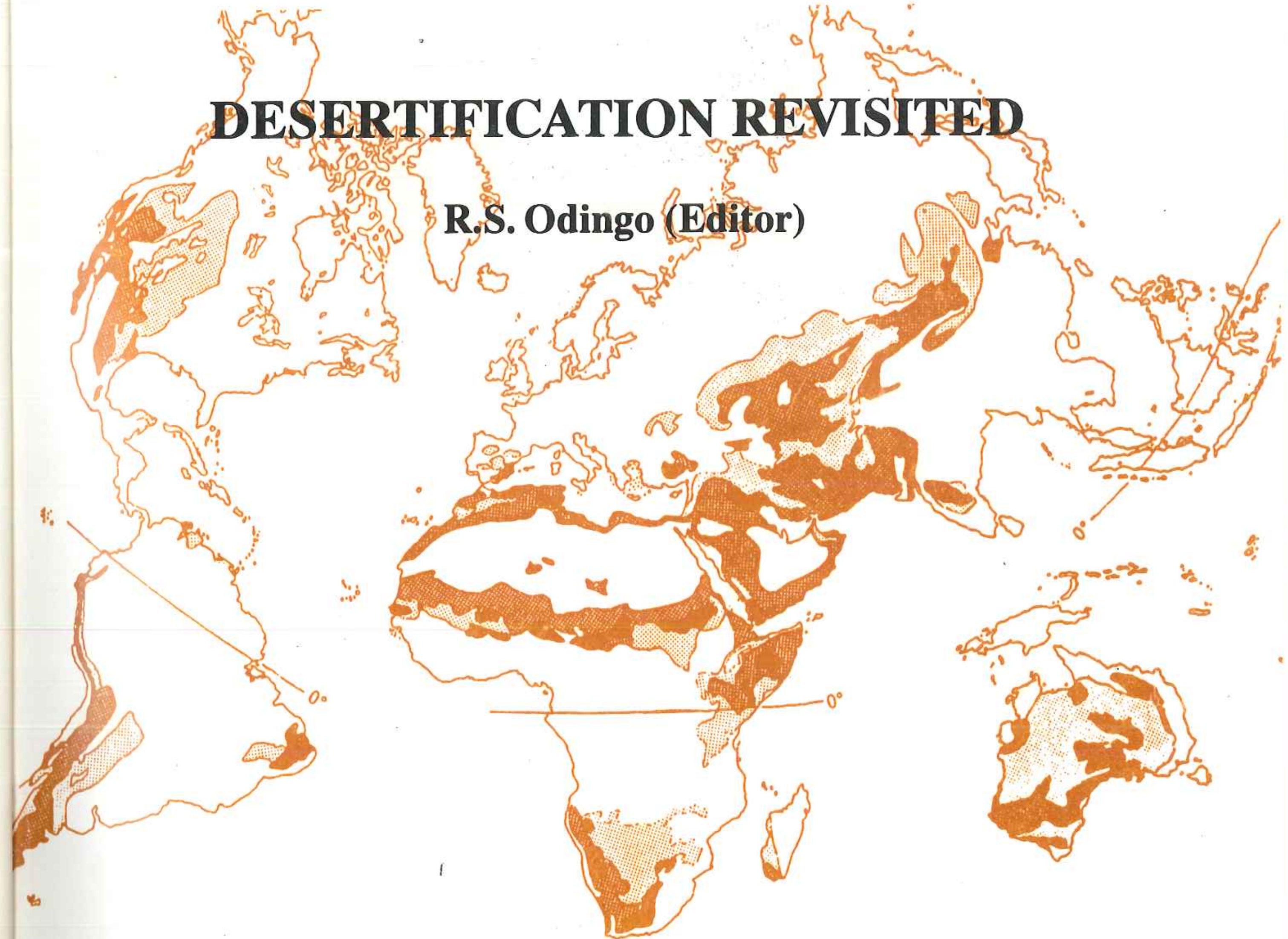
DESERTIFICATION REVISITED

R.S. Odingo (Editor)



Proceedings of an *Ad Hoc* Consultative Meeting

on the Assessment of Desertification

UNEP-DC/PAC, Nairobi, February 1990

DESERTIFICATION REVISITED

R.S. Odingo (Editor)

Proceedings of an *Ad-Hoc* Consultative Meeting on the Assessment of Desertification

UNEP-DC/PAC, Nairobi, 15-17 February 1990

CONTENTS

GLOBAL ASSESSMENT OF DESERTIFICATION

PREFACE AND INTRODUCTION

TO THE PAPERS PRESENTED TO THE AD-HOC CONSULTATION MEETING ON ASSESSMENT OF GLOBAL DESERTIFICATION: STATUS AND METHODOLOGIES (15-17 FEBRUARY 1990, UNEP - NAIROBI - KENYA)

The United Nations Conference on Desertification was held in Nairobi, Kenya, in 1977 and endorsed a blue-print for "dealing with" this major environmental problem. The blue-print was contained in a document entitled the Plan of Action to Combat Desertification [PACD], and it was subsequently approved by the UNEP Governing Council as well as the United Nations General Assembly. In that document a target date was selected (the year 2000) for bringing the problem of desertification under control. The first major assessment not only of the desertification process but also of the achievements of the Plan of Action to Combat Desertification [PACD] was carried out in 1982/83 and was presented to the UNEP Governing Council in 1984. The next major assessment of Desertification is due in 1992, and will probably be presented contemporaneously with the United Nations Conference on Environment and Development [UNCED] which will be held in Brazil. Preparations are already under way for this forthcoming assessment, and the papers contained in this publication give an indication of the current thinking as to how best to achieve a comprehensive result including the new maps to be produced to indicate the global picture of desertification in the 1990s and up to the year 2000. In so far as the papers were mainly intended for an Ad Hoc consultation, they are not necessarily the polished piece of work which will have to be presented to the world in 1992. However, it is possible to obtain an indication of the directions being taken by way of new regional, as well as country-studies of the process of desertification including efforts at the various levels to address the problem of its possible control.

One of the major criticisms which has been voiced by numerous individuals concerns the operational definition of "Desertification" which was adopted at UNCOD in 1977, and the contribution to this publication by Prof. Richard S. Odingo critically addresses this problem attempting to find a way out and to urge for a more scientifically realistic and acceptable definition to guide future programmatic activities under the auspices of the UNEP Desertification Control PAC. It is important to note that no meaningful assessment can be carried out without a clearcut definition of the problem, hence the need for an unequivocal one. Following the discussions which were generated during the *Ad-Hoc* Consultancy meeting the following definitions were adopted for the purposes of the assessment which is in process:

> *"Desertification/Land Degradation, in the context of assessment is, Land Degradation in Arid, Semi-Arid and Dry Sub-Humid areas resulting from adverse human impact".*
>
> *"Land in this concept includes soil and local water resources, land surface and vegetation or crops".*
>
> *"Degradation implies reduction of resource potential by one or a combination of processes acting on the land. These processes include water erosion, wind erosion and sedimentation by these agents, long term reduction in amount and diversity of natural vegetation where relevant, and salinization and sodication".*

"Assessment should provide measures and estimates for the effects of these processes, e.g. in the form of status or severity of water erosion based on explicit criteria".

"The information on the status for each process should form part of the assessment, which should not merely present an aggregate severity class for undifferentiated desertification/land degradation".

The important point is not the exact wording of the definition of desertification as such but the fact that moves are now being made to find a more operationally suitable definition. It is clear that if the new assessment of desertification is strictly guided by something like or close to the above comprehensive definition, one may come closer to getting the true global picture.

The one most substantial paper contained in this volume is that by Prof. Boris G. Rozanov entitled **"Global Assessment of Desertification: Status and Methodologies"**. This is a fairly comprehensive look at desertification globally but with the most interesting examples coming from the USSR in general and Middle Asia (USSR) in particular. The study leaves no doubt in one's mind that desertification or land degradation resulting largely from human activities is fast accelerating even in the so-called developed world. This new emerging picture is contrary to the posturing by most of the industrialized countries at UNCOD that desertification was a problem they were aware of and that they had the technology to eliminate it altogether. The study is largely qualitative but it produces a new and more insidious picture of a problem of land degradation which is still largely being underrated in most countries but which is bound to have serious ecological and economic consequences for all of them. For Africa, South West Asia (the ACSAD Region) and for East and South Asia as well as for central and South America, the study makes a quick general survey of the current status. Finally an attempt is made to provide a tentative statistical characterisation of the global status of desertification. In short, here is a preliminary statement of what the new assessment is likely to produce, using agreed assessment methodologies, and it enable one to have a glimpse at the magnitude of the problem to be faced by all the countries affected by desertification.

Apart from the specific global document prepared by Prof. B. G. Rozanov, the publication contains some regional examples. These include the Kenya Case Study co-ordinated by W. Ottichilo and prepared by the Department of Resource Surveys and Remote Sensing. The case study is particularly important because it attempts to adopt the FAO/UNEP Desertification Assessment Methodology to a particular situation, in this case the two semi-arid districts of Baringo and Marsabit in Kenya. The lessons learnt from the Kenya Case Study could be extremely useful in other similar situations around the world. Added to the Kenya Case Study, is the study prepared by Soviet scientists entitled **"Recommendations on Application in the Sahelian Zone of the FAO/UNEP Provisional Methodology for Desertification Assessment and Mapping by Dr. N. Kharin"**. This particular study for the Sahel Region in West Africa also uses aerial photography and satellite imagery very extensively to pinpoint areas subject to desertification in Sahelian West Africa. The problems encountered should be shared by all interested persons in similarly affected countries. The point which needs emphasis concerns the promise presented by the use of multi-temporal satellite imagery to pinpoint areas undergoing land degradation and possible **"desertification"**. Nevertheless the methodologies available still have to be perfected and may not be ready for the 1992 Global Assessment of Desertification. The presentation by L. Guyot entitled **"Development of a New Method for Monitoring of Desertification in Sahelian and Sudanian Regions 1952-1987"** falls in the same category.

The *Ad-Hoc* meeting benefited immensely from several contributions from the USSR by N. Kharin, E. Milanova and Kalyenov. All these give a regional picture of the land degradation/desertification problem in several parts of the USSR and in Afghanistan. Also by Kharin is the study of Desertification in Mongolia. The importance of these contributions lies in the fact that the problem appears to be increasing rather than decreasing in the studied areas and thus for the global picture there will be no easy solutions to be jumped at.

One area which received adequate attention during the Ad Hoc meeting was that concerned with the preparation of maps at various scales and from say, a small district in one country, to a whole region, for purposes of comparison. It became clear that because of the lack of a clearcut definition of desertification and also because of the lack of ready-made data, it is going to be difficult to come up with detailed maps. Instead there will be prepared "indicative maps", but the advantage will be the possibility to include large scale maps from case studies such as the ones already mentioned together with the much more generalised small-scale maps at the global or regional levels. All these maps are expected to be included in the proposed UNEP Thematic Atlas of Desertification. In this connection, it was realised that much use could, and will be made of the Guidelines for General Assessment of the Status of Human induced Soil Degradation (GLASOD) produced by the International Society of Soil Sciences (ISSS), because soil degradation is an essential aspect of land degradation which may also ultimately mean desertification.

The materials are mainly aimed at those who maintain a live interest in the problem of desertification and the need for a more realistic approach to its possible containment, and for profitable investments globally towards its control, if that is at all possible. Some materials in this publication for example that from Iran shows the efforts which are being made in individual countries, but it is important to point out that efforts which merely attack the symptoms rather than the causes of desertification will not get very far. It is this among other things that calls for a much more clearer definition so that one may decide whether one is dealing with a natural, or with a man-made phenomenon. It is therefore recommended that this limited publication be made available to libraries which are the depository of knowledge about desertification, and the global as well as other efforts to control it.

REVIEW OF UNEP'S DEFINITION OF DESERTIFICATION AND ITS PROGRAMMATIC IMPLICATIONS[1]

Richard Samson Odingo
Professor of Geography
Department of Geography
University of Nairobi
Nairobi, Kenya

for
Desertification Control Programme Activity Centre
United Nations Environment Programme

May 1989

1. TERMS OF REFERENCE

The Terms of Reference for this particular task were as follows:

1. Undertake a desk study of UNEP's conceptual and programmatic definition of desertification and examine the level of implementation and constraints in the Plan of Action to Combat Desertification and major relevant General Assembly Resolutions and UNEP Governing Council decisions adopted since the UN Conference on Desertification in 1977.

2. Assess major areas of UNEP/DC-PAC intervention in desertification control to determine their validity realism and consistency with the definition of the desertification phenomenon and its control.

3. Carry out a critical review of major reports of UNEP on assessment of the status of desertification and progress on combating desertification and on that basis make an objective evaluation of UNEP's approach and consistency in formulation of programmes designed to address problems of desertification.

4. Examine reports and reviews of the concept and definition of desertification from other scientists, organizations and institutions for comparison and synthesis with UNEP's.

2. INTRODUCTION

2.1 Following the Stockholm Conference on the Human Environment in 1972, and the establishment of the United Nations Environment Programme (UNEP) the following year, several environmental issues

---

1 The report was presented as background material for the discussion of the meeting.

were taken up as being of major international concern, and the newly established UNEP was charged with the initiation of action programmes with clear-cut objectives as follows:

(i) To improve the scientific and technological understanding of the selected environmental issues;

(ii) To "combat" the environmental problems by working out sound strategies for halting and wherever possible reversing the adverse environmental tendencies which had been observed;

(iii) To work out alternative strategies for the use of the earth's natural resources with a view to minimizing the adverse environmental tendencies;

(iv) To bring about visible and sustainable improvements in the Human Environment and thereby improve the quality of life for the earth's inhabitants.

These lofty objectives were to guide the emergence of environmental programmes affecting many facets of natural resource use on the surface of the earth, and as the programmes grew so did the scientific back-stopping required to justify the intended actions and the expenditure of large sums of money to halt the damage and to reverse the processes where this was found to be feasible. It is perhaps appropriate to mention at this stage that many of the "corrective activities" have tended to be guided by the often false assumption that technology has the answer to all the problems being addressed. This has over the years influenced the language used which has tended to be militaristic, such as to "combat", to reverse, and so on. It also led to some unrealistic deadlines like halting desertification by the year 2000. This "technological superiority approach", has tended in some cases to mark the processes being studied, and led to false assumptions, and false hopes that the solutions to the problems being addressed were just around the corner, if only the massive funds required could be raised from the international community. In this report, an attempt will be made from time to time to throw in a word of caution in cases where it is felt that the science involved is not exact and that the assumed technological superiority needs to be subjected to further inquiry in order to find more rational and technologically sound solutions to the problems being addressed.

2.2 At Stockholm desertification as a topic did not feature much as a separate topic,though the word "desertification" was actually used, and it was not until the Sahelian Drought (1968-1973) and its devastation in the sub-region became an international issue three years later that most of the nations affected by various degrees of land degradation, particularly in the semi-arid and sub-humid ecological belts, saw desertification as an all-pervading process that deserved full international attention with the view to setting in motion "corrective measures". At Stockholm there was strong support for general activities intended to prevent ecological or environmental damage (Recommendations No.19, 24, 38, 39, 51, 55, 58, 60, 66, 68 and 102) as well as to "protect" and "enhance" the environment, and it is fair to assume that land degradation which was later to acquire the title of "Desertification" was also in the minds of the delegates who were attending that Conference. The Stockholm Conference established several intended activities under the titles Environmental Assessment (Earthwatch), Environmental Management and Supporting Measures. These areas of concentration were among the items which formed the programme of the newly created UNEP, and from then additional areas of concentration have since emerged to add to the programmatic responsibilities of the UNEP. Recommendation 20 of the Stockholm Conference dwelt at length on the importance of improved knowledge and the transfer of experience on soil capabilities, degradation, conservation and restoration. In it were suggestions for the preparation of a World Map of Soil Degradation Hazards which if implemented was bound to pinpoint areas subject to "desertification", especially in arid and semi arid, and sub-humid lands of the world in general, and of the tropics in particular.

