unidirectional (NE–SW). If the opposite is the case, a network of different meshes would be required. As the fence will eventually be engulfed by sand, its height will need to be increased once the sand has reached within ten to fifteen centimetres of the top of the fence.

Hedges

After stabilizing sand by mechanical means, it is essential to fix the dunes definitively by promoting vegetation growth. The final aim is to recreate the ecosystem as it existed in the past, which means to conquer land degradation and shifting sands by covering them with as dense a vegetation as possible.

The choice of forest species and local and exotic grasses for biological fixation depends on the capacities of the species to adapt to this environment (its aridity and soil structure). The best adapted local species are *Acacia spp, Balanites aegyptiaca, Leptadenia pyrotechnica, Ziziphus mauritiana* and *Panicum turgidum*. Exotic species that are also well adapted include *Prosopis chilensis, Prosopis juliflora, Parkinsonia aculeata* and *Cajanus cajan*.

Taking into consideration the intensity of sand encroachment in Kanem, biological fixation of shifting dunes is technically only possible with planted species grown in nurseries. The production of plants relies on, among other things, harvesting seeds, choosing an appropriate site and training nursery growers. Work should begin in January and terminate in August. Plants grown in the nurseries should be healthy and vigorous, with a height of fifty to eighty centimetres. They should be planted out in mid-July, or as soon as soil humidity reaches a depth of thirty to forty centimetres, at a density of four hundred plants per hectare — to minimize the cost of the operation and to limit competition between plants, thus favouring natural regeneration.

Involving the Local Population

The results over the course of the six-year experiment are very encouraging. The method of intervention (using a participatory approach) was based on a contractual agreement between local people and project organizers. The nature of the relationship, the reciprocal engagement and the working methods were written up into a standard contract defining the terms of agreement between the two parties. Agreement to the terms of the contract reflected the two parties shared responsibility. Any community wishing to subscribe to a contract to combat sand encroachment must first

organize itself into a united group, which becomes the principal actor in the project.

As a result of numerous public-awareness campaigns in recent years, women often find themselves as front-line players in terms of their contribution to agricultural production activities and to the rehabilitation of deforested areas outlying villages (establishing plant nurseries, constructing fences, planting and maintaining trees, etc.)

2.3 SOCIO-ECONOMIC IMPACTS

As well as the immediate ecological and technical impacts achieved by the agro-forestry pastoral development project in Kanem (nineteen villages have been stabilized, forty-two *wadis* have been protected by constructing brush fences, planting live fences and setting up windbreaks, and vegetation has been successfully introduced on 71.5 hectares of bare land and moving dunes), the socio-economic impacts of the project have been encouraging. Among these impacts are the recuperation of agricultural and pasturelands in villages and *wadis* that were otherwise abandoned to sand dunes and which are now being farmed. Small mammals (hares and other rodents) long since disappeared from the landscape are returning to these regions.

The development project has then contributed significantly to the local economy. The seasonal rural exodus towards large urban centres such as N'djamena, Moundou and Sarh, or neighbouring countries (Saudi Arabia, Sudan, and Libya) has diminished significantly as local people have become increasingly involved in constructing fences and rehabilitating dunes.

Conclusion and Recommendations

Actions to combat sand encroachment are often instigated in Kanem either in response to a state of urgency (Tarfey) or through short-term projects with often very limited funds. In the absence of a global programme integrating the whole of the ecosystem, these actions have generally been localized one-off projects with limited goals, essentially aimed at combating the encroaching dune fronts.

Future studies should be orientated towards elaborating a national plan to combat sand encroachment and integrating a national scheme of land planning and development projects at the regional level, based on a systematic approach and careful analysis of the economic feasibility of projects.

The participation of local populations through the provision of incentive measures and the involvement of local authorities is essential to the success of these projects.

23 Desertification in Bokoro, Chad: A Case Study of Wind Erosion

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Introduction

Wind erosion is a phenomenon that is reasonably common in regions where dry winds blow. For the most part, these regions correspond to the drylands; areas where the soil, generally dry and shifting, lacks vegetation for most of the year. The winds are sufficiently strong to lift and move sand and soil particles. The repeated removal of superficial layers by the action of winds can modify the texture of the topsoil, by removing the finest particles and leaving only the larger soil elements.