2.3 At its first session in June 1973, the Governing Council of UNEP was quick to spell out policy objectives and among these were the obvious concerns for the need to "prevent the loss of productive soil through erosion, "salination" or contamination; to arrest the process of "desertification" and to restore the productivity of desiccated soil" (Compendium of Legislative Authority 1972-1977 p.53)[1]. This was the first major mention of the process subsequently known as "desertification", within the UNEP circles, and it is important to link it with the clear concern for the loss of productive soil through erosion, salination and contamination". It is equally important to point out that at this stage there was no effort to define the term "desertification", and that serious conceptualization of the process was to come much later when this word had found its way into the vocabulary of the environmental movement where it would be handled by scientists and policy makers all at the same time with a clear likelihood of misunderstanding in at least some of the quarters that would be called upon to focus on this phenomenon. Even more significant at this stage, was the use of the word "to arrest" in reference to the process of desertification because it implied that in the minds of the policy makers, here was an environmental problem which could easily be "arrested" if the existing technology was used appropriately. This "technological superiority approach" has to a large extent bedeviled the correct scientific understanding of desertification as a partly natural, though largely a man-made process. In spite of these uncertainties the Executive Director of UNEP was requested by the First Governing Council to mount a programme of action to focus on this area. According to the Compendium of Legislative Authority 1972-1977 (p.56)[1], The Executive Director of UNEP was requested to perform the following tasks:

> *"To mount a concerted programme to help countries control the loss of productive soil through erosion, salination, desertification, and lateralization, and to help them in land reclamation which is ecologically compatible, with special emphasis to be laid on arresting the spread of deserts"; and also "to support, encourage and initiate national and international efforts for efficient drought forecasting and help countries in mitigating the consequences of drought"* [1]

It is therefore very clear from the very beginning that in terms of perception and in terms of the eventual definition of the term "desertification", there was a perceived dichotomy between desertification and drought which has tended to be perpetuated even in recent thinking. In December of that same year (1973), the General Assembly by its Resolution 3054 (XXVIII) noted with interest *"the recommendations and resolutions of the heads of state of the drought-stricken countries, including the medium-term and long-term action programme, and the establishment of the Permanent Inter State Committee on Drought Control in the Sahel, which is to co-ordinate national and regional action"*[1]. With hind-sight it is unbelievable that is was the plight of the drought-stricken Sahelian lands, which led to the global "desertification movement" which finally culminated in the convening of the United Nations Conference on Desertification (UNCOD) in 1977. It is interesting to note at this stage the apparent reluctance to link drought and desertification. At the UNEP level, although there is no evidence of a definition of the term "desertification" programmatic activity was commenced with the sole purpose of "arresting" the process of desertification and to restore the productivity of desiccated soil. That year (1973), at the first meeting of the UNEP Governing Council, some $1 million were set aside for the newly created programme on Land, Water and Desertification (Compendium of Legislative Authority 1972-1977 p.69)[1]. In the absence of a clear-cut definition at this stage it would be fair to assume that drought was seen as an ephemeral and annoying phenomenon, naturally occurring, whereas desertification was being seen as a more insidious phenomenon which was liable to be "exacerbated by drought", and that unlike drought it was largely man-made. These assumptions have been arrived at by synthesizing the tone of the debates at the UNEP Governing Council meetings and at the UN General Assembly meetings.

2.4 To a large extent the "desertification movement" acquired its own momentum largely as a result of the initial concern for the occurrence of widespread and debilitating droughts, in particular the Great Sahelian Drought (1968-1973), and the series of almost contemporaneous droughts which were at that time being experienced in several other parts of the world. Up to that moment, droughts had been regarded as a "normal" aspect of climatic variability and even climatic fluctuations, as will be explained later. But now it was noticed that the droughts were also associated with a more permanent ecological damage or land degradation which was termed "desertification", and which was of a more global concern to the extent that it deserved detailed international attention both at the level of the UNEP, and at the level of the UN General Assembly. In this Report an attempt will be made to trace the origins of the word "desertification", its employment within the UNEP circles, including a brief look at the programmatic activities that have been, and are still being established under the leadership of the UNEP. In addition, analysis will be made of the various approaches to arid lands studies and the "desertification problem" by the scientific community to establish to what extent there is a unanimity of views both at the scientific and technological levels to guide the programmes at the various levels that are the responsibility of UNEP.

3. THE SCIENTIFIC AND TECHNOLOGICAL RESEARCH BASE FOR THE ANTI DESERTIFICATION MOVEMENT

3.1 In order to put things in their proper context, it is important to mention, even briefly, the decades of scientific and technological research which was carried out both at the national and international levels on problems of arid and semi-arid lands. Since many regions in the developed and developing countries are afflicted by aridity, with large tracts of their territory either true desert or semi-desert, there have emerged over the years numerous viable scientific and technical research programmes in Australia, West Asia, China, Africa, North and South America, arrived at finding immediate as well as long-term solutions to the challenges put forward by the need to understand the ecology, as well as to manage rationally the natural resources of these lands. Within the United Nations system, the UNESCO had pioneered a viable arid lands research programme from as a far back as 1951, such that by 1958 this was one of its largest research projects. The term "desertification" was not being used at this stage. An Advisory Committee on Arid Zone Research had been created in 1951 and this was quickly expanded into a global research programme primarily dedicated to the study of deserts, though later it extended its activities into the semi-arid belts of the world. The research on arid lands pioneered by UNESCO had as its main objective, the promotion and stimulation of research in the various scientific disciplines which have a bearing on the problems of the arid regions. Studies included such fields as biology, meteorology, geomorphology, botany, geology and even archeology, of the arid lands, and in the earlier period they tended to remain along these narrow disciplinary lines. But later UNESCO decided to sponsor multi-disciplinary research projects because it was quickly realized that the problems of the arid lands needed the combined expertise from many different disciplines. At first the majority of the research projects tended to concentrate on the arid lands *per se*, but later there was a genuine effort to cover the semi-arid lands as well. The justification for the research was first and foremost to improve the scientific and technological knowledge about arid lands, and secondly to bring about the use of this knowledge for the improvement of the living conditions of mankind, and in particular the inhabitants of the deserts and semi-desert regions. To achieve these aims UNESCO encouraged the establishment and development of Special Desert Research Institutes and Arid Zone Research Centres with the function of providing the basic scientific information needed for any development plans. (See UNESCO 1963)[2]

3.2 The catalogue of research areas covered by the UNESCO programme was long and included arid zone hydrology, utilization of saline water, plant ecology, wind and solar energy, human and animal ecology, climatology, salinity problems in the arid zones, plant-water relationships, land use, and nomads and nomadism. In its programme UNESCO established a history of co-operation with other UN agencies such as the FAO, WMO, as well as other national and international organizations. When the UNEP was established in 1973, UNESCO offered its assistance and experience in many areas of knowledge, including that of Arid Lands.

3.3 The World Meteorological Organization (WMO) for its part had carried out studies in collaboration with UNESCO on arid lands climatology, which naturally touched upon the frequent occurrence of droughts in the semi-arid lands bordering the deserts. Unfortunately much of the research work in these early days was not always applied and it tended to concentrate on perfecting the science rather than rendering the findings of immediate use by human societies afflicted by drought.

3.4 The UN Food and Agriculture Organization (FAO) had made some valuable scientific and technological findings on many aspects of arid and semi-arid land ecology, and during the Stockholm Conference in 1972 it was requested (Rec. 20) to co-operate, specifically *"with other international agencies concerned, strengthen the necessary machinery for the international acquisition of knowledge and transfer of experience on soil capabilities, degradation, conservation and restoration"*[1]. The FAO was indeed requested to work towards the production of a World Map of Soil Degradation Hazards. With hindsight it is gratifying to comment on the fact that this proposed map which had its origins in the Stockholm Conference turned out to be the closest one could get to a global picture of desertification.

3.5 The points which have been made in the last four paragraphs are that when the topic "desertification" was pushed to the center stage of the "Environmental Movement", there was already a wealth of scientific and technical knowledge to provide a back-stopping for any proposed activities by the international community. Whether or not this knowledge was adequate as well as appropriate remains to be seen. But the fact that it was there made it easy to mount, at short notice, programmes of drought control or amelioration, and later what became known as "anti-desertification" programmes. The first such test programme with international spot-light on it was the disastrous and crippling drought that struck the Sahelian lands of West Africa between 1968-1973. Using the existing scientific and technological knowledge, and bringing together expertise from international organizations like UNESCO, WMO, FAO and several bilateral and multilateral donors, the Comitè Permanent Inter-etats de Lutte Contre la Sècheresse dans le Sahel (CILSS) — or the Permanent Inter-State Committee on Drought Control in the Sahel was quickly established in 1973. The aim of the Committee was to put into operation a viable drought control programme, thereby attempting to alleviate human suffering due to drought, and bringing science and technology to "fight" drought, and to rehabilitate drought-damaged land in the Sahel. In the search for the origins of the definition of desertification, it is important to go back into this recent history because it is a well-known fact that it was the Sahelian Drought that succeeded in galvanizing world opinion to "fight" desertification, and that led to an outcry for a fully-fledged United Nations Conference to bring political weight to bear upon the problems faced by arid and semi-arid lands globally. The way CILSS had been conceptualized reveals scientific and technical "superiority" assumptions over environmental problems like drought, by suggesting that all the "armaments" were available for the "war" against drought, and that what was now important was to work out a battle plan. To some extent it can be said that although they called for additional scientific and technological research to accompany the operation of CILSS, they were overawed by the strong political will that existed here, and that was arrived at bringing the drought problem under control.

3.6 This unmistakable "military approach" to problems of the environment were later to be found in international efforts to tackle desertification, when it was realized that desertification was a more deadly enemy than drought, because it threatens the whole ecological basis of production in the affected lands. Unlike drought which was thought to be natural, desertification was increasingly being visualized as man-made, and more difficult to tackle. Hitherto, droughts had been seen as a "normal" aspect of climatic fluctuations and even climatic change, but it now became obvious that prolonged droughts tended to exacerbate the severe <u>land degradation</u> which was progressively occurring not necessarily on the desert margins alone, but also in the semi-arid and sub-humid belts, often far removed from the deserts. Thus efforts to better understand drought climatology pioneered by the World Meteorological Organization (WMO) in collaboration with UNESCO, and the worldwide scientific community, helped to clarify the position and to set aside drought as one phenomenon to be dealt with through short-term measures, and <u>land degradation</u>, mostly man-induced which was later to be termed "<u>desertification</u>", to call for a separate effort with an array of scientific and technological tools, and "weapons" used in the "fight" against this more insidious problem.

4. SCIENTIFIC ORIGINS OF THE TERM DESERTIFICATION

4.1 It has been pointed out that due to widespread scientific and technological research on the problems of arid and semi-arid lands, the word "desertification" had quietly crept into the scientific literature that by the time of the Stockholm Conference it could be used in the deliberations without creating any doubt or consternation! One of the earliest scientists to use the term "desertification" was Aubreville (1949)[3] who is associated with originating it. Aubreville was referring to conditions in what could be legitimately regarded as semi-arid and even sub-humid zones with annual rainfall totals ranging from 700-1500 mm per annum. He was emphasizing the process of land degradation that was taking place in these zones, largely as a result of human activities. The now famous quote in French was as follows:

> *"ce sont des dèserts qui naissaent aujourd'hui, sous nos yeux, dans les pays où il tombe cependant annuellement de 700 à plus de 1500 mm de pluies"* (Aubreville A. 1949 <u>Climats, forets et désertification de l'Afrique tropicales</u>, Societé d'Éditions Géographiques et Coloniales, Paris).[3]

To a large extent the definition of desertification most commonly used by the UNEP can be assumed to come closer to this original Aubreville definition, which on second thoughts was an expression of horror by Aubreville of the extent to which vegetation was being destroyed in these semi-arid and sub-humid regions that he was writing about. This assertion can be gleaned from the English translation of Aubreville's comment as follows:

> *"These are real deserts that are being born today, under our very eyes, in regions where the annual rainfall is from 700 mm to 1,000 mm".*[3]

Having crept into the vocabulary, and being used by the scientific community over the whole globe, the word "desertification" has over the years, acquired different meanings, according to the emphasis being made by the individual or group of scientists, depending on their training and their disciplinary backgrounds, such that some are emphasizing vegetation or the lack of it, and yet others are more interested in the geomorphological impacts of the removal by man of the vegetation cover.

4.2 By the time of the Stockholm Conference the word "desertification" was being liberally used by most scientists, as a phenomenon representing some environmental, and even developmental symptoms that were characterized by land degradation in general, and soil and vegetation degradation in particular. These early records show a lack of specificity in terms of areas affected because the usage was indiscriminately applied to all lands from the desert proper, to the semi arid and sub-humid belts. For example, one encounters the use of the term "desertification" in relation to land degradation in some Saharan oases. (see Despois, J. (1973))[4]. The crisis of the Saharan Oases in D.H. Amiran et. al. (Eds.) Coastal Deserts, Tucson, pp.167-169; Echallier J.C. (1972): Villages deserts et structures agraires anciennes du Tonat — Gourara (Sahara algèrien) Paris, 122p.[5]; Meckelein, W. (1976): Desertification caused by land reclamation in deserts: The example of the new valley, Egypt. In Pre-Congress Symp. K26 of XXIII Int. Geog. Congress, Working Group on Desertification in and around Arid Lands, Ashkabad, USSR, 1976, pp.151-153[6]; Meckelein, W. 1980 Desertification in Extremely Arid Environments. Stuttgarter Geographische Studien, Band 95; I.G.U Working Group on Desertification in and around Arid Lands — Sub-group Extremely Arid Environments[7]; Evenari, M., Shanan, L. and Tadmor, N.H. 1971. The Negev: The challenge of a Desert. Cambridge Mass., Harvard University Press, 345 pp.[8]; Novikoff, G. (1975). The desertification of rangelands and cereal cultivated lands in pre-Saharan Tunisia: a statement on some possible methods of control in Novikoff et. al. (Eds.) Tunisian pre-Saharan Project.[9]

4.3 For a time the French-speaking scientific community showed a preference for the term "desertization" instead of "desertification". To these groups, "desertization" (to mean desertification, or desert encroachment) was defined as the spread of desert-like conditions in arid or semi-arid lands (Rapp.A., Le Houerou, H.N. and Lundholm, B. (Eds.) Can Desert Encroachment be stopped?, SIES, Stockholm, (1976)[10]. Anders Rapp and his colleagues (op. cit.)[10] tried to rationalize the use of the alternative terminology by specifying the conditions under which desertification occurs as due to:

(i) severe prolonged drought; and
(ii) man's over-exploitation of vegetation and soil in dry lands.

But the Geographical Union set the standard when in 1972 they set up a Working Group on Desertification in and Around Arid Lands. Since then most of the scientific community seem to have agreed to the use of the term "desertification" instead of "desertization". The important point that needs to be made at this stage is that at the beginning, a large majority of the scientific contributions approached "desertification" from the desert margins into the semi-arid and sub-humid lands, and this tended to color their thinking, such that they came to view the process as one in which the deserts were encroaching on the margins of semi-arid and sub-humid lands, rather than the kind of land degradation that can, and does, take place within and outside these two latter zones as a result of mismanagement by human populations.

4.4 It has been indicated earlier that world opinion "to do something about desertification" was galvanized by the Sahelian Drought and by the realization of the global scientific community that there were significant "teleconnections" between drought occurring in one part of the world with another. Thus after

the Governing Council of UNEP held in March 1974, the pace of activities began to quicken. In discussing activities to be pursued in respect of Land, Water and Desertification, the Governing Council directed that first priority *"should be given to the establishment of integrated research programmes on arid and semi-arid lands"* (UNEP GC 1974)[1]. Even more important was the decision to pay particular attention to Sudano-Sahelian Region. Following the General Assembly Resolution 3054 (XXVIII) of 17 October 1973 and because of the urgency of immediate intervention, the Executive Director of UNEP was requested to treat this region afflicted by droughts as a priority area of concentration within the programme and activities planned for 1974 (Compendium of Legislative Authority 1972-1977, p.93)[1]. The General Assembly 29th session at the end of that year went even further than the UNEP Governing Council. Prior to this session the United Nations Development Programme (UNDP) Governing Council had called for the need to undertake in-depth studies on the extent of the drought in Africa, and draw up corresponding action programmes. The General Assembly (29th Session) now emphasized the need to ensure that all available knowledge in the area was fully utilized, in particular the experience available in the Office of Technical Co-operation at United Nations Headquarters, the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), the World Health Organization (WHO), the United Nations Industrial Development Organization (UNIDO), the United Nations Conference on Trade and Development (UNCTAD) and the Committee on Science and Technology (CST) of the Economic and Social Council. It went even further by deciding to initiate concerted international action to "combat" desertification and to convene in 1977 a United Nations Conference on Desertification, to give impetus to the international action to combat desertification (Compendium of Legislative Authority 1972-1977, p.124)[1]. Even before defining "desertification" in detail, and trying to understand what it was that was to be "combated", the General Assembly instructed that the Inter-Agency Task Force set up should undertake as one of its first functions the preparation of a World Map of areas affected and areas likely to be affected by the process of desertification. The General Assembly was reacting to a bad sub-regional drought, and there was a real risk that the drought would be confused with the much more complicated phenomenon known as "desertification".