Once the wind speed reaches 15 kilometres per hour, it can lift and remove particles of 0.1 millimetres in diameter. Salinization also causes these and other particles of between 0.05 and 0.5 millimetres in diameter to move; while particles measuring 0.5 to 2 millimetres are moved by reptation phenomena (soil creep). Sandy soils are the most vulnerable to erosion. They are characterized by poor structural stability, due to a deficiency of fine elements and of organic matter. It is also important to note that animals, through the mechanical pulverizing action of their hooves and their excessive grazing of plants and vegetation that otherwise protects the soil, add to aeolian erosion.

The research site of Bokoro in Chad is situated east of N'Djamena (12°20′ north latitude; longitude 17°03′ east; at an altitude of three hundred metres). Physical and chemical analysis of soil samples reveal Bokoro is characterized by soils that are vulnerable to wind erosion. In addition, East Bokoro is an excellent region for breeding cattle. With the help of the meteorological station at N'Djamena, we were able to follow the pattern of wind cycles in the area from March to June in 1992 and 1993: the results, in terms of wind strength and direction, allowed us to understand the violence of these strong winds, and explained the extent of wind erosion in this part of Chad. Wind speeds varied between one-and-a-half and two metres per second.

Generally speaking, it is the fairly long dry period after sowing that is particularly harmful to the agro-producer. However, in Bokoro, the violent hot winds that blow in June and July, after the first rains and the sorghum harvest, cause the most damage (it should be noted that the yield is generally good).

Objectives

The study, which has been conducted for two years and should continue for another three years, aims to help Bokoro agro-producers to control, as much as possible, the phenomenon of wind erosion — both a cause and a consequence of desertification — and its consequences on agricultural production, by proposing easily applicable solutions that take the local environment into consideration.

Resources and Method

Five plots of land were delineated, all aligned in a south-west–northwest direction:

- Plot BW-3 is surrounded by three rows of windbreaks; the outer row is made up of *Parkinsonia* species, and the inner two of *Prosopis joliflora*.
- Plot BW-2 is surrounded by two rows of *Prosopis joliflora*.
- Plot BW-1 is surrounded by one row of *Prosopis joliflora*.
- Plot BC is not surrounded by a windbreak. Immediately after sowing, this plot receives the following treatment: a row of dried cow manure is systematically applied around the seed holes in the form of a circle, so that the manure acts as a protective screen against hot particles (fine sand) displaced by the wind (Table 2).
- Plot T is the control sample. It is worked following the traditional methods of the region (simple scarification and direct sowing).

All the plots are the same size and dimensions; each has been divided into three sub-plots of equal dimensions.

These sub-plots are numbered 1, 2 and 3 and receive the following treatments:

1) Simple scarification followed by direct sowing.
2) Earthen ridging was constructed, with seeds sown on the ridges.
3) Earthen ridging was constructed, with seeds sown in the furrows.

The crop planted was a local variety of sorghum: 'Kourtofan'. The seeds were sown in rows sixty centimetres apart, with one every forty centimetres.

The seedlings that were to make up the windbreak hedges were planted in rows at regular one-metre intervals. When planted, these seedlings were twenty months old and were a maximum of one metre high.

Results

After measuring the percentage of sorghum plants that sprouted, the percentage of these that died as a result of sand encroachment was measured at fifteen, thirty and forty-five days after sprouting (d.a.s).

- Plot BW-3: 45 days after yield, only 39%, 58% and 28% of plants in sub-plots 1, 2 and 3 respectively escaped the erosive action of the wind and reached a height of 13 cm, with an average of five leaves.
- Plot BW-2: 36%, 53% and 24% of plants survived after 45 days after sprouting.
- Plot BW-1: 31%, 48% and 21% of plants survived 45 days after sprouting.
- Plot BC: 89%, 78% and 80% of plants survived 45 days after sprouting.
- Plot T: 58%, 32% and 19% of plants survived 45 days after sprouting.

These results are presented in the following two tables (Tables 1 and 2).