4.5 Even before the preparations for the forthcoming Desertification Conference were started, one of the most worrying problems was, that many of the developing, and newly independent African countries had no previous experience in coping with a major drought which did not just last for one year, but which looking back now was to last for over ten years in some cases. Due to lack of scientific and technical preparation the droughts proved to be devastating, and in some cases succeeded in completely paralyzing the economies, to the extent that in their minds and even in the literature emanating from these countries, they tended to treat drought and desertification inter-changeably, thereby complicating any serious efforts at definition of either phenomenon in future. For the purpose of this Report, drought will be treated as a natural hazard, to be classified together with floods, earthquakes and similar "climatic accidents". If such a definition is accepted, then it goes without saying that societal response to drought should be largely similar to that which would be the case for floods or earthquakes, as the case may be. Unfortunately this does not make it any easier to comprehend the prolonged droughts which should be better termed "desiccation" (see Kenneth Hare 1987. Drought and Desiccation: Twin Hazards of a variable climate in Wilhite D.A., Easterling, W.E. and Wood D.A. (Eds.), Planning for Drought; towards a reduction of societal vulnerability, Boulder and London, Westview Press 1987)[11]. Desiccation according to Kenneth Hare is a *"prolonged period in which drought slowly and intermittently intensifies. Even natural ecosystems may be confounded by two or three decades of decreasing rainfall"*[11]. He classifies the Sahelian Drought which triggered the "Desertification Movement" as a process of "desiccation". Now it is a well-known fact that the Great Sahelian Drought of 1968-73 was *"a much more prolonged and profound disturbance of rainfall over much of Africa"*[11]. One should, therefore, be prepared to forgive those in Africa to whom drought was a greater reality than desertification.

4.6 In efforts to define desertification attempts have been made to underline its more permanent nature as compared to drought, as will be seen later in this Report. However, Wilhite and Glantz (1987)[12] in their recent analysis of drought definitions, have endeavored to point out the fact that drought impacts are long lasting, at time lingering for years, and that human and social factors often aggravate the effects of drought. These statements come rather close to certain definitions of "desertification", which emphasize the fact that it is a man-made rather than natural, phenomenon. In the same way as one struggling to find a workable definition of desertification, Wilhite and Glantz (op.cit.)[12] have the following to say:

"The inadequate understanding of the concept of drought and the lack of appreciation of its physical and social impacts by the scientific community and governments has serious world-wide implications for the future as the difference between food production and food consumption narrows" (Wilhite and Glantz, 1987, p.24)[12].

5. PREPARATIONS FOR THE UN DESERTIFICATION CONFERENCE

5.1 It was during the preparations for the United Nations Desertification Conference that the scientific community was constrained to agree on a definition of this phenomenon for presentation to the Conference. The fact that an agreed definition was arrived at does not necessarily suggest that the whole of the scientific community was in agreement, but it provided UNEP with a working definition which has been used now for 12 years, which suggests that it was very close to the mark even though there are now some indications that the scientific community is beginning to have second thoughts as to how absolute the definition which was selected at the time should be.

5.2 As already indicated the decision by the UN General Assembly to hold a Conference on Desertification was a momentous one, and it called upon the UN Agencies to tap all the available knowledge both in-house and among the scientific community at large. The General Assembly decision was a political one, and it now needed the science and technology to make it a reality. At the international level the results of the Arid Zone Research previously sponsored by UNESCO, and more specialized work on soils and many other aspects of agriculture like dry farming, rangeland development, and forestry in arid lands would now be made available to the proposed Conference on Desertification. The World Meteorological Organization was charged with the preparation of papers on the link between climate and drought, and climate and desertification. Some of the overview papers were expected to have clearly pointed objectives. For example the climatological studies had to try and answer some of the following questions:

"Was the Sahelian Drought evidence of larger changes in the global climate? Was the Sahara expanding south? What implications did this have for the countries directly involved? For their neighbors? For the international community? Most important, what could be done to cushion the impact of, or prevent disastrous changes?" (UNCOD: Round Up Plan of Action and Resolutions, p.1).[13]

The whole of the scientific community was expected to address itself to the above questions and others as well. On the basis of the massive researches on arid lands which had so far been carried out by Unesco, FAO, WMO, ICSU and IUCN, there was a general feeling that scientific knowledge on how to handle the arid lands existed, and what was now wanted was the application of this scientific and technological knowledge to the solution problems associated with desertification.

5.3 It is surprising that many of the scientific groups which had worked on arid lands knew the symptoms of desertification and yet only a few were prepared to define it clearly and openly. According to Per Brink (1976)[14], a lot of the basic scientific research findings were not in a ready form to be applied, and this included the many years of Arid Zone Research pioneered by Unesco, and the more recent programme "Man and the Biosphere" (MAB) by the same agency fell into the same category. However, now that they were challenged by the UN General Assembly, these agencies and organizations had now to find ways of applying the accumulated knowledge and specially of incorporating socio-economic considerations into their equations. The Swedish National Science Research Council in a book entitled "Can Desert Encroachment be stopped?" (1976)[10] prepared for UNCOD and authored by several known experts on arid lands, were the first to put forward a definition of desertification in the following words:

"Desertisation or the degradation of arid and semi-arid ecosystems is a stepwise decomposition of the plant and animal communities. Initially, there is a reduction of production of part of the species within the amplitude — that is the limits of variations — of the ecosystem. In terrestrial ecosystems the process usually occurs through soil deterioration via loss of primary species and invasion by new specific material. When the density of vegetation decreases, certain conditions of soil and climate may also induce desertization.... The loss of species indicates an incipient irreversible evolution which transmutes the system" (Rapp, A. et. al. 1976, pp.8-9).[10]

This definition though close to the one which was finally accepted at UNCOD was not sufficiently unequivocal in spelling out what is and what is not desertification. In any case, the authors were using the word "desertization" instead of the now more generally accepted one namely "desertification".

5.4 The actual preparations for UNCOD were a massive exercise. Several distinguished groups of scientists were asked to prepare background papers on key aspects such as Climate and Desertification, Ecological Change and Desertification, Population, Society and Desertification, and Technology and Desertification. There was one Overview Paper. In addition to these several countries affected by desertification were asked to prepare case studies which were intended to specify the problems of desertification and to indicate how technology was being applied to deal with them, and if in their experience, any success was being achieved. Furthermore the whole of the scientific community was encouraged to hold national, regional and international seminars before UNCOD, to discuss and throw some light on desertification, and to make useful inputs to the main conference process. It is also important to indicate that a week before UNCOD an important science congress on desertification was held in Nairobi with the very purpose of deliberating on the scientific, technological and human issues surrounding this phenomenon, and of making important inputs to the main Conference process.

5.5 Since in the eyes of many observers, both scientists and others, climate was supposed to be the culprit which manifested itself in the form of prolonged droughts and even possible climatic change, the climatic study set out to answer the following four questions in respect of desertification:

(i) What is our present knowledge about secular or long-term shifts of climate?

(ii) To what extent can climatic variations be attributed to man's action?

(iii) What are the prospects for longer-term (season and longer) forecasts? and

(iv) What is the likelihood of significant human amelioration of present conditions?

To the first question there was no comforting answer except to point out that climatic fluctuations of up to 30 year intervals are normal, so are the accompanying droughts, such as the Sahelian Drought. The same is true of wet periods. Historic and pre-historic records show many much longer fluctuations. In other words "Nature Pleads Not Guilty" (see Garcia R. 1981)[15]. To the second question it was revealed that human activities can lead to "deteriorating surface microclimates, and increases in albedo", and if widespread, could combine to modify large-scale climate. To the third question the answer was that there is no present method available for such forecasts, and progress towards it will be slow. And finally to the last question it was agreed that better land-use methods will improve local micro-climates. In other words the climatic evidence also tended to point a finger towards human activities in causing desertification, and to re-emphasize that droughts will continue to come and go. ("Climate and Desertification" A/CONF.74/5)[16]

5.6 The report on "Ecological Change and Desertification" (A/CONF.74/7)[17] showed the indicator marking the progressive stages leading finally to desertification. It showed that perceptions of what constitutes desertification will vary depending on the culture of a people in question, and went ahead to suggest methods of rehabilitating desertified land, using sound ecological principles.

5.7 The Background Document on Population, Society and Desertification (A/CONF.74/8)[18] associates the process of desertification with apart from climatic fluctuations, two major aspects of human change as follows:

(i) That both the growth and decline of population appear to cause desertification;

(ii) Three types of social change also contribute to desertification: integration into wider socio-economic systems alters the dynamics of local livelihood systems; the invasion of the new and the retreat of the old technologies truncates the evolution of indigenous expertise; and the fluctuating strength and effectiveness of governments drastically affect stability and survival in the dry margins.

The study was not in favour of the definition of desertification as "the spread or intensification of desert-like conditions". It insisted that human societies are not merely passive recipients of the harmful effects of desertification, and that all societies have coping strategies to deal with desertification. In other words desertification is very much a human-induced process in their constant efforts to adjust to difficult environmental conditions associated with the occurrence of prolonged droughts.

5.7 The Background Document on Technology and Desertification (A/CONF.74/6)[19] went even further in endeavoring to clarify issues surrounding first drought and then desertification. It commented on the Sahelian Drought as follows:

"Drought is something to be expected in the earth's drylands and it has been experienced many times in places with a severity sometimes even greater than the recent disaster in the Sahel. Yet this century's great improvements in communications brought the Sahel drought forcibly to the world's attention and served to remind mankind of one of its most serious and enduring problems — the advance of desert-like conditions onto once-productive land".[19]

The Document also attempted in its own way to define desertification as follows:

"Desertification is the impoverishment of arid, semi-arid and some sub-humid ecosystems by the impact of man's activities. It is the process of change in these ecosystems that leads to reduced productivity of desirable plants. Alterations in the biomass and in the diversity of life forms, accelerated soil degradation, and increased hazards for human occupancy. Desertification is the result of land abuse."[19]

The rest of the Document went on to assess the role that had been played by the application of technological innovation in reducing the threat of desertification and restoring desertified land to a more productive status.

5.8 The four Background Documents thus gave a review of desertification from four points of view namely, climate, ecological change, population, and technology and society. Assuming that these studies were representative of what the scientific community at that time, was saying about desertification, they brought everybody much closer to a working definition of the phenomenon, although the final definition still had to wait for the Conference process which would combine the scientists with policy and decision makers from around the globe. The Conference would also provide an opportunity for all those from the different parts of the world to exchange notes on the phenomenon which had proved to be sufficiently worrying, to bring them all to Nairobi to deliberate about it, and to suggest solutions at the various levels of human society. All these papers had been prepared at the request of the Executive Director of UNEP upon whom the General Assembly by its resolution 3337 (XXIX) had delegated the responsibility of preparing for the Conference. It is important to observe the fact that the four major scientific reviews prepared for the UNCOD were not unanimous in defining desertification, with each disciplinary group trying to emphasize its own angle of the problem. Nevertheless for UNEP's purposes, there was a certain amount of agreement about the fact that desertification, however, described, was caused by man in his effort to seek sustenance from his environment. Looking at the Overview Document prepared for the Conference (A/CONF.74/1/Rev.1)[20] there is a clear sense of caution that not all the science was in the right place, and that there was need for more scientific and technical research needed to be sure that all the aspects of the

complicated problem were understood. In particular the understanding of the role of climate was still extremely tentative, with clear calls for more research.

5.9 The Overview Document[20] was very explicit in pointing out where the desertification problem should be looked for as can be seen from the following quotations:

"Deserts themselves are not the sources from which desertification springs. Except for hot winds, the deserts themselves supply none of the essential impetus for the processes described. Desertification breaks out, usually at times of drought stress, in areas of naturally vulnerable land subject to pressures of land use", and

"These extreme deserts do not concern us, they are not subject to further desertification and they remain unclassified on the World Desertification Map" (Overview Document p.24).[20]

It was therefore unfortunate that too many of the Case Studies and Associated Case Studies tended to be from true desert situations where reclamation measures were being undertaken. All the same it is instructive to give a brief review of the case studies in order to get an idea of the messages that they were giving to the UNEP before the UNCOD was held, and to see if they were clear in giving directions on what should be done after the Conference process was over.

5.10 The Iranian Case Study based on the Turan (A/CONF.74/19)[21] area in the country was properly located in a virtual desert environment, and was rather non-committal in trying to define desertification. According to the study *"no precise figures are available for the extent of desertification in Iran, partly because opinions differ on the definition, but all sources of information indicate that it is considerable and accelerating"*. Thus while it was a detailed and carefully prepared case study, it did not really throw sufficient light on the problems to be considered by UNCOD, and it certainly did not venture anything more than an impressionistic definition.

5.11 The Chinese case study entitled "Combating Desertification in China" (A/CONF.74/18)[22], though technically very sound was rather too much of a political statement, and it certainly did not offer a working definition of desertification.

5.12 The USA Case Study (Associated) (A/CONF.76/21)[23] concerned itself with a badly degraded rangeland located in the desert in Southern Oregon, and how it was being rehabilitated, but did not offer a clear cut definition of desertification.

5.13 The USSR Case Study (Associated) (A/CONF.74/22)[24] entitled Integrated Desert Development and Desertification Control in the Turkmenian SSR, was clearly located in a true desert, and once again offered little by way of a definition, although it showed a clear awareness that from the ecological point of view, desertification was man-made, and often irreversible.

5.14 The Australian Case Study (Associated) (A/CONF.74/15)[25] from the Gascoyne Basin in the center of the country was located in an extremely semi-arid location, and was much more pre-occupied with general "land degradation" in a rangeland situation and how to rehabilitate it. It squarely blamed the observed land degradation on domestic livestock rather than climate. The case study used the term desertification rather freely without trying to define it. But what came out of this study was that even after 60 years of mismanagement the situation was reversible, with careful scientific management.

5.15 The Iraq Case Study (A/CONF.74/10)[26] based on an irrigated desert land, the Greater Mussayeb Project provided a typical situation where "desertification" was equated with severe water logging and soil salinization in addition to wind-blown sand. The case study apart from giving insight into the indicated problems did not attempt to clearly define desertification.

5.16 The Tunisian Case Study (A/CONF.74/12)[27] based on the Oglat Merteba Region was located in a virtual desert situation (annual rainfall 100-200 mm), and was quite helpful in attempting to define desertification. The authors of the case study were quite clear in their minds that desertification was clearly linked to increased human pressure in what was already very marginal land. According to the study, the observed land degradation was due to overgrazing and wind erosion. It emphasized the fact that desertification should be equated with "irreversible degradation" measured in terms of *"diminished productivity, reduction in water content of the soil, increased run-off and diminished yield from the natural rangeland even in high rainfall years"*.

5.17 The Niger Case Study (A/CONF.74/14)[28], selected from the Eghazer and Azawak Region of the country, was once again located in a virtual desert. It used the words "desertification and "desertization" rather freely and quite often interchangeable. The authors influenced by Le Houerou's work defined desertification as denoting *"action which produces a more or less irreversible reduction in plant cover and ends in the extension of new desert landscape into regions that previously did not have these features"*. The case study was unequivocal that it was studying "desertification" and not "desertization", but it was undecided as to whether to attribute the phenomenon to drought and the lack of rainfall, or due to human activities which are accompanied by increased human and animal pressure on the land.

5.18 The Pakistan Case Study based on the Mona Reclamation Experimental Project (A/CONF.74/13)[29] was located in an irrigated semi-arid belt of the country with an annual rainfall of 380 mm. This was a clear case of soil degradation under conditions of irrigation leading to widespread water logging and soil salinization. The case study made no particular effort to define desertification.

5.19 In conclusion it can be stated that for UNEP's purposes, the signals from the UNCOD case studies were not always clear and unanimous, even though it was becoming clear that desertification was caused by human activities, whether it was overgrazing leading to range and soil degradation, or whether it was due to "unscientific irrigation practices" which inevitably led to soil salinization and alkalinization. For operational purposes it is extremely useful to go back to these instances, of what the scientists were saying about desertification in their own separate ways, and from different corners of the earth before UNCOD, and several years after the Conference, to find out whether the signals they were giving were consistent, and could form a sure foundation for desertification control activities.

6. THE UNITED NATIONS DESERTIFICATION CONFERENCE DEFINITIONS

6.1 Apart from the General Debate at the Conference held in Nairobi in August-September 1977, the main business of the Conference was to discuss in detail "Processes and Causes of Desertification" and the "Plan of Action to Combat Desertification". The scientific community had done its wok in spelling out in detail what in their view could be regarded as the processes and indicators of desertification and what corrective measures were called for to make a concerted effort to start dealing with desertification. Now it was the turn of the policy and decision makers to agree on a course of action, which was mainly political. All the conference papers which have been discussed above and many others were made available to the participants for discussion and action. These included the Draft Plan of Action to Combat Desertification.