The differences between plot BC and the other plots are obvious, and demonstrate the positive effect of cow manure on the preservation and growth of sorghum plants. As well as providing a protective barrier around the seed holes, the cow manure also was seen to maintain a significant level of humidity — even after several days of drought — creating a micro-climate 'housing'

Table 1: Percentage of sorghum plants that had sprouted four days after sowing

Section	Plot BW-3	Plot BW-2	Plot BW-1	Plot BC	Plot T
1	80	79	74	89	82
2	68	84	86	78	79
3	83	91	89	90	69

Table 2: Rate at which plants were killed by sand encroachment

	Plot BW-3	Plot BW-2	Plot BW-1	Plot BC	Plot T
15 days after sowing					
1	53	61	65	11	3
2	31	31	44	21	65
3	61	73	74	19	78
30 days after sowing					
1	61	63	68	11	40
2	42	37	50	22	67
3	70	74	78	20	80
45 days after sowing					
1	61	64	69	11	42
2	42	37	52	22	68
3	72	76	79	20	81

the sorghum seedlings. Moreover, the seedlings of plot BC were two to four centimetres taller than seedlings from the other plots.

The two years following this study will permit us, after analysis of the results, to ascertain the effect of the cow manure on the growth of this type of sorghum, and therefore on the production of this sorghum grain under such conditions. We will be able to determine with greater precision which determining factor is more likely to lead to positive results: the maintenance of humidity, the supply of organic matter, or the protective 'screen' effect.

It will be necessary to wait at least three seasons for the analysis of our results to be scientifically legitimate. This is further justified by the fact that after only two years the hedge windbreaks are not tall enough to have a noticeable influence on the development of the test crops, nor to have any effect on the different treatments given to the sub-plots.

Despite the weak statistical value of this study, which prevents us from drawing any hasty conclusions, it is clear that the drought that plagues the Bokoro region seriously accelerates the degradation of the environment. The rains, when they come, are often very violent — breaking up the topsoil and making it even more vulnerable to wind erosion. This phenomenon has been exacerbated over the last three decades, as vegetation has been steadily reduced to almost nothing in the Bokoro region; destroyed by cattle and human activities. The few rare species that exist are those characteristic of a desert climate: it seems evident that wind erosion, which increases significantly every year, is for the most part due to the loss and in some cases the total disappearance of vegetation cover.

While it is true that the anti-erosion method of protecting seedlings with cow manure seems to constitute an effective and accessible technique for Boroko farmers, it is not enough in itself to combat the phenomenon of wind erosion.

We believe that to effectively combat soil erosion and desertification we must embark on the restoration of flora across the entire region. Although certain plant species have been seen to adapt to the region's arid conditions (xerophytes, for example), it is important to note that these adaptations are limited; beyond a certain level of drought and desertification, the plant will wither and die. The strong winds that occur in certain periods of the year in the Bokoro region carry and deposit large quantities of sand, preventing young shoots from growing satisfactorily and causing them to die relatively quickly. It is for this reason that — financial resources permitting — the continuation of our work should consist of combining reforestation practices, the creation of live fences and the use of cow manure.

In working towards reforestation, *Acacia senegal* and *Prosopis africana* species are worth noting. We also suggest covering uncultivated lands with such herbaceous species as *Andropogon gayanus* and *A. amplectus;* planting vetiver on the slopes of the area's shallow valleys could assist in securing the topsoil. These are just a few hypotheses and possible projects that have been suggested in our attempts to find solutions to the problems of wind erosion in the Bokoro region.

Conclusion

This study has allowed us to verify the following:

- The creation of boscages — barriers made up of hedging and trees — using species that are resistant to or adapted to drought conditions and aridity is a potential and feasible action for local farmers to take.
- The application of cow manure is beneficial: it supplies the soil around the seedling with organic matter, maintains soil humidity in the immediate surroundings of the seedling and protects the seedling from encroaching sand and from being scorched by hot sand particles;
- It is possible to restore degraded land, even severely degraded land, by employing inexpensive and accessible methods.

Seminar Recommendations

Over fifty participants from fourteen African, Arab, Asian and European countries, as well as representatives of United Nations organizations — the Food and Agriculture Organization (FAO), the United Nations Convention to Combat Desertification (UNCCD), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and other intergovernmental and regional organizations — the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), the Francophone Institute for Energy and the Environment (IEPF), the Islamic Educational, Scientific and Cultural Organization (ISESCO) and the Sahara and Sahel Observatory (OSS) — met in N'Djamena, Chad, from 30 October to 4 November 2000 to attend the 'International Seminar on Combating Desertification: Freshwater Resources and Rehabilitation of Degraded Areas in Drylands'. The seminar was jointly organized by ISESCO and UNESCO in collaboration with IEPF, OSS, the International Energy Foundation (IEF) and the Chadian Ministry for National Education.