Out of UNCOD the following definition of desertification which has guided UNEP's programmatic activities was arrived at:

> *"Desertification is the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems and has diminished or destroyed the biological potential i.e the plant and animal production, for multiple use purposes at a time when increased productivity is needed to support growing populations in quest of development".*[13]

6.2 As is now well-known, the UNCOD produced the Plan of Action to "Combat" Desertification (PACD), a carefully crafted document which put forward the scientific case, and the action needed at each

stage "to combat" desertification. This deliberate use of military language was clearly based on the premise that there was already sufficient scientific and technical knowledge to "combat", and if necessary, to reverse the process of desertification. The six official feasibility studies which had been presented at UNCOD had been intended to guide UNEP in its future programmatic activities on Desertification Control by demonstrating practical ways to achieve trans-national co-operation to combat desertification. It could even be said that the conference over-emphasized the ecological aspects and the transnational aspects of the problem at the expense of the "national level", which is where desertification is to be found. Conference participants were encouraged to accept that existing knowledge was adequate for making the Plan of Action to Combat Desertification realistic. What was needed was the political will to go ahead and combat desertification and the line of action was carefully spelled out in the 28 Recommendations in the PACD, and a target date (the year 2000) was set for bringing the "war" to an end. Looking back now, it is clear that there was a certain amount of optimism in achieving the desired results in what might then have appeared a simple environmental problem, and what in subsequent years has proved to be much more complex. There was a belief that the experience already gained from the Sahel, put together with the suggestions contained in the case studies, would be sufficient. To quote from the UNCOD Document[13], the Plan of Action was to be guided by certain basic principles which was to be guided by a central theme as follows:

> *"A central theme will be the immediate adaptation and application of existing knowledge, particularly in the implementation of urgent corrective measures against desertification, in educating the people and the affected communities to an awareness of the problem, and instituting training programmes in collaboration with international organizations such as the Permanent Inter-State Committee on Drought control in the Sahel, the United Nations Educational Scientific and Cultural Organization (UNESCO), through its Man and the Biosphere Programme, the Food and Agriculture Organization of the United Nations, through its programme on Ecological Management of Arid and Semi-Arid Rangelands".*[13]

In retrospect, the basic assumptions were not only too optimistic but they took away from UNEP the possibility of defining the problem in its own way and working out its action programme according to its own interpretation of the mandate of the PACD. In a sense the language for dealing with desertification must go back to the Sahelian Drought and the promotion of CILSS, and in particular to General Assembly Resolutions 3054(XXVII) of October 1973 and 3337(XXIX) of 17 December 1974, which discussed modalities for international co-operation to "combat" desertification. If the whole issue is viewed in the proper context, it becomes apparent that there was a strong political "tide" and "desertification movement" which had started with efforts to deal with the Sahelian Drought. UNEP as the lead agency was forced to follow the momentum, but now nearly 12 years after UNCOD there is room for going over the same terrain, first to see if the definition(s) given to UNEP at that time were appropriate and if the programmatic activities that have followed have been appropriate and sustainable.

6.3 The Recommendations of UNCOD[13], however, did not necessarily conflict with the definition of desertification. If anything they provided practical steps of dealing at the national, regional and international levels, with the scourge. They can be divided into sections as follows:

(a) Evaluation of Desertification and Improvement of land management (Recs. 1-3). These attempted to standardize evaluation and monitoring methods globally to ensure that one was dealing with the same problem in each case. They also set down the principles for resource assessment and management.

(b) The Combination of Industrialization and Urbanization with the development of agriculture and their effects on the ecology in arid areas (Rec. 4). This recommendation was intended to find out the link between industrialization and urbanization with the development of agriculture, and the demands which these processes made of the ecology on adjacent areas.

(c) Corrective anti-desertification measures (Recs. 5-11). These recommendations contained a synthesis of what should be done from the point of view of the application of science and technology to redress the ecological balance damage by the processes of desertification as defined. A closer look at these recommendations shows their strong agricultural and ecological bias. Recommendation 5 for example urges *"efficient, socially economically and* *environmentally sound planning, development and management of water resources"* as a means for combating desertification. Recommendation 6 concerned itself with the amelioration of conditions of degraded rangelands, by correct management of livestock and wildlife resources. Recommendation 7 dealt with soil and water conservation; 8 with preventing salinization and alkalinization of irrigated lands; 9 with re-vegetation of denuded lands; 10 was addressed to governments *"to ensure the conservation of flora and fauna in areas subject or likely to be subject to desertification"*; and 11 for the monitoring of climatic, hydrological or pedological conditions.

(d) Socio-Economic Aspects. These Recommendations (12-17) were intended to add the human dimension to the anti-desertification process, including attention to social economic and political factors (Rec. 12), suitable economic and demographic policies (Rec. 13), the provision of adequate primary health care services (Rec.14) correct human settlements policies (Rec. 15) and monitoring the human condition (Rec. 16).

(e) Insurance against the Risk and Effects of Drought. These recommendations concerned themselves with drought-loss management (Rec. 18), use of alternate energy resources to prevent desertification (Rec. 19), training, education and information (Rec. 20), national machineries for combating desertification and drought (Rec. 21);

(f) Integration of Anti-Desertification Programmes into Comprehensive Development Plans. Recommendation 22 was perhaps one of the most important, yet it was given rather casual treatment. It was as follows:

"Programmes to combat desertification should be formulated, whenever possible, in accordance with the guidelines of comprehensive development plans at the national level".[13]

In order to avoid a sectoral approach to anti-desertification activities the notion of incorporating them into national development planning processes was extremely important. It was only later to be realized that this is where most of the emphasis should have been placed, because in the final analysis desertification is a development problem with important environmental implications, and it is not always easy at the national level to separate environmental issues from overall national resource management, which is easier to provide for in a comprehensive national development plan.

(g) International Action-Under this heading Recommendation 23 sought to involve the whole of the United Nations System in national and international anti-desertification activities; Recommendation 24 sought to involve WMO, ICSU and the other UN Agencies in a greater understanding of climate by supporting and participating in the World Climate Programme, the World Climate Conference, and the Global Atmospheric Research Programme; Recommendation 25 requested the UN Secretary General to involve all inter-governmental and non-governmental organizations in the implementation of the PACD;

(i) International Co-operation. Recommendation 26 called for equitable sharing of resources on the basis of equality, sovereignty and territorial integrity, and co-operation in the management of shared water resources for anti-desertification processes; Recommendation 27 charged UNEP with the follow up of the PACD working in close collaboration with the Regional Commissions and the Environment Co-ordination Board; and finally Recommendation 28 dealt with financial matters including sub-regional co-operation, bilateral, multi-lateral and multi-bilateral assistance, a Consultative Group (later DESCON) to work on mobilizing resources for anti-desertification programmes; the possibility of establishing a Special Account, and Additional Measures.

6.4 The above summary of the PACD has been carried out deliberately to see if any of the Recommendations was amenable to a "crash-programme", as the tone of the United Nations Conference on Desertification (UNCOD) would appear to have suggested. Looked at in its entirety the Plan of Action to Combat Desertification was indeed a treatise on natural resource management, with many different sections, none of them amenable to a crash programme. Secondly because desertification at UNCOD had been defined "almost too much" at the ecological level, it should have been realized that ecological processes take a long time to correct, even under very informed management, and on the assumption that during the period in question climate agrees to co-operate. Management strategies with less than five years are not likely to be successful, and longer periods of up to 20 years may be required before regeneration can take place for badly denuded rangeland or badly salinized soil.

6.5 Though the definition of desertification at UNCOD and the PACD could be regarded as being narrowly ecological for a problem which should be viewed more at the human level, the spelling out of indicators of desertification which was done at the Conference was extremely useful and could be said to have enhanced the definition for operational purposes. The indicators agreed on at UNCOD include the following:

(i) Sand dune encroachment onto agricultural lands. This problem need not be experienced only on desert margins. Where the land has been sufficiently degraded by a combination of drought and human activities, the land may be so bare of vegetation that sand dunes begin to form because of the work of wind erosion.

(ii) Rangeland deterioration or even degradation. This is a major characteristic of areas under the process of desertification anywhere in the world. On the one hand it may mean the rangeland is so poor it is being invaded by unpalatable species, and on the other hand, the rangeland may be so eroded that wind erosion takes over. This is the case where rangeland is being used by nomadic pastoralists and where there is a high incidence of overgrazing.

(iii) Deterioration of rain fed agricultural lands — a common problem hence an indicator of desertification in the semi-arid and sub-humid parts of the world.

(iv) Degradation of irrigated lands accompanied by high incidence of soil salinization and alkalinization.

(v) Deforestation, particularly common in the sub-humid areas where the expansion of human population and settlement is leaving large areas bare of the original vegetation.

(vi) Declining availability of ground water and surface water — a process exacerbated by prolonged droughts.

6.6 From the point of view of resource management at the ecological level the indicators have proved to be very practical, and a lot of the management strategies that have emanated from UNEP as the body in the United Nations charged with the follow-up of the PACD, have been inspired first by the definition of desertification as already discussed and secondly by close attention to the indicators of desertification in various countries of the world, and the establishment of programmes to handle them at various levels starting with the national level where the actual processes are usually located.

6.7 Brian Spooner (1982)[30] in a book entitled <u>Desertification and Development</u>, argues that the outcome of UNCOD should be seen at two levels viz. (1) that of ecological resource management, and (2) that of the political levels of management (p.5). He states that *"while all the delegates accepted the ecological explanations of desertification (cf. evidence of this in the definition which was being discussed) and the technical solutions, many were more concerned with causation at another level: that of the economic and political conditions that generate land use decisions"* (Ibid)[30]. He asserts that *"the campaign to organize for the purpose of conserving resources can never entirely free itself from the campaign to reorganize the distribution of resources"*. He for instance calls for a correct appreciation of the perceptions and values of pastoralist populations.

6.8 So far this report has avoided comment on financing anti-desertification programmes following the convening of UNCOD and approving of the Plan of Action to Combat desertification, because it is fair to assume that if the problem was correctly defined, and the action plan appropriately designed, the financing of the various activities emanating from the conference would almost be mechanistic. Unfortunately this has not been the case, because in the process of implementing the Plan of Action, many obstacles have arisen which must point back at desertification as it was defined at UNCOD, and all the programmatic activities which have been built around that definition and the accompanying Action Plan to Combat Desertification. Desertification as an issue is essentially a problem of land degradation arising from human misuse of the land and any meaningful programmes to "combat" it call for action(s) in a very broad front, so broad that it can be called ambitious. Thus efforts to finance such a broad programme, if desertification is left so broadly defined, is likely to meet donor resistance, whether one is attempting to deal with the problem at the national level, sub-regional as well as regional levels. Arising from the UNCOD definition of desertification, the mandate given to the UNEP, albeit operating in collaboration with the whole of the UN System and other Inter-governmental and Non-Governmental Organizations, was to produce an action programme in keeping with the Plan of Action to Combat Desertification. Such an action programme was supposed to be based on the following toward understanding, as reported in the first issue to Desertification Control Bulletin in 1978[31]:

(i) The main cause of desertification is the interaction between man and a fragile environment in dry lands ecosystems; man is the initiator and the victim of desertification; land use practices which are inappropriate in degree or in kind are the immediate causes of desertification in the marginal areas;

(ii) The problem of desertification is global and countries not directly affected suffer indirect effects;

(iii) The problem is serious, especially so in an era when food production must be dramatically increased to provide adequate nourishment for growing populations;

(iv) In view of the world's food requirements, and because desertification could be a self-accelerating process, certain aspects of the problem require urgent action;

(v) Man now possesses sufficient knowledge and technical means to begin actions against desertification without delay.

6.9 Looking back, it is surprising that the PACD was not analyzed critically by UNEP's own Governing Council, neither was it given a critical review by UNCOD which passed it, because the declared immediate goal of the PACD was in retrospect rather ambitious; the immediate goal of PACD was stated to be *"to prevent and arrest the advance of desertification and, where possible, to reclaim desertified land for productive use"*[13]. An even more ambitious concept was introduced at this time, perhaps because of the misunderstanding of how slowly ecological activities respond to management. This was expressed as the ultimate objective which was *"to sustain and promote within ecological limits, the productivity of arid, semi-arid, sub-humid and other areas vulnerable to desertification in order to improve the quality of life of their inhabitants"* (UNEP Governing Council 1978)[32].

6.10 Whereas many of the anti-desertification projects which emanated from UNCOD and the definition of desertification for UNEP's purposes, were straight forward land rehabilitation exercises, the rest were both political and clearly buoyed by the technological belief that desert encroachment could truly be halted. In particular attention should be drawn to the following two projects:

(i) The Northern Trans-Saharan Green Belt covering five countries in the Maghreb;

(ii) The southern Trans-Saharan Green Belt — running across the Sahelian lands of West Africa from the Atlantic Ocean eastward.

It is quite possible that at the time it was strongly felt that if funding could be assured these two projects were truly worthwhile and would make a permanent dent on desert encroachment by forming buffer zones, one across the north and the other across the south. But such a scheme was not likely to succeed

unless the individual parts of the overall plan were well and truly discussed at the national level and then presented together in a co-ordinated manner. Even from the ecological point of view the approval of these two projects dented the credibility of the anti-desertification lobby, and subsequently made it impossible to fund them properly.

6.11 With the UNCOD definition of desertification as a guideline it would have been easier to pass off a lot of the suggested projects as agricultural and rural development projects, rather than to view them as being "environmental" even if it is a fact that each of them has a strong environmental content. In so far as most of the processes being studied could be referred to as involving ecological change, it would have been prudent to realize that different social groups view such changes differently. In order to get greater support for anti-desertification programmes, it would have been more appropriate to emphasize the critical relationships which exist between population and resource use.

7. POST - UNCOD DEFINITIONS OF DESERTIFICATION

7.1 The period between 1978 and 1982 was taken up by the establishment within UNEP of the Desertification Branch and later the Desertification Programme Activity Center (DC/PAC), the convening of DESCON (Consultative Group on Desertification) Meetings, and the meetings of the Inter-Agency working Group on Desertification (IAWGD). The Plan of Action to Combat Desertification (PACD) was approved by the UN General Assembly in resolution 32/172 of 19 December 1977, and it was that resolution which authorized the establishment of Desertification Control Branch and later on DC/PAC, DESCON and the IAWGD. During this time also, the United Nations Sudano-Sahelian Office (UNSO) a joint UNEP-UNDP organization handling anti-desertification activities in the Sahel was strengthened and its mandate extended to include assistance in the implementation of the PACD among the Sudano-Sahelian countries. However, there is no evidence of a questioning of the definition of desertification as had been accepted during UNCOD. In any case as the drought menace was still very much around, any anti-desertification activities would continue to be justified without any questioning. The only adjustment on record within UNEP at this time was the decision to concentrate all the activities which had previously been handled separately in the newly created Desertification Unit. This meant bringing together all activities connected with arid and semi-arid lands ecosystems and the combat of desertification in line with the PACD. The newly created Desertification Unit was asked to provide a Secretariat for the Inter Agency Working Group on Desertification and for Desertification Consultative Group (DESCON).

7.2 Soon after it was formed the Inter-Agency Working Group on Desertification (IAWGD) concentrated its attention on co-ordination of UN activities on desertification Control in keeping with the PACD, and saw its job as that of implementor rather than a refiner of the concept of desertification. Consequently, there is no evidence that the IAWGD ever tried to re-define desertification.

7.3 Similarly, DESCON at its first and subsequent meetings confined its attention to discussing its own modes of operation and concentrated on the six transnational projects which had been proposed at UNCOD. The six projects which were promoted unchallenged were as follows:

(1) The North African (Trans-Saharan) Green Belt;

(2) Major Regional Aquifer in North East Africa;

(3) Management of Livestock and Rangelands to combat desertification in the Sudano-Sahelian Zone (SOLAR) and the Sahel Green Belt;

(4) The Transnational (Desertification) Monitoring Programme in South America;

(5) Transnational Monitoring Programme in South-west Asia;

(6) An assortment of anti-desertification projects under UNESCO such as the Integrated Project in Arid Lands (IPAL) and the UNEP/FAO — Ecological Management of Arid and Semi-arid Rangelands in Africa (EMASAR); there were other smaller projects covering other countries such as China and the USSR.

7.4 In approving the PACD, the UN General Assembly left some room for UNEP to re-assess the definition of desertification should this be necessary. This is evident in the recommendation to the Secretary-General (UN) to involve the whole of the *"United Nations System, as well as the scientific institutions concerned outside the system for further research, development and refinement of the data pertaining to desertification, in order to close any existing gaps in scientific knowledge and technology,"* and for the involvement of inter-governmental and non-governmental organizations in efforts to realize success for the implementation of PACD".