In line with the seminar agenda, which consisted of four specialized sessions, seminar participants formulated and agreed upon a number of recommendations.

I. Session on Freshwater Resources and Desertification

Considering the topic of Session I, 'Freshwater Resources and Desertification', the session's introduction to UNESCO's International Hydrological Programme (IHP) and the series of national case studies on water resources management that were presented, the participants of the seminar formulated the following *recommendations*:

1. Seminar participants note that the sixth phase of the strategic plan of the International Hydrological Programme (IHP-vi, 2001–2007) contains many themes and focal areas which are of direct relevance to the subject of this seminar. They also note that there is a global call for contributions to the implementation of this plan. The meeting recommends that all countries and organizations represented in this seminar liaise with their respective IHP national committees/UNESCO national commissions to propose relevant projects of a national, sub-regional or regional nature to be included in the implementation of the IHP-vi, and specifically projects in the following areas identified during the seminar:
    i. Water resources assessment and management in arid and semi-arid zones, with an emphasis on focal areas related to drylands, wetlands, mountainous areas, coastal areas and small islands
    ii. Water and society, including socio-economic aspects of water
    iii. Transboundary aquifers and surface water
    iv. Endorheic basins such as Lake Chad
    v. Water education and training
2. The seminar highlighted the importance of water harvesting. Presentations of water-harvesting techniques made by individuals and organizations were appreciated. Consequently, the seminar recommends the establishment of a regional network on surface-water harvesting, to be supported by relevant organizations such as UNESCO, FAO, ISESCO, UNCCD and other organizations. It also recommended that user manuals and CD-ROMs on ensuring sustainable food security through combining proven water-harvesting practices and techniques with the utilization of locally available materials to improve soil fertility be prepared and disseminated.

3. The seminar considers that one of the crucial problems in Africa is the deterioration of hydro-meteorological networks. As hydro-meteorological networks are an important prerequisite for any national water resources management programme, the seminar strongly suggests that states, through their own resources and with the aid of relevant donors, should give a high priority to the rehabilitation and augmentation of hydro-meteorological networks and to the establishment of a minimum network configuration.
4. The seminar notes that one of the main constraints to improving freshwater resources management in Africa is a lack of availability of finance and funding to undertake and implement various priority actions in the water sector, including the above-mentioned issues. It invites UNESCO, FAO and ISESCO, in collaboration with other appropriate partners, to mobilize external funding for these activities from states and relevant organizations. It also invites sub-regional organizations to strengthen their technical cooperation.

II. Session on Land Degradation and Rehabilitation

Considering the topic of Session 2, 'Land Degradation and Rehabilitation', with reference to UNESCO's Programme on Man and the Biosphere (MAB) and its World Network of Biosphere Reserves, and *taking note* of a series of country presentations and concrete case studies on the rehabilitation of degraded drylands, the participants of the seminar formulated the following *recommendations*:

At the regional and sub-regional level, the seminar recommends that:

1. testing sites be identified: in particular transboundary sites, such as biosphere reserves and other similarly managed areas, to be used for environmental conservation research and interdisciplinary research for the rehabilitation of degraded drylands, which through rehabilitation efforts in collaboration with local people can generate sustainable benefits for the local people in desertification-affected areas. UNESCO's MAB Programme, in collaboration with other interested partners and programmes, is particularly invited to assist in the identification of such sites;
2. research and scientific collaboration among countries sharing similar problems of dryland degradation be strengthened through the use of appropriate testing sites. Specific attention should be given to studying the socio-economic and ecological dynamics of dryland ecosystems, to provide information essential to the restoration of degraded areas;
3. preventative measures to combat environmental degradation be established, such as:
    i. The conservation of natural resources in protected areas, including biosphere reserves, as reference sites to assess the natural structure, composition and dynamics of dryland ecosystems
    ii. The establishment of early warning and environmental-monitoring systems, with periodic reviews of aspects such as the evolution of production systems, the appearance and/or disappearance of specific indicator plant species, and abnormal fluctuations of animal and plant populations
    iii. The promotion of renewable energy sources, including the provision of information on such energy sources
4. the inventorying, validation, dissemination and application of traditional/indigenous knowledge about sustainable dryland management and resource use be developed and fostered, through the involvement of rural people — keepers of traditional knowledge — and scientists and students. Seminar participants and their scientific institutions, UNESCO, the UNCCD and other interested partners should embark on joint activities on the study of traditional knowledge, which can contribute significantly to combating desertification;
5. responsible land-use practices, such as crop diversity, crop rotation and pastoral management, that are based on sound scientific and technical research should be promoted. Such land-use practices should be diffused using advanced information and communication technologies;
6. collaboration in the fields of research and training among the various sub-regional organizations in Africa concerned with desertification and drought should be strengthened: CILSS, the Economic Community of Western African States (ECOWAS), the Intergovernmental Authority on Development (IGAD), the Arab Maghreb Union (AMU), the Southern African Development Community (SADC) and others, in partnership with UNESCO, ISESCO and other relevant organizations.