7.5 One of the recommendations of UNCOD for projects to be undertaken after the conference was the preparation of a World Desertification Map. Unfortunately, the idea of the map was not finally approved by the UNEP Governing Council until its Twelfth Session in 1982. The project aimed at developing a common methodology for the assessment of desertification. In the process of its execution it became a project jointly sponsored by the UNEP, FAO, UNESCO and WMO. What transpired was that a Desertification Hazards Map was produced instead. But even more important was that in the process of preparing the maps, the FAO and UNEP made an effort to agree on at least a "Provisional Methodology for Assessment and Mapping of Desertification". This too provided an opportunity for a new attempt at the re-definition of desertification. This was now given as follows:

> *"In the context of the FAO/UNEP Desertification Assessment and Mapping Project, desertification is defined as a comprehensive expression of economic and social processes as well as those natural or induced ones which destroy the equilibrium of soil, vegetation, air and water, in the areas subject to edaphic and/or climatic aridity. Continued deterioration leads to a decrease in, or destruction of the biological potential of the land, deterioration of living conditions and an increase of desert landscapes"* and
>
> *"Desertification is a continuous process going through several stages before reaching the final one, which is an irreversible change. Natural threshold changes exist- historical events as well as current geo-socio-economic changes — which either provoke or keep constant the intensity of desertification processes. Desertification is therefore the result of natural processes and of processes due to human and animal pressures, but only through man's activity can it be slowed down or stopped"* (FAO/UNEP 1982 Provisional Methodology for Assessment and Mapping of Desertification)[33].

This definition presented to UNEP in 1982 was to a marked extent different from the previous UNCOD definition which had guided the programmes on desertification control so far. In the first instance there was now a deliberate effort to emphasize less, ecological considerations, and more "economic and social processes". Secondly, there was now an admission that "natural" processes were equally important in understanding desertification. The emphasis on the biological potential was now given a back seat! And now there was a clear reference to the fact that at some stages, desertification could be reversible, although there was always a point of no return beyond which the processes would be irreversible. In the closing parts the new definition specified that desertification is *"the result of natural processes and of processes due to human and animal pressures, but only through man's activity can it be slowed down and stopped"*.[33]

To a certain extent the methodology developed was biased in the direction of climate as explaining the process of desertification and four different arid Zones as follows:

(i) The Hyper-arid Zone — i.e. extreme desert, virtually unsettled;

(ii) The Arid Zone — dryland with sparse perennial vegetation with nomadic pastoralism and the absence of rain fed agriculture;

(iii) The Semi-Arid Zone — in which livestock breeding and rain fed agriculture is possible;

(iv) The Sub-Humid Zone — mainly an area of rain fed agriculture, but with crops adapted to seasonal drought.

On the basis of their divisions they produced a map of vulnerability of land to desertification, but the small scale at which these maps were produced (1:5 million) made them rather limited in usefulness. There is no indication of UNEP's reactions to this new tentative definition which would have been a departure from the UNCOD definition, and when the assessment of desertification came in 1982/83 for presentation to the UNEP Governing Council in 1984, there was more or less a reconfirmation of the UNCOD definition of desertification.

7.6 During the first major review or assessment of desertification on a global basis, UNEP decided to keep the UNCOD definition despite indications to the contrary. This assessment period was an important one and the opportunity should have been taken to re-examine the scientific merits of the basic assumptions under which the anti-desertification programmes had been arrived at. It is true that since 1977 the programme was being propelled by the "political steam" that had been generated at UNCOD. But now it seemed that the "steam" was running out, and it would have been very appropriate to re-examine the 1977 definition. But as long as the definition remained the same, all the conceptions about and around desertification would rely on the earlier basic assumptions, and the whole of the international community would still wait for guidance from UNEP.

7.7 For the Assessment, UNEP employed several High-level consultants, who being largely scientists, and especially ecologists, insisted on keeping the previous (UNCOD) definition of desertification. It is true that 1984 marked the peak of the several years of a new drought which was still raging in many parts of Sahelian Africa, and the general feeling even at the UNEP Governing Council in February that year was that desertification accompanied by drought should still remain high on the global development agenda. But this was not an excuse for the scientific failure to make a proper assessment, and a thorough re-evaluation of earlier basic assumptions. For this reason the scientific community in general, and the particular scientists who advised UNEP on this occasion must bear some of the blame for apparently simplifying a problem which defies simplification, even if this was done for political consumption.

7.8 The 1984 Assessment presented to the UNEP Governing Council was the outcome of several activities. A questionnaire had been sent out to at least 90 countries as well as institutions interested in desertification. Unfortunately the questionnaire did not contribute any significant data because most respondents found it difficult, if not impossible to complete it correctly. This was despite the fact that some of the developing countries were given some assistance with responding to the questionnaire. In addition to the questionnaire there were several regional assessments most of which did not prove useful. One of the most important regional assessments was that for the Sudano-Sahelian Region which was prepared by scientists from Clark University in the United States[34]. In so far as the "Desertification Movement" had been launched by the troubles of the Sahelian lands in the early 1970's, it is important to look at what this particular assessment said. Whereas this particular assessment was not only competent, but also very comprehensive, it did not endeavor to challenge the UNCOD definition of Desertification. If anything this particular assessment was content to restate the UNCOD and PACD definition of the term, and they just accepted the synthesized version which described desertification as *"a process which is characterized by the diminution or destruction of the biological potential of the land which can lead ultimately to desert-like conditions"*[34]. In other words they allowed themselves to fall into the "ecological trap", and narrow definition which had been pushed at UNCOD. As a result of this a comprehensive assessment report which heavily leaned on the human side of the problem did not give UNEP a chance to re-examine earlier basic assumptions and to come up with a new definition. This particular Report looked at the economic trends of the Sahel countries, the demographic trends, political events related to the prevalence of prolonged droughts, changes in agriculture and the use of natural resources, climatic trends, and the status and trends of desertification. But once again liberal use was made of the essentially ecologically defined desertification indicators, namely:

(i) Sand dune encroachment;
(ii) The deterioration of rangelands;
(iii) The deterioration of rain fed agricultural lands;

(iv) Degradation of irrigated lands;
(v) Deforestation;
(vi) Declining availability of groundwater and surface water.

Unfortunately these were symptoms and not necessarily causes of desertification. The Report[34] went into great detail about anti-desertification activities in each part of the Sudano-Sahelian Region, including a discussion of institutions, actual anti-desertification programmes, finance, and constraints to the implementation of the Action Plan to Combat Desertification. Although it does not give sufficient weight to it, the Report sees the problem of desertification *"as an overall problem of the inappropriate use of resources"*. Even more important, it points out the fact that the *"Plan of Action has been less successful in persuading governments to build environmental, especially desertification control provisions into their development plans and development projects, and to give some practical priorities to these problems"*.[34] Nevertheless in the absence of a new definition which would put desertification in the proper context of the "development problematique", UNEP would still find its hands tied to pushing the ecological and environmental theme and thereby missing the over all economic development aspects of the problem.

7.9 The final Desertification Assessment Document presented to the Governing Council[35] was even more disappointing in not striking into new directions. If anything it re-stated the UNCOD's and PACD definition without making even small changes, as follows:

> *"Desertification is the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems, and has diminished or destroyed the biological potential, i.e. plant and animal production, for multiple purposes at a time when increased productivity is needed to support growing populations in quest of development"*.[35]

This definition as stated in earlier sections of this Report puts too much emphasis on the biological or ecological aspects, and too little on human populations who are known to be the major part of the problem. It also fails to focus on natural resources, and to see desertification as a problem of resource use. Even more worrying were the statistics of global desertification which were put forward in the assessment, which appeared absolute and scientifically credible, but which had been based on rather thin and tentative sources of information. Despite the problems with definition contained in the PACD which was at best tentative the assessment of global desertification was based on the following as the main sources of information:

(i) A questionnaire addressed to 91 countries affected by desertification and to 12 donor countries - as already indicated the questionnaire - was a failure. First because it proved too difficult to fill, and secondly because much of the data it requested was not available in the countries in question in the form expected by or presumed by the questionnaire.

(ii) Requests addressed to Regional Commissions seeking their co-operation in preparing regional assessments on desertification — once again in the absence of agreed assessment methodology this proved difficult, if not impossible task.

(iii) Updated versions of 1977 conference documentation, including the Case Studies (revised in a few cases).

(iv) A revised paper on Climate and Desertification prepared by WMO.

(v) A new study on Population, Society and Desertification — with special reference to demographic changes since 1977.

(vi) Anti-desertification activities globally, since 1977.

Those preparing the papers during the assessment should have noticed that one of the national studies, that from Australia[36] had now jettisoned the word "desertification" in preference for the term "Land Degradation in Australia". On the basis of all the above, it was concluded as follows:

> *"The scale and urgency of the problem of desertification as presented to the Desertification Conference and addressed by the Plan of Action have been confirmed. Desertification threatens 35 per cent of the earth's land surface and 20 per cent of its population; 75 per cent of the threatened area and 60 per cent of the threatened population are already affected through deterioration of the environment and living conditions, and between a quarter and a half of the affected population severely so. In the years since the Conference, the land irretrievably lost through various forms of desertification or destroyed to desert-like conditions has continued at 6 million ha annually as reported in 1977; and the land reduced to zero or even negative net economic productivity is showing an increase over the 1980 estimates, at 21 million ha annually."* and

> *"The direct cost of desertification, excluding social costs, stands at $26 billion annually. This is largely as a result of decline in productivity"*.[36]

Looked at in the context of the absence of a definitive, tangible, and practical definition of the term desertification, and of the lack of agreement in assessment methodologies, these assessments were not always scientifically supportable, and UNEP was put in a rather weak position of having to defend a rather untenable position.

7.10 Despite the problems with definition and clarity of purpose even at the assessment stage, anti-desertification activities were expected to continue uninterrupted, and the UNEP was expected to realize the funding targets which had been made to progress with the programmes as previously agreed at UNCOD in 1977 and the other periodic reviews which had been carried out since then, the last major one being in 1980. Anti-desertification activities had been commenced long before UNCOD, but it is debatable whether they were addressing desertification as such, or whether they were concentrating on ameliorating the harsh effects of prolonged drought. For example since the establishment of UNSO and strengthening it after UNCOD, it became extensively involved both at the national and sub-regional levels with numerous projects under the following headings:

(i) Water improvement projects — including water conservation, improved supplies, water and sewage treatment, groundwater exploration, the sinking of boreholes, the construction of dams and the establishment of irrigation schemes;

(ii) Rangeland improvement and cropland management projects;

(iii) Forestry development projects including re-afforestation, re-vegetation, village fuelwood development and efforts to establish green belts on the desert margins;

(iv) Development of alternative sources of energy to lessen pressure (human) on the natural vegetation;

(v) Soil conservation projects — as an aspect of reducing land degradation;

(vi) Monitoring of rangeland and other ecological conditions; also closely allied to this, research;

(vii) Attention to public participation and the creation of public awareness about environmental degradation;

(viii) Institution Building and training of technical cadres.

The question which arises is; "was there any real justification for adopting a sectoral approach to these normal economic development problems in the name of combating desertification?", and "Would it not have been more appropriate to treat each and everyone of these problems as part and parcel of national development planning processes, and in particular the use and management of natural resources?"

7.11 A look at the list of projects which were funded globally up to 1984 as part of anti-desertification programmes, includes, assessment, land use planning, public awareness, industrialization/urbanization effects, water, range improvement, rain fed croplands, irrigated lands, vegetation improvement, conservation of flora and fauna, ecological monitoring, socio-economic evaluation, population health care, human settlements, monitoring the human condition, drought contingency, national science and technology, energy sources, information, national machineries, national desertification programmes, climate studies and shared water resources. The inevitable conclusion one arrives at is that if desertification was to be treated sectorally, then it clearly lacked specificity, and that even if it has sufficient specificity, then it must be treated as part and parcel of national development planning, to guard against its being given a low priority. If indeed according to the adopted definition desertification was a process that led to irrevocable loss of biological productivity, such diffuse financing as suggested by the long list of projects listed above would have very little impact on the problem because it could easily be lost in the welter of other projects trying to solve other aspects of the development problematique'.

7.12 The above comments do not mean to say that at its first assessment nothing had been achieved in the "fight" against desertification or land degradation. UNEP itself at the Session of the Governing Council of 1984 listed a number of important achievements, even with the limited funding which had been realized at the time. The point being made is that as defined, desertification as a topic was bound to raise some in-house jealousies and conflicts within the UN system as a whole. This caution arises from the quantification which was produced in 1984[35] as follows:

(i) The Plan of Action to Combat Desertification (PACD) is confirmed;

(ii) Desertification has continued to intensify;

(iii) 6 million ha per annum continues to be desertified, and the affected land was increasing from 20-21 million ha per annum;

(iv) The assessment indicated the following in terms of land areas affected by moderate desertification:

3100 million ha of rangeland
335 million ha of rain fed croplands
40 million ha of irrigated land

(v) Compared to 1977 when 57 million people globally were assumed to be affected by desertification the figure in 1984 was now 136 million.

7.13 Even with such a narrow definition of desertification as has been indicated earlier, the Assessment Report was able to make the following observation:

"The cost of losses in production due to desertification amounts to five times the cost of battling desertification".[35]

The question immediately raised is that in the face of clear difficulty with definition of desertification, and even greater difficulties in quantifying the problem on a small, let alone , global scale, was it really possible to accurately cost the presumed losses so as to work out a cost-benefit position? Somehow or other this is where the problem has started, and it is instructive to go back to the scientists to see if they are agreed on a water-tight definition of desertification, and hence of desertification assessment methodology, which can be used to support such a stand. Only then can UNEP's position be secured, when it is looking for massive funds to "wage the war" against desertification. In the meantime it is fair to say that, however defined, if they remain sectoral, anti-desertification control measures are unlikely to be attractive to donors because they do not easily translate into cost-benefit figures.

7.14 One clear indication of the need for a more human and resource-use oriented definition of desertification may be gleaned from the reactions of DESCON (Consultative Group on Desertification) to resource mobilization for anti-desertification activities since UNCOD. No matter what explanations may be given, there is evidence of a clear lack of enthusiasm on the part of donors to fund anti-desertification projects, and this must inevitably relate to how the term "desertification" is perceived within the UNEP circles. The 1984 assessment and subsequent assessments should indicate that DESCON is not interested in supporting an anti-desertification programme unless a new definition is used, or unless a completely new approach is adapted. Two major criticisms have been levelled by DESCON about projects presented to it for funding:

(i) That projects presented for funding were not accorded high priority in the development plans or foreign assistance requirements of those same countries;

(ii) That projects presented for funding have lacked innovations, have been too costly or were poorly constructed;

The inevitable conclusion that must be arrived at is that since UNCOD, the conceptualization of desertification at all levels has not been precise enough to make it easy for governments to put a proper finger on the problem at the national level, hence the difficulties they are encountering with project preparation. What has been used to counter this argument which may also be true, is that, populations living in areas suffering from desertification are in any case already marginalized and have little political weight. All the same, a clearer definition of the problem, followed by more determined ways to find solutions, should make it easier globally, to make at least some headway, in dealing with a problem that is truly multi-disciplinary in nature. As long as desertification is viewed as largely an ecological problem, leading finally to the loss of biological productivity of the land, it fails to command the same urgency that the so-called economic problems do.

8. THE POPULARIZATION OF THE DESERTIFICATION CAUSE

8.1 Perhaps are of the most outstanding achievements in the desertification debate since UNCOD in 1977 has been the creation of public awareness at all levels, beginning from the local, to national, sub-regional, regional and global levels. Along with this has gone several resource management educational programmes that have been intended to prepare the nations for action to "combat" desertification, and to involve individuals in participating effectively in the common effort. It is suggested in this Report that part of the problem with the definition of desertification and UNEP's own position in the debate has been created by this popular participation, and the clear preference of scientific journalists and others for the more dramatic catch phrases like "rolling back the deserts", "stopping desert encroachment", "How can it be that the war against desertification is being lost?", the "March of Deserts Unstoppable". It is true that regular scientists have more often than not provided the ammunition for these careless phrases which have succeeded in confusing the issue and putting UNEP on the defensive. The origins of the notion of the encroaching deserts, particularly the Sahara, go back to E.W Bovrill in 1971 and to 1935 and 1938 when E.P. Stebbing first made the allegations of an encroaching desert (quoted in H.E. Dregne and C.J. Tucker 1988. Desert Encroachment, Desertification Control Bulletin No.16, 1988)[37] , and in 1975 Hugh Lamprey in his Report on the desert encroachment reconnaissance in northern Sudan (21 October to 10 November 1975, UNESCO/UNEP)[38] provided the now much quoted data about rates of the encroachment of the Sahara (90-100 km between 1958 and 1975) which have recently been severely challenged. It is important to emphasize the fact that a lot of the irresponsible statements have looked at desertification from the "desert end of the stick", rather than from the sub-humid and semi-arid ends of the spectrum. To the extent that these banners have been taken by the press and the media, they have denied UNEP the initiative of defining desertification in a cool and calculated scientific manner, so that corrective measures can be discussed meaningfully. In the same context, the Desertification Information Campaign which was launched in 1984/85 after the First Assessment of Progress in the Implementation of the Plan of Action to Combat Desertification, was not supervised sufficiently to prevent the melodramatic aspects of the case being exaggerated and put across to the peoples of the world, (see Eckholm, E.P and Brown, L.R. 1977. Spreading Deserts — The Hand of Man, Worldwatch Paper No.13[39], the Video Programmes produced by UNEP 1985, and Grainger, A. 1982, Desertification: How people make Deserts, How People can stop and why they Don't. An Earthscan paperback, IIED[40]). In the same vein, one of the popular publications produced by UNEP as recently as 1987 entitled "Rolling back the Desert: Ten Years after UNCOD",[41] had an unfortunate connotation in suggesting that Desertification is such a simple process that it can be made light work of; a more appropriate title should have concentrated on protecting the arid and semi-arid environments at the edge of the true deserts from land degradation. The aim here is not to criticize what has proved to be a very successful public education campaign about desertification, but to show that in its success it has created some difficulties for the UNEP and for the definition of desertification, by always focussing it on the true deserts rather than on the semi-arid and sub-humid areas where the real problem is. If it is possible to "roll back the desert", as suggested by the popular publication, why should one stop on reaching the boundaries of the Sahara, the Gobi Desert, or for that matter the Australian Desert? Put this way it can be seen that such suggestions of technological superiority and what money can do if the UNEP had it, do make it very difficult to define desertification correctly and to concentrate on areas where efforts to halt, control or contain land degradation, are likely to yield real fruits.

8.2 It is pertinent to say that along with increased awareness, and a willingness to work out detailed National Action Plans to Combat Desertification, efforts should go along to define desertification at a more manageable level, i.e at the local level, and what can be done by a rural community first and foremost, before moving on to the more grandiose levels where one will eventually be dealing with a global problem. In other words, in the process of creating world-wide awareness, UNEP should not over-emphasize the irreversibility of the process of desertification, at the expense of underlining what individuals or the nations can do to introduce concepts of sustainability of development in land areas subject to desertification.

9. A REVIEW OF CONCEPTS AND DEFINITIONS OF DESERTIFICATION OUTSIDE UNEP

9.1 In so far as the United Nations Desertification Conference was held under the umbrella of the UNEP and since the Conference succeeded in bringing together the leading scientists and policy and decision makers in the World, UNEP's leadership in conceptualizing desertification, and spearheading the global anti-desertification programme has tended to be accepted for a long time, without much questioning. This has not necessarily been a bad thing, but unfortunately, along with it has gone the assumption that UNEP must be left with the responsibility of "ridding the world of the desertification scourge". Equally surprising has been the expectation by other UN Agencies such as UNESCO, FAO and others, for the UNEP to raise the funds required for global anti-desertification programmes, to give to them in order to enable them to mount anti-desertification components of their programmes. Along with these attitudes has been the reluctance of some of these agencies to contribute to a new definition, and a better understanding of desertification. Consequently they have tended to perpetuate the process of desertification in the context of marching sands and encroaching deserts as may be seen from the following quotation obtained from a project proposal prepared for funding under IGADD, by the FAO and the EEC:

> *"The southward spread of the Sahara has been proved and documented. The issue is no longer whether or not the desert has been moving southward, but at what speed. The drought conditions which have almost been a regular feature in the sub-region is testimony enough that countries must take countermeasures to arrest the spread of the desert with its attendant drought conditions"*[42].

9.2 At the other end of the scale there have been differences of opinion within the United Nations System with some Agencies and Regional Commissions not always accepting the special relevancy of the desertification problems. To illustrate this latter point, a letter from the Executive Secretary of ESCAP addressed to the Executive Director of UNEP in 1983 has the following:

> *"A number of activities that can be cited as PACD-related are in fact regarded as straightforward development projects in the field of agriculture and natural resources. Secondly one has to appreciate that at the time of adoption of the PACD in 1977, institutional machineries of governments which have their own momentum and need time to change, were geared for development, not for campaigns against desertification".*[43]

9.3 Definitions as well as conceptualization of desertification by individual scientists are always value loaded with some emphasizing climate, and in particular prolonged droughts or "desiccation" as an essential element, others more concerned with the partial or total loss of biological productivity, others seeing good prospects of recovery provided climate co-operates, while others especially those who work in desert research institutes, holding out no hope for recovery. These divisions of opinion have always existed even prior to UNCOD, but some scientists appear to have hardened their stand at, and since UNCOD, probably to keep the political case for anti-desertification programmes strong. But it is important for UNEP to be aware of all the varying shades of opinion even if it wants to take the political line for fund raising purposes.

9.4 An early and unbiased indication of the thinking by scientists can be seen from the work of Le Houerou who in 1959 from his work in Southern Tunisia[44] came to the following conclusion:

> *"In the case of Southern Tunisia it is man who has made the desert, climate is only a favorable circumstance"*[44]

This view was confirmed when a National Seminar on Desertification was held in Tunisia in 1972 when the participants concluded that:

1. *"Desertization (or desertification) is a man-induced phenomenon; there is no evidence of increased climatic aridity during the period of instrumental record"*. and

2. *"Desertisation (or desertification) is a result of high 'demographic pressure' which results in generalized overgrazing, clearing of natural pastures for cereal production and over-cultivation of sandy soils; destruction of woody species for fuel, and extension of mechanized farming".*

   "These cumulative causes result in accelerated soil erosion (both water and aeolian) which in many cases leads to new desert landscapes".[45]

The above quoted observations have been typical of the "desertification debate" where scientists and decision makers try to define desertification by defining the symptoms and falling prey to impressionism. Also typical of this Tunisian definition under the leadership of Le Houerou was the ever-present attempt to down play or underplay the impact of climate, a feature reminiscent of many other conceptualizations and definitions of desertification. This is unfortunate because inevitably a climatic turn for the better, even if it comes after 30 years of "desiccation" may sooner or later start a process of recovery.

9.5 Professor Kenneth Hare, one of the most outstanding climatologists in the world, emphasizes the fact that at the end of each period of prolonged drought(s) or "desiccation" there is always the chance of a recovery but he emphasizes that such recovery can take decades as can be seen from the following quotation:

> *"In a drought the losses can be made good, but not so in a true desiccation. Woody vegetation and organic content in soil disappear and do not return for decades. Desiccation means a loss of capital stock, a writing off of assets, perhaps also permanent impoverishment".* (Hare, K. 1987. In Planning for Drought; Toward a Reduction of Societal Vulnerability, Whilhite, D.A. et. al. (Eds.), Boulder & London, Westview Press p.7)[11]

It is the feeling of this Report that many of the definitions of desertification that have been reported in the Sahel, in other parts of Africa, and even in Asia, North and South America, have been closer to Kenneth Hare's "desiccation", because they are definitions derived from symptoms which have ignored the time-scale of a desiccation. But where permanent impoverishment is reached, be that in Africa or Australia (if it were not for the drought insurance schemes), the word desertification can be equated with "desiccation".

9.6 Professor Dregne defined desertification in 1977 as:

> *"the impoverishment of arid, semi-arid and the sub-humid ecosystems by the combined impact of man's activities and drought. It is the process of change in these ecosystems that can be measured by the reduced productivity of desirable plants, alteration in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy"* (Dregne 1977. p. 324)[46]

But he was quick to add that extreme cases of irreversible desertification were few. In his view *"there are not many large areas where economically irreversible desertification has occurred"* (Dregne op.cit. p.329).[46] This view expressed in 1977 was overridden by the 1984 UNEP Assessment of Desertification without adequate ground research, and makes it wise to revisit it twelve years later. In short Dregne did not want to support those who insisted on irreversibility being one of the essential elements of desertification.

9.7 The lack of consistency among the scientists in defining and/or conceptualizing the desertification problem is clearly brought out in a collection of studies put together by Professor Wolfgang Meckelein of the University of Stuttgart in West Germany under the heading "Desertification in Extremely Arid Environments" (Meckelein 1980)[7]. He has the following to say about the problem:

> *"The term 'desertification' is not well defined scientifically. In most cases it means the process of desert encroachment, especially caused by man interfering with an unstable ecological equilibrium in semi-arid lands".*[7]

However, in spite of the above emphasis on the semi-arid lands he also refers to land degradation within desert oases as a kind of desertification which he defines as follows:

> *"Desertification in this case means the process of deterioration of cultivated lands, which had already been wrested by man from the desert"*

He ends his contribution by offering a more generalized definition of desertification as follows:

> *"Desertification means natural and cultural processes leading to an encroachment or intensification of desert conditions in arid lands and their marginal zones".*[7]

9.8 In the same publication Professor M. Mainguet (1980) offers a valid comment to clarify the apparent confusion in terminology and conceptualization of desertification by giving the following comment:

> *"Blowing sand-dunes are more linked to winds from true deserts than necessarily to a process of desertification".*[7]

9.9 Other scientists tend to prefer conceptualizing desertification as a general process of land degradation in which case it does not have to be restricted only to marginal semi-arid areas. Desertification as a term in this case would be used for resource mismanagement, and especially land degradation, in a multiplicity of environments, including areas within the deserts where localized agriculture is practiced.

9.10 Prof. Horst Mensching of University of Hamburg who spent many years studying arid lands in Sahelian countries like Niger, Burkina Faso, Mali and the Sudan, feels it is wrong to ignore the impact of secular climatic changes as being closely linked to the process of desertification. He emphasizes the fact that due to lack of adequate data, the scientific community as a whole does not really understand long-term climatic trends. This, according to him, applies equally to the historical period and the forecasts for future

centuries. However, according to him, the term "desertification" *"should be restricted to processes whereby the ecological potential is seriously damaged or even destroyed by human exploitation ..."* He ends by cautioning those who would accept the idea of rapid desert encroachment, and the wild generalizations about the pace of world-wide desertification which is based on too limited and not always supportable evidence (Mensching, H. 1986. Is the desert spreading? Desertification in the Sahel Zone of Africa. Applied Geography and Development, Vol. 27, pp. 7-18).[47]

9.11 In a recent article re-visiting the "desertification debate", one of the three leading scientists who have steered the desertification cause which has included Professors Mohamed Kassas, Jack Mabbutt, namely Professor Harold Dregne, has clearly urged caution in defining and conceptualizing desertification. He has emphasized the fact that even at UNCOD the scientists gathered agreed that desertification was a complex process, having many causes and effects. He regrets the fact that even scientists are now repeating falsehoods about desertification in very reputable scientific journals (H. Dregne and C.J. Tucker 1988. Desert Encroachment in Desertification Control Bulletin No. 16, pp.16-19).[37]

9.12 Professor Mohamed Kassas, the first person to use the term "desertification" in an English publication in 1970, in an article entitled "Desertification versus potential for recovery in circum-saharan territories" (in Dregne, H. (Ed.) 1970. Arid Lands in Transition)[48] was one of the first scientists to raise the issue of "reversibility" and "irreversibility" of the process. In the earlier stages he thought at least some of the processes were reversible. He was particularly concerned at the possibility of permanent shifts in the boundaries of vegetation zones in the arid and semi-arid lands close to the true deserts, but was prepared to wait for definitive research to settle the question. In a recent publication entitled "Ecology and Management of Desertification" (M. Kassas 1988, in Earth '88: Changing Geographic Perspectives)[49], he has called for a clear distinction between drought and desertification. He believes that drought is a natural hazard which can be contained by proper planning (also personal communication). But as far as desertification and drought are concerned he asserts that though related, they should not be confused. He defines desertification as *"primarily a man-made ecological degradation..... by which bio-productivity potential (in economic terms) of land is reduced. This is often a gradual process that operates through systems of land use that overtax inherent bio-productive capacity. Excessive reduction of plant growth destroys its ability to regenerate and deprives the soil of its protective plant cover thereby exposing it to erosion. This deterioration is exacerbated by the inherent fragility of the ecosystems in arid, semi-arid, and sub-humid regions of the world. One causative of this fragility is recurrent drought".*[49] Kassas introduces new ideas in the desertification debate, such as the observation that it can be caused just as much by the lack of population as by overpopulation.

9.13 The main area of disagreement among the scientists is whether ecological boundaries are shifting because of desertification. Herein too lies the strength of the anti-desertification calls. The proponents state categorically that the work of man is destroying the semi-arid and the dry sub-humid lands so fast that there is a permanent movement of ecological boundaries, in other words there is desert encroachment winning on the outlying areas. The opponents of this argument state that apart from many but localized areas of severe ecological (especially vegetation) degradation, there are no permanent shifts in ecological boundaries and that such shifts if they were to occur would have to be linked to observed, and observable climatic change. Le Houerou and Rapp (1976)[10], were some of the earliest scientists to emphasize the fact that the *"desert boundary zone is not static but can shift over periods of years. In periods of extremely low or ill-distributed rainfall (such as the Sahelian Drought years of 1968-1973), the desert boundary can shift into surrounding lands. In other periods of favorable rainfall and low pressure of (human) exploitation, the desert boundary may shift back again, provided the degradation of vegetation and soil has not been irreversible".* Joel Schecter (1977)[50] writing about desertification in the Negev (Israel) observes that the processes associated with desertification of the Negev have been in progress for many millennia. He joins the group of scientists who consider that there has been no ecologically significant climatic change since 7000 BC or possibly even 8000 BC. He suggests caution about attributing any increase in the desert area to man alone, and points out the evidence from the Negev areas which receive 150-400 mm of rainfall per annum. In such areas he asserts, *"even seemingly insignificant fluctuations in precipitation create an ecological response causing the northern border of aridity to fluctuate and the desert to expand or contract"*[50].

9.14 Dennell, R.W. (1983)[51] in an article entitled Archaeology and the Study of Desertification (in Spooner (Ed.) 1983)[30] also calls for a longer time view in conceptualizing desertification. He asserts that investigations into the causes, processes and even diagnosis of desertification are frequently hampered by the lack of a long time-scale, and that *"given the vulnerability of dry lands to the effects of minor climatic oscillations, historical climatology clearly becomes far more than a mere academic exercise with no relevance to the contemporary world"*.[51]

In his view, our knowledge about the environmental changes that have occurred in drylands since the last ice age is inadequate because of poor data. We cannot speak with scientific confidence about environmental change over the last 5000 years, and according to him an unfortunate consequence of these uncertainties is that our understanding of the long-term causes of desertification are weakened *"if we do not know the extent to which present desert environments are a climatic or human product"*.[51]

9.15 Ulf Hellden (1984)[52] from Lund University in Sweden, basing his work on an analysis of a combination of old and new aerial photographs (1961 and 1979) as well as Landsat imageries (satellite imageries) of the same region that Hugh Lamprey had studied in 1975 and used to claim the southward movement of the Saharan boundary of 6 kilometers per year between 1958 and 1975[38], challenged Lamprey's assertions of relentless southward creep of the Sahara Desert. Dregne (1988) has recently questioned Hellden's methodology offering counter-evidence based on NOAA AVHRR (Advanced Very High Resolution Radiometer) Satellite data[37]. However, since the AVHRR Satellite data was based on averaged observations over a period of one year only they too are worthless when dealing conceptually with a phenomenon which should be traced over a 30-40 year period. In the same breath it is important to point out that the use of satellite imagery for desertification monitoring will be worthless unless it can cover periods of up to 20 years. Dregne himself admits that to study a permanent vegetation shift of 5-6 km per year as alleged by Lamprey *"would require perhaps 30 to 40 years of observation by meteorological satellites and ground studies before it would be possible to conclude that the shift was, indeed permanent"*. The truth of the matter is that even within the scientific community there is a lot of loose talk and lack of precision about defining desertification, and it is strongly felt that if the UNEP with all its political weight and with all its easy access, cannot get the scientists to agree, its own programmes on "combating" desertification should be more carefully worked out to prevent it from "going against nature", and trying to propose solutions which are difficult to solve because even the scientists are not fully agreed on how they should be tackled.

9.16 Recently the World Bank, and the International Institute for Environment and Development (IIED) have "entered the affray" by challenging the UNEP's definitions of desertification and proposing alternative definitions which are more "fundable" because they can be reduced more readily into cost benefit ratios. Whereas the present Consultancy Report is not fully in sympathy with them, it is only fair to look at what they are saying to see if it is any different from what the UNEP itself is saying and doing. In an in-house paper of the newly established Environment Department of the World Bank entitled "Dryland Management: The "Desertification" Problem" (Working Paper No. 8), Ridley Nelson (1988)[53] has tried to tackle the "Desertification Issue", and to challenge many of the basic assumptions presented at UNCOD in 1977 and subsequent programmes of action guided by the PACD. This paper levels five criticisms at the way desertification has been characterized by UNEP as follows:

(i) That the impression has been given that the extent of the problem of desertification is well known, when in fact the evidence is extraordinarily scanty.

(ii) That there has been an overestimation of the degree of professional agreement among the scientists and practitioners about desertification

(iii) That the extent of desertification as an irreversible state has probably been exaggerated, although it is correct to classify it as a serious problem.

(iv) That the image created of desertification has been that of *"inexorably advancing sands, as opposed to more subtle more complex, pulsating deteriorations, sometimes with reversals, but at least, with substantial periodic remissions, radiating out from centres of excessive population pressure"*.