At the national level, the seminar recommends that:

7. institutions involved in the elaboration and implementation of UNCCD National Action Programmes (NAPS) seek collaboration with and support from United Nations and other intergovernmental organizations such as ISESCO, so as to fully benefit from existing research, training, education and financing schemes;
8. countries nominate dryland areas for Biosphere Reserve designation, so as to participate in regional and sub-regional research, training, and information exchange schemes;
9. national research institutions, universities and NGOs promote inter-disciplinary study approaches to better understand dryland degradation and rehabilitation;
10. research findings be communicated to National Coordinating Organs (NCOs), and be accorded appropriate consideration at the level of National Action Programmes (NAPS) for combating desertification;
11. research on land degradation and rehabilitation respond to local needs and be application oriented, with a view to ensuring food security and combating poverty, essential to sustainable development.

III. Session on Desertification Benchmarks and Indicators and the UNCCD

Considering the introduction by the OSS to the topic of Session III, 'desertification benchmarks and indicators' in relation to the UNCCD, the presentation provided by CILSS and a series of presentations from several states on the implementation of the UNCCD and on groundwater resources, participants of the seminar have formulated the following *recommendations*:

1. *Considering* the importance given by the UNCCD to monitoring and participatory evaluation as part of action programmes to combat desertification; *underlining* the necessity of reinforcing national capacities and sub-regional capacities on this matter; and *taking into account* the work already carried out in this respect in northern Africa and in western Africa by OSS, CILSS and their partners in applying the relevant resolutions of the COP/CCD, the seminar *recommends* that:
    i. work supporting the establishment of national indicators and benchmarks for action programmes to combat desertification be extended to other countries of the region;
    ii. the OSS and CILSS encourage and assist other countries to benefit from their acquired experience and knowledge, notably by developing training programmes and strengthening national capacities in areas relevant to and aspects of benchmarks, indicators and information handling.
2. *Taking into account* efforts deployed by CILSS in the application of the UNCCD in the field of environmental education for the benefit of its member states and the establishment of sub-regional West African action programmes, the seminar *recommends* that CILSS expand its actions in this field to all countries concerned by the West African Sub-regional Action Programme, with the support of UNESCO, ISESCO and IEPF.
3. *Considering* that water is and remains the essential factor for all sustainable socio-economic development, that groundwater resources constitute the only alternative resource in case of pluviometric deficiency, and that the aquifers of the large basins are of transboundary character; *taking into account* studies carried out, in particular by the OSS, on large-basin aquifers, the seminar *recommends:*
    i. that states become more conscious of their primary role in carrying out studies leading to a better knowledge of aquifers;
    ii. that institutions and development partners support actions to continue studies on aquifer basins in the African region.

Principles of Action

The seminar participants also agreed upon the following basic principles of action:

1. To capitalize on scientific and technical knowledge and achievements and to synthesize such knowledge in terms of countries, climatic zones and ecological zones
2. To simultaneously promote research in all scientific and technical fields associated with desertification and concrete actions and interventions based on knowledge already aquired
3. To promote holistic approaches to solving problems linked to or caused by desertification
4. At the national level, parties are invited to include members of the scientific community in their respective delegations to enable a more active participation in the work of the UNCCD's Committee on Science and Technology

The participants of the seminar wish a follow-up of the present seminar to be held every two years, on a rotational basis.

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List of Acronyms

AFVP	French Association of Volunteers for Progress *(Association Française des Volontaires du Progrès)*
AMU	Arab Maghreb Union
AZAP	Arid Zone Afforestation Project — Nigeria
BRAAF	Biosphere Reserves for Biodiversity Conservation and Sustainable Development in Anglophone Africa. (UNESCO project)
CBD	Convention on Biological Diversity
CCD	see UNCCD
CEC	Commission for Environmental Cooperation
CILSS	Permanent Inter-State Committee for Draught Control in the Sahel (*Comité permanent Inter-états pour la lutte contre la sécheresse dans le Sahel*)
CONACILSS	National Committee of the Permanent Inter-State Committee for Drought Control in the Sahel (*Comité national du Comité permanent Inter-états pour la lutte contre la sécheresse dans le Sahel*)
COP	Conference of Parties
CREFELD	Regional Centre for Environmental Education and Training to Fight Desertification in the Chad Basin (*Centre Régional d'Etude et de Formation Environnementale pour Lutter contre la Désertification*)
CSI	Coastal and Small Islands Project. (UNESCO project)
CST-CCD	Committee on Science and Technology — Convention to Combat Desertification
DERBAC	The Lower Casamance Rural Development Project — Senegal (*Projet de développement rural de la Basse Casamance*)
ECN	Energy Commission of Nigeria
ECOWAS	Economic Community of Western African States
EDF	European Development Fund
EEC	European Economic Community
EIA	Environmental Impact Assessment
EIS	Environmental Information Systems
ETP	Evapo-transpiration
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GIS	Geographic Information Systems
ICHS	Inter-African Committee of Hydraulic Studies
IDWSSD	International Drinking Water Supply and Sanitation Decade (1981–1989)
IEF	International Energy Foundation
IEPF	Francophone Institute for Energy and the Environment (*l'Institut de l'énergie et de l'environnement de la francophonie*)
IFAD	International Fund for Agricultural Development
IGAD	Intergovernmental Authority on Development
IGCP	International Geological Correlation Programme
IHP	International Hydrological Programme
IOC	International Oceanographic Commission
IRD	Institute for Research and Development — France (*Institut de Recherche pour le Developpement*)
ISERST	National Institute of Higher Scientific and Technology Research — Djibouti *(Institut Supérieur d'Etudes et de Recherches Scientifiques et Technique)*

ISESCO Islamic Educational, Scientific and Cultural Organization

ISRA Senegalese Institute of Agronomic Research (*l'Institut sénégalais de Recherche Agronomique*)

ITK Indigenous Technical Knowledge

IUCN World Conservation Union (formerly the International Union for the Conservation of Nature)

IVH Improved Village Hydraulics — Côte d'Ivoire

KSACDP Katsina State Agricultural and Community Development Project — Nigeria

MAB or UNESCO-MAB. Man and the Biosphere Programme, UNESCO

MOST Management of Social Transformation (MOST).

NAP National Action Programme

NCB National Coordinating Body

NEAZDP Northeast Arid Zone Development Programme — Nigeria

NGO non-governmental organization

OIC Organization of the Islamic Conference

ORSTOM French Institute of Scientific Research for Co-operative Development (now known as the *Institut de Recherche pour le Developpement*, IRD)

OSS Sahara and Sahel Observatory

PDLCD General Plan to Combat Desertification (*Plan directeur de lutte contre la désertification*)

PIDAC Integrated Development of the Casamance Project — Senegal (*Projet intégré de développement de la Casamance*)

PRG Regional Program for the promotion of butane gas

PRIMOCA Integrated rural development project of the Mid Casamance — Senegal (*Projet de développement rural intégré de la Moyenne Casamance*)

PRODULAS Anti-salinity programme — Senegal (*Programme de lutte anti-sel*)

PROGES Southern Water Management Project — Senegal (*Projet de gestion des eaux du sud)*

PRS Sedhiou Rice Cultivation Project — Senegal (*Projet rizicole de Sédhiou*)

PWC Potable Water Conveyance

RBDA River Basin Development Authority — Nigeria

SADC Southern African Development Community

SECADEV Catholic Relief Fund (*Secours Catholique pour le Développement*)

SEPP Sokoto Environmental Protection Programme — Nigeria

SODECI Society for Water Distribution in Côte d' Ivoire (*Société de distribution d'eau de Côte d'Ivoire*)

SRAP Sub-Regional Action Programme

SRCC Sub-Regional Co-ordination Committee

UNCCD United Nations Convention to Combat Desertification

UNCED United Nations Conference on Environment and Development (Rio de Janeiro, 1992)

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNESCO United Nations Educational Scientific and Cultural Organization

WHO World Health Organization

WHYCOS World Hydrological Cycle Observing System

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