(v) That the availability of profitable technologies to combat the problem has been overestimated because the gap between what is socially profitable and what is perceived as privately profitable has been under-estimated.

Because so much has been written about desertification in the last 20 years, and especially in the last 12 years, many of the views expressed above have been expressed in one forum or another although the dominant message put forward by the UNEP has tended to take the hard political line in the hope of raising sufficient funds to enable them to mount a sufficiently viable, and environmentally meaningful programme of anti-desertification. The World Bank paper has offered the following alternative definitions of desertification:

> *"Desertification is a process of sustained land (soil and vegetation) degradation in arid, semi-arid and dry sub-humid areas, caused at least partly by man. It reduces productive potential to an extent which can neither be readily reversed by removing the cause nor easily reclaimed without substantial investment"*.[53]

This definition lays more emphasis on land degradation and confines it to the arid, semi-arid, and dry sub-humid areas of the world, and is coined in the traditional language of the banker. But apart from removing the excesses which have been associated with the desertification debate, and conceptualization of the problem it remains essentially the same as the concerns which have been voiced by the scientific and technical communities about the problem. In particular his elaboration of the five phases of desertification taken from the Ethiopian example are surprisingly in much agreement with other conceptualizations of the problem. The most poignant statement in this report is that intended to demolish the previous assumptions that we have the technologies here and now to successfully "combat desertification". Even more important, in a number of brief country surveys the paper tends to suggest that desertification is quite often reversible, although it also points out a few cases where the damage is clearly irreversible within the short span of 10-20 years. While laying a lot of emphasis on the real and general process of land degradation in the affected parts of the world the paper has the following words to say:

> *"The prevention strategy of halting the desertification problem seems to have diverted attention from the more promising strategy of simply developing profitable land management systems in dry areas, and this prevention strategy seem in turn to have diverted attention from profitability. Past studies and experience have shown that farmers and pastoralists responses are rather well explained by perceptions of profitability and worst-year outcomes"*.[53]

The question the World Bank paper does not answer is "Where in the World, particularly in marginal areas, are successful and sustainable agricultural or pastoral pursuits found without much subsidy from governments to protect them from the effects of prolonged droughts and general land degradation?" Nevertheless it is gratifying to see that at the end of a fairly comprehensive analysis of the problem, the World Bank paper concluded that the Bank should *"probably somewhat increase its lending in dryland areas over the pre-1987 level because of the possibly very high costs of inaction"*[53]. And the paper admits in conclusion that for the Bank and its borrowers, *"improved dryland management must be addressed, over the next five years, as one of the major and most intractable global development issues"*[53].

9.17 The position held by the International Institute for Environment and Development is inclined towards equating desertification with land degradation which interferes with its continued availability as a basic natural resource. They show a preference for the definition of desertification in its most unambiguous form as follows:

> *"Desertification is the notion that the extent of deserts-dry areas with few plants —is increasing, usually into the semi-arid lands"*.[54]

Thus defined it conveys the original meaning which Aubreville in 1949 had intended. According to the IIED paper prepared by Andrew Warren and Clive Agnew (1988)[54], there has emerged an unacceptably loose use of the term "desertification" globally, to include all forms of land degradation including those in humid areas. According to the paper *"most reports about desertification base their arguments on a litany of* *statistics, themselves derived from conflicting definitions"*[64]. They are in favour of separating the climatic true deserts from the semi-arid lands and warn against efforts to measure the advance of the deserts edge because of the lack of accurate data and because of scientific disagreements about definition. Since most scientists believe in the loss of vegetation as a primary indicator of desertification, they examine the available evidence, and they come to the conclusion that from Aubreville's time in 1949, *"acute devegetation has been shown repeatedly to affect only small parts of the semi-arid landscapes"*[13]. The report accepts progressive decline in productivity as a more appropriate way to conceptualize desertification, and for this they would prefer the use of the term "land degradation" rather than desertification. In the final analysis the paper is against the use of desertification as an "institutional fact" for fund raising purposes if it is not sufficiently supported or supportable by science. They end by proposing their own array of solutions to the land degradation problems, which in fairness must be measured against other solutions and especially the very comprehensive ones which had been proposed in the PACD.

9.18 With the recent new advances in the study of climatic impacts and possible climatic change, a group of scientists who prefer to take a longer view of natural processes, as appropriate, has raised the question as to whether in conceptualizing desertification we are not missing the point by not linking it to global climate change and to warming (especially greenhouse warming). In a recent article entitled "Global Prospects for the Prediction of Drought: a Meteorological Perspective", Eugene M. Rassmusson (1988)[55] has classified desertification, deforestation and greenhouse warming together as anthropogenic effects of the climatic change saga. In his view they together are more closely related to questions of climate change than climate variability.

9.19 Thus before concluding it is fair to say that there is now a strong global mood for re-assessment of earlier definitions and earlier basic assumptions about the process of desertification. Opinion is swinging in the direction of seeing desertification as a slow and insidious process of land degradation, which is on the one hand exacerbated by prolonged droughts, and on the other, by carelessness in resource use by human populations. The dramatization of the processes in the form of "desert encroachment" is quietly moving out of favour and the UNEP in planning its future strategies for anti-desertification should take note of that. The new mood is aptly summarized by the recent contribution to UNEP's Desertification Control Bulletin (1988. No. 16, pp. 16-19)[37] by Harold E. Dregne in the following manner:

> *"Desertification is a term that evokes visions of an expanding Sahara destroying villages, water supplies, and fields in its path while sand dunes move inexonerably forward like waves on the ocean. In fact, desertification does bring destruction to peoples livelihoods and land resources, but usually in a stealthy and insidious fashion which is usually less dramatic than burying a village under moving dunes".*[37]

It is to this slower and more insidious process of land degradation that the World Bank and the IIED subscribe, and call for research and a better understanding and new conceptualization to make any new proposed anti-desertification programmes more meaningful.

9.20 A similar word of caution has come from a scientist and practicing ecologist of many years experience in Africa and the dry parts of the United States Allan Savory who has the following to say: (Holistic Resource Management 1988, pp.294):[56]

> *"Politicians more than those in any other profession, have most difficulty in overcoming the temptation to ignore cause and effect ...... The worldwide response to desertification shows how people may fall into the same trap without the slightest trace of cynicism"* and .....
>
> *"When leaders face a problem and have money, they come under great pressure to act somehow, anyhow"*[56].

In his view there is probably now an adequate understanding of the symptom of desertification, but in order to find a true solution to the problem there will be need to better understand the process and if possible to be able to modify it.

10. PROGRAMMATIC IMPLICATIONS OF THE DEFINITION PROBLEM

10.1 Even before the United Nations Conference on Desertification in 1977 the United Nations General Assembly by Resolution 3337 (XXIX)[1] of 1974 had called for international co-operation as the only way to combat desertification.

In that Resolution the General Assembly recognized *"the urgent need to prepare a world integrated programme of development research and application of science and technology to solve the special problems of desertification in all its ramifications and reclamation of land lost to desertification"*[1]. As this Resolution was being passed, the Permanent Inter State Committee on Drought Control in the Sahel (CILSS) had been established to provide regional anti-drought and anti-desertification activities in the drought affected Sahelian lands. The establishment of CILSS was soon followed by the creation of a sort of "sub-Agency" within the United Nations System, namely the United Nations Sudano-Sahelian Office (UNSO), to take care of the needs of the affected countries on the Sahel, also in 1973. Both UNSO and CILSS and other tributary institutions created around them such as the Club du Sahel, AGRHYMET, provided the first programmatic activities in the sub-region long before the United Nations Conference on Desertification (UNCOD) was held. It is important to point out that at this stage drought was considered a more immediate threat than desertification, although, as already analyzed, the programmes carried out in the sub-region tended to color the conceptualization of desertification and the way it was finally defined at UNCOD.

10.2 Following UNCOD and the PACD, UNEP as the UN Agency charged with co-ordinating the global anti-desertification programme, was expected to interpret the PACD in such a way as to begin to realize the following four objectives among others:

(i) To prevent and arrest the advance of desertification

(ii) Where possible to work towards the reclamation on global basis, of desertified land for productive use

(iii) To sustain and promote within ecological limits, the productivity of arid, semi-arid, sub-humid, other areas vulnerable to desertification with the view to improving the quality of life of their inhabitants;

(v) Deforestation — especially in so far as it affected semi-arid and sub-humid lands; and

(vi) Declining availability of groundwater and surface water — as a result of human activities.

The value of this standardization of indicators was to make it possible to compare progress in anti-desertification strategies from one part of the globe to the next, but it is legitimate to ask the question as to whether this approach tended to oversimplify a problem which had proved particularly difficult to conceptualize. In the midst of such questioning, the most important area of agreement was that one was dealing with a man-made problem, rather than with a natural process. But looking at the way sand dune encroachment was put first on the list of indicators, it now appears possibly with hindsight, that the "battle plan" was poorly made, because as indicated in previous pages sand dune encroachment tends to be localized, and it puts too much emphasis on the work of wind in desert margins than on other man-made land degradation processes.

10.4 "Ecological messages" and even more generally what can be called "environmental messages", are not always easy to put across to governments throughout the world, largely because in the initial stages, no one wants to feel particularly responsible for the environment, until public opinion has been so aroused that something has to be done. The anti-desertification programme has been faced by this dilemma and it is important to try and trace it back to the definition of desertification that was adopted by UNCOD and any further definitions which have subsequently been offered. As already indicated in this Report, there was for a long time, a tendency to conceptualize, and to define desertification largely as a process of ecological decline, which in itself was not only untenable but also environmentally unsound, and to be "combatted". However, despite very elaborate steps for inventorying, monitoring the processes, and working out a "battle plan", the political responsibility for such action at the global, regional and national levels was not always clear, and this may have been responsible for the lack of adequate funding which has been experienced in trying to put across the Recommendations contained in the PACD into action. The Recommendations themselves were very detailed and very elaborate, pointing out at each level, who should take action, but the question to be asked is "Was UNEP expected to create a separate Desertification Constituency outside the normal Development Constituency?". If the UNEP adopted the former, it would insist on the creation at the national level in each country of a Desertification Control Unit, and a National Plan of Action to Combat Desertification. If on the other hand it adopted the latter "Constituency", then UNEP would work towards the development of strong multi-disciplinary teams within each country and the incorporation as well as the full integration of anti-desertification measures within the normal national development planning processes.

10.5 The second programmatic consideration linked to the definition of desertification refers to the time-scale over which intervention is envisaged whether such intervention is carried out separately, or as part and parcel of national development programmes. Defined ecologically, corrective measures to "control" or even to "combat" desertification must be viewed over a 15-30 year period, and if the complications brought about by climatic variations are added to the equation, it may even be necessary to think in terms of 30-50 years for recovery to take place

It is not clear if the UNEP ever gave serious enough thought to the time-frames implicit in the definitions adopted for desertification. However, an observation from the 1984 General Assessment of the Progress in the Implementation of the Plan of Action to Combat Desertification indicates the thinking surrounding problems with implementation. That year the UNEP complained that "despite the priority given under the Plan of Actions to "arrest" desertification, such measures have ranked low in the effort so far". But the UNEP itself pointed out the existing conflict when it showed that from past experience, priority was being given to actions in the shorter term and that this was "inconsistent with the long-term perspective of the Plan".

10.5 From the analysis of the evolution of definitions and the conceptualization of desertification there is no doubt that the phenomenon is a global problem "not merely by reason of its scale and urgency but also through the universality of its impacts and causes, which extend far beyond the drylands more directly affected" (UNEP G.C. 12/9 p. 6). But having said that, it is important to add that apart from the general agreement to equate desertification with <u>land degradation</u>, there is not always an agreement on all its manifestations in different parts of the world. It is this aspect which has made it difficult from the programming point of view to translate the PACD into meaningful and measurable activities. The Action Plan in a way oversimplified the required activities by suggesting that they could be divided out as follows:

(i) Those activities primarily aimed at "arresting" desertification;

(ii) Activities aimed at establishing sound and ecologically sustainable land use systems; and

(iii) Activities aimed at ultimately bringing about the social and economic advancement of the communities previously affected by desertification.

In the first instance many activities calculated to "arrest" desertification are of necessity presumptuous because they belittle what in actual fact is a complicated ecological problem exacerbated by human activities. Secondly if climatic variability and even climatic changes are brought in as other possible inputs to the problem, the position becomes less clear. One of the reasons for this is that despite the remarkable technological developments which have taken place over the last fifty years, mankind has not discovered how to deal with climate. Thus any actual activities must of necessity have long gestation periods before the results can be easily evaluated. For example the degradation of rangelands throughout the world, and in particular in the developing countries is often quoted as an indicator of the desertification process. 'Arresting' rangeland degradation as rightly pointed out by the PACD would require a lot of activities at the socio-economic level, such as the complete change of land tenure systems, the enactment of appropriate legislation to bring about planned as well as improved land use practices, and even bringing about changes

in the life styles of traditional pastoral populations. It goes without saying that most of these activities are not amenable to "crash programmes", hence the use of "military" language in dealing with desertification is certainly uncalled for!

10.6 A recommendation which appears so easy to implement concerns desertification monitoring. The PACD recommended that efforts should be made "to monitor desertification by observing atmospheric processes, the state of vegetation and soil cover, dust transport, shifting sand dunes, the distribution, migration and abundance of wildlife, the condition of livestock,the phenology of crops, crop yields, and changes in "irrigated lands" (UNCOD: Round Up Plan of Action and Resolutions, p. 10)[13]. In view of the apparent scientific disagreements about definitions, these recommendations appear to be more appropriate to drought monitoring rather than the monitoring of desertification. Secondly even where it is possible to use Meteorological Satellites as well as those with better ground resolutions like Landsat, Spot or Cosmos, the end result will be the monitoring of drought impacts rather than desertification, especially if definitions of desertification insist on using desert encroachment as one of their goals. H. E. Dregne and C. J. Tucker[37] have shown how the status of drought across Sahelian Africa was easily shown by employing images representing the Normalized Difference Vegetation Index (NDVI) data from NOAA's Advanced Very High Resolution Radiometer (AVHRR). However, it was generally agreed that this method is more appropriate for showing changes in green biomass production from year to year. In order to establish irreversible ecological change that some scientists insisted on, Dregne and Tucker (Ibid)[37] indicate that it would require satellite observations over a period of 30 to 40 years before a conclusive statement could be made about desert encroachment. Even if it is agreed that one could concentrate on soil degradation and land degradation in general, desertification monitoring will still face a lot of methodological controversies before it is finally settled, and this will in turn depend on the definitions adopted by UNEP.

10.7 Looked at from the more general, and less specific level, the definitions of desertification have been extremely important in guiding the whole of the UNEP anti-desertification programme at all levels, including the international, regional, sub-regional, and at the national levels, a change of definition requiring a change of course would be difficult to effect except at a time of a more generalized assessment of progress such as was possible in 1984, but on that occasion it was decided to re-state the ecologically biased definition which had been accepted at UNCOD in 1977. However, in the period between major assessments, such as now it is paying to re-visit earlier definitions and to prepare for future programmatic changes if these are considered necessary. Critics of the UNEP and in particular, of its anti-desertification strategy have suggested that *"with the wrong problem planted in the minds of decision makers, some of the policies adopted to fight the loss of sand have been 'futile and even damaging'. This can affect the lives of millions of people since land degradation is a major ingredient in the recipe for famine"* (Bill Forse, New Scientist, 4 February 1989 p. 32)[57]. In response to this it must be pointed out that the UNEP has rightly concentrated most of its anti-desertification activities at the national level, with supporting activities, particularly new institutions, and training, being sponsored at the sub-regional and regional levels. To that extent there was a tendency to insist on the need for the formulation of National Action Programmes to Combat Desertification (NPACD). However, on realizing that most nations, especially the Developing Nations in Africa, Asia and Latin America, either found it difficult or inappropriate, to establish separate anti-desertification units in their own countries, it has proved possible to shift the emphasis in such a way as to promote anti-desertification programmes which are part and parcel of national development planning. From the point of view of fund raising this should also prove more acceptable, especially since bilateral and even multi-lateral funding agencies have indicated their preference for dealing with individual countries. In dealing with individual countries, the UNEP can in fact begin to introduce the changing views about the conceptualization of desertification while encouraging them to produce comprehensive anti-desertification programmes to be incorporated in national development plans. This should be in keeping with national aspirations as each country will tend to prioritize its anti-desertification activities in such a way as to prevent internal conflict.

10.8 In view of the continuing disagreement among the scientists on how best to define desertification, the UNEP should continue to emphasize the part played by man in bringing about <u>land degradation</u> in particular and his responsibility for rehabilitating the degraded natural resource in the interest of sustainability for future generations. The word "desertification" has now acquired an inexactitude and a notoriety which in some respects prevent it from serving mankind in a more focussed way. Short of holding another UNCOD, it would be difficult to prevent its misuse by the various groups, including some scientific circles. Nevertheless efforts should be made by the UNEP to focus much more on what are intended as anti-desertification strategies at all levels, and in particular at the national and grass roots levels. The guidelines contained in the Plan of Action to Combat Desertification (PACD) are still largely valid as an indicator of what should be done at all the various levels, to stop deterioration and severe land degradation. Finally it appears that for fund raising purposes, the UNEP has tended to underplay the role of climate, and especially of desiccation in helping to explain desertification. If indeed climate is changing through a combination of factors including human activities, then there is likely to be an increase in the occurrence of severe droughts which reflect directly in land use, particularly in the lands located in the semi-arid and sub-humid, climatic zones of the world. It is in these zones where the impact of droughts is immediately felt in the field of food production thereby striking at the roots of the societies which inhabit these lands. A global drop in food production is bound to be felt at all levels of the human society hence the need to keep desertification as an important global issue on the United Nations agenda. In so far as the UNEP has been entrusted with providing leadership at the world level in finding solutions to these problems, it should continue with efforts to better understand the problem even if this will mean a complete re-definition of the word desertification. This may mean less emphasis on the impact of desertification on environmental quality and more emphasis on the socio-economic as well as the political impacts of this phenomenon.

10.9 So far this Report has concentrated on the scientific aspects of the desertification problem including the various definitions, and how they have been interpreted by the UNEP for programmatic purposes. In the final analysis, however, what is achieved at the national, sub-regional, regional and international levels, depends on the collective political will to get things moving, even in the absence of complete information. It would be erroneous to give the impression that the UNEP has over the last 12 years achieved nothing or little. The truth of the matter is that even in the absence of complete information, the UNEP has developed a viable and consistent approach to the problem of desertification, and has made clear-cut programmes to achieve its objectives. Since 1978 the UNEP has been able to give a clear-cut international leadership in working towards the consolidation of international efforts to "combat" desertification. In this worthy task it has asked for and received support from the Environment Co-ordination Board, DESCON, and regional and national efforts to 'combat' desertification on the lines spelled out by the PACD. Among the success stories was the creation of an enlarged United Nations Sudano-Sahelian Office (UNSO) as a joint responsibility of UNEP and UNDP. Even if it is now being suggested that the action programmes were inadequate and even "misguided", UNSO has been able to realize tangible international financing for anti-desertification programmes in at least 18 countries, first in Western Africa and recently in Eastern Africa as well. UNSO was created to provide on the spot and close supervision of activities programmes in the region as well as at the national levels. If it were not because of donor resistance the UNSO module should have been replicated in other regions such as south west Asia and Latin America equally affected by land degradation or desertification. Granted that more than 75 percent of the UNSO projects have fallen within agriculture, forestry, range management and energy, but indirectly they have enabled the countries and the region concerned to make a start in addressing the problem. The activities of UNEP, working in close collaboration with DESCON, Inter-Agency Working Group on Desertification (IAWGD), the Environment Co-ordination Board as well as national institutions many of them newly created has led to the development of programmes and strategies which have directly addressed desertification. The other main area of achievement already mentioned has been in the field of public awareness. This has had the very welcome effect of generating national, bilateral as well as multi-lateral programme to 'combat' desertification which would not have existed in the absence of UNEP's leadership. And now that there is a clearly stated donor preference for national as well as regional anti-desertification projects, this should be given every encouragement with the UNEP coming in to assist in the formulation of viable national action programmes incorporated within the national development plans.

10.10 In conclusion the position of the ACC must be reiterated, that desertification, however defined is a vast field and UNEP cannot be expected to go it alone. It is at once a development, as well as an environmental problem. Action to 'Combat' desertification must be long-term, which is not always politically popular because the results may not be realized within a five year period, the normal time frame for political decisions followed by functioning agencies as well. For UNEP it may be best to sharpen the definition of desertification to enable it to do what it can do best with limited funding. One such area is in the field of global awareness creation for understanding the process even if it is called land degradation; such global awareness should be aimed at stimulating action at the national and grass roots levels where it matters most.

The second area of concentration should be to continue to give leadership to other UN agencies who have the capacity to carry out programmes which complement those of UNEP in dealing with desertification. If it can continue to harmonize activities in the two main areas, it will be able to build basis for the long-term application of programmes designed eventually to address those aspects of desertification which can respond to corrective measures.

References

1. UNEP 1978. Compendium of Legislative Authority 1972 - 1977.

2. UNESCO 1963. Changes of Climate. Proceedings of the Rome Symposium, Paris, UNESCO.

3. AUBREVILLE, A. 1949. Climats forets et désertification de l'Afrique tropicales, Societé d'Éditions Géographiques et Coloniales, Paris.

4. DESPOIS, J. 1973. The crisis of the Saharan oases in D.H. Amiran, et. al. (Eds.) Coastal Deserts, Tucson.

5. ECHALLIER, J.C. 1972. Villages deserts et structures agraires anciennes du Tonat — Gourara (Sahara algerien), Paris 122p.

6. MECKELEIN, W. 1976. Desertification caused by land reclamation in deserts: the example of the New Valley in Egypt. In Pre-Congress Symposium K 26, of XXIII Int. Geog. Congress, Working Group on Desertification in and around arid lands, Ashkabad, USSR.

7. MECKELEIN, W. (Ed.) 1980. Desertification in Extremely Arid Environments. Stuttgarter Geographische Studien, Band 95; IGU Working Group on Desertification in and Arid Lands - Sub-group Extremely Arid Environments.

8. EVENARY M. et. al. 1971. The Negev: The challenge of a Desert, Cambridge, Mass., Harvard University Press. 345pp.

9. NOVIKOFF, G. et. al. (Eds.) 1975. The desertification of rangelands and cereal cultivated lands in pre-Saharan Tunisia, Tunisian pre-Saharan Project Times.

10. RAPP, A., Le Houerou, H.N. and Lundholm, B. (Eds.) 1976. Can Desert encroachment be stopped? Stockholm, SIES.

11. HARE, K. 1987. Drought and Desiccation, twin hazards of a variable climate in WILHITE, D.A. et. al. (Eds.), 1987 Planning for Droughts: towards a reduction of societal vulnerability, Boulder and London, Westview Press.

12. WILHITE, D.A and GLANTZ, M. 1987. Definitions of Droughts in WILHITE, D.A. et. al. (Eds.), Planning for Droughts; towards a reduction of societal vulnerability, Boulder and London, Westview Press.

13. UN 1977. United Nations Conference on Desertification: Round-up Plan of Action and Resolutions. 43p.

14. PER BRINK 1976. Present knowledge of arid ecosystems — in RAPP, A. Le Houerou H.N. and Lundholm B. (Eds.) 1976. Can Desert encroachment be stopped? Stockholm, SIES.

15. GARCIA, R. 1972. Nature Pleads Not Guilty. Sahelian Drought A Case Study, Stockholm, IFIAS.

16. UNCOD 1977. Climate and desertification - UNCOD background document, component review (A/CONF.74/5).

17. UNCOD 1977. Ecological change and desertification - UNCOD background document, component review (A/CONF.74/7).

18. UNCOD 1977. Population, Society and desertification - UNCOD background document, component review (A/CONF.74/8).

19. UNCOD 1977. Technology and Desertification - UNCOD background document, component review (A/CONF.74/6).

20. UNCOD 1977. Desertification: an overview - UNCOD principal conference document (A/CONF.74/1/Rev.1).

21. UNCOD 1977. Iran: The Turan Programme, associated case study (A/CONF.74/19).

22. UNCOD 1977. China: Combating Desertification in China, associated case study (A/CONF.74/18).

23. UNCOD 1977. United States of America: The Vale rangeland rehabilitation programme: The desert repaired in south-eastern Oregon, associated case study (A/CONF.74/21).

24. UNCOD 1977. Union of Soviet Socialist Republics: Integrated desert development and desertification control in the Turkmenian SSR, associated case study (A/CONF.74/22).

25. UNCOD 1977. Australia: Gascoyne Basin, associated case study (A/CONF.74/15).

26. UNCOD 1977. Case study on desertification - Greater Mussayeb Project, Iraq (A/CONF.74/10).

27. UNCOD 1977. Case study on desertification - Oglat Merteba Region, Tunisia (A/CONF.74/12).

28. UNCOD 1977. Case study on desertification - The Eghazer and Azawak Region, Niger (A/CONF.74/14).

29. UNCOD 1977. Case study on desertification - Mona Reclamation Experimental Project, Pakistan (A/CONF.74/13).

30. SPOONER, B. (Ed.) 1982. Desertification and Development, London, New York, Academic Press.

31. UNEP 1978. Desertification Control Bulletin. Vol 1, No. 1.

32. UNEP Governing Council Sixth Session 1978.

33. FAO/UNEP 1982. Provisional Methodology for Assessment and Mapping of Desertification Rome, FAO/UNEP.

34. Berry, L. with the United Nations Sudano-Sahelian Office 1984. Assessment of Desertification in the Sudano-Sahelian Region 1978-1984 (UNEP/GC.12/Background Paper 1)

35. UNEP 1984. General Assessment of Progress in the Implementation of the Plan of Action to Combat Desertification 1978-1984 (UNEP/GC.12/9)

36. WOODS, L.E. 1983. Land Degradation in Australia, Department of Home Affairs and Environment, Australian Environment Statistics Project, Australia Government Publishing Service, 105p.

37. DREGNE, H.E. and TUCKER,C.J. 1988. Desert encroachment, in Desertification Control Bulletin No. 16 pp. 16-19.

38. LAMPREY, H. 1975. Report on the desert encroachment reconnaissance in Northern Sudan, 21 October to 10 November 1975. UNESCO/UNEP Paris, Nairobi, 16p.

39. ECKHOLM, E.P and BROWN L.R. 1977. Spreading Deserts — The land of Man, Worldwatch Paper No. 13.

40. GRAINGER, A. 1982. Desertification: How people make deserts, how people can stop and why they don't, Institute of Environment and Development, An Earthscan Paperback.

41. UNEP 1987. Rolling back the desert: Ten years after UNCOD. UNEP, Nairobi.

42. IGADD 1987. Donors' Conference Vol. 3-f National Projects — Uganda.

43. UNEP 1983. Official Correspondence ESCAP/UNEP.

44. LE HOUEROU, H.N. 1959. (Quoted in Rapp et.al. 1976. Can Desert Encroachment be Stopped?, Stockholm, SIES).

45. LE HOUEROU, H.N. 1972. In National Seminar on Desertification, Tunis.

46. DREGNE, H. E. 1977. Desertification of Arid Lands, Economic Geography, Vol.53, no.4, pp.322-331.

47. MENSCHING, H. 1986. Is the desert spreading? Desertification in the Sahel Zone of Africa. Applied Geography and Development, Vol. 27, pp. 7-18.

48. KASSAS, M. 1970. Desertification versus potential recovery in circum-Saharan territories — in DREGNE, H. (Ed.) 1970. Arid Lands in Transition.

49. KASSAS M. 1988. Ecology and management of desertification. In Earth 1988: Changing Geographic Perspectives.

50. UNCOD 1977. Israel: The Negev - a desert reclaimed, associated case study (A/Conf.74/20)

51. DENNELL, R.W. 1983. Archaeology and the study of desertification in Spooner B. (Ed.) Desertification and Development, London, New York, Academic Press.

52. HELLDEN, U. 1984. Drought impact monitoring. Lunds Universites Naturgeografiska Institution Lund, Sweden 61p.

53. WORLD BANK 1988. Dryland management: the desertification problem by Ridley, Nelson - Working Paper No. 8.

54. WARREN, A. and AGNEW, C. 1988. An assessment of desertification and land degradation in arid and semi-arid areas. IIED Issue Paper No. 2, November 1988.

55. RASSMUSSON, E.M. 1988. Global Prospects for the Prediction of Drought: A Meteorological Perspective in WILHITE, D.A. et. al. (Eds.), 1987 Planning for Droughts: towards a reduction of societal vulnerability, Boulder and London, Westview Press.

56. SAVORY, A. 1988. Holistic resource management. Washington D.C., Island Press.

57. FORSE, B. 1989. The myth of the marching desert. New Scientist, 4 February 1989, pp 31-32.

GLOBAL ASSESSMENT OF DESERTIFICATION: STATUS AND METHODOLOGIES

Professor Boris G. Rozanov
Head, Chair of General Pedology, Faculty of Soil Science
Moscow State University, USSR

for
Desertification Control Programme Activity Centre
United Nations Environment Programme

February 1990

PREFACE

This report was Prepared at the request of the Desertification Control Programme Activity Centre [DC/PAC] of the United Nations Environment Programme [UNEP] to serve as a discussion paper to be presented at the Ad-Hoc Consultation Meeting, Assessment of Global Desertification: Status and Methodologies, held in Nairobi from 15 to 17 February 1990.

The objective was to conduct a thorough investigation on the status of desertification as well as the state-of-the-art of the methdological aspects of desertification assessment and monitoring, on the basis of the information which is currently available mainly in published form.

The report should not be regarded as a comprehensive documentation of the status of desertification by country nor by region, but as a working document showing the global magnitude of the desertification problem, its perception, and various approaches taken towards its assessment both qualitatively and quantitatively, with particular emphasis on the methodological aspect.

In search for the relevant information, the author was provided with an opportunity to visit, on behalf of UNEP, several organizations concerned with desertification and its assessment. The consultancy visits were organized to FAO, Rome and to Arab Council on Semi-Arid and Drylands [ACSAD], Damascus.

Nairobi, 4 February 1990

TABLE OF CONTENTS

INTRODUCTION

1. DESERTIFICATION AND ARID TERRITORIES

The United Nations Conference on Desertification [UNCOD] in 1977 defined desertification as a process of, "diminution of the biological potential of land that may eventually lead to the desert-like conditions", or as, "an impoverishment of arid and semi-arid ecosystems under the impact of human activity"; in both cases connecting it with the inappropriate use of natural resources by man [United Nations, 1978]. Due to certain difficulties in using this definition for the quantitative assessment and monitoring of the process, there have been some attempts to make it more precise and operational when UNCOD adopted the Plan of Action to Combat Desertification.

According to H.E. Dregne [1978, 1983, 1986], desertification "is an impoverishment of terrestrial ecosystems that results from human activity. This process may be assessed in accordance with the degree of productivity decline of cultivated plants, the degree of adverse changes in the biomass and of the diminution of the diversity of micro- and macro-fauna and flora, the degree of accelerated soil degradation, and the degree of growth of risk in agricultural production". From another point of view, in the definition developed by B.G. Rozanov [1981, 1982, 1986] attention is focused on the irreversible change of soil and the ecosystem as a whole towards further aridization, which can be monitored by the degree of decrease in the ability of the geosystem to provide vegetation and other organisms with a productive water supply.

Any of the above definitions underlines the close connection of the desertification process with arid territories comprising nearly one third of the global land area, as Table 1 demonstrates.

Table 1. Area of Arid Territories of the World, million ha

Arid Territories	By P. Meigs, 1956	by FAO/UNESCO/WMO map (1977)
Hyper-arid	581	900
Arid	2,174	2,680
Semi-arid	2,126	1,750
Total	4,881	5,330

According to the FAO/WMO World Map of Desertification [1977], arid lands, given in Table 1, are classified as follows:

Hyper-arid territories: Annual precipitation is less than 100 mm; vegetation is absent with exception of ephemeral plants and shrubs in watercourses; agriculture and animal husbandry are impossible, except in oases. These are "true" deserts with an index of aridity less than 0.03 [the index of aridity is taken as a ratio of mean annual precipitations to potential evapotranspiration calculated by Penman's method];

Arid territories: Annual precipitation from 100-200 mm; sparse annual and perennial plants; agriculture is possible only under irrigation while animal husbandry is nomadic; the index of aridity is from 0.03 to 0.20;

<u>Semi-arid territories:</u> Annual precipitation from 200-400 mm; semi-desert and shrub vegetation with discontinuous cover; rain-fed agriculture is possible but not reliable while the animal husbandry is generally practised; the index of aridity is from 0.20 to 0.50.

The area estimations of arid territories of the world by different scholars vary a lot as summarised below [Zonn, 1986]:

Author	Million km^2
De Martonne, 1927	41.8
P. Meigs, 1956	48.8
F. Joly, 1957	47.7
M. Kassas, 1977	57.5
M.P. Petrov, 1973	31.4
H.E. Dregne, 1976	46.1
FAO, UNESCO, WMO, 1977	53.3

According to M. Kassas, 1977, the area of "climatic" deserts is 48.4 and that of "anthropogenic" deserts is 9.1 [Kassas, 1977].

Because the hyper-arid territories are already "true" deserts, the process of present anthropogenic desertification is mainly associated with the arid and semi-arid regions; this fact was clearly underlined by UNCOD in 1977. However, later studies show the occurrence of desertification as being present in semi-humid regions as well, in the territories with annual precipitations of 400-800 mm with an aridity index of 0.50-0.75 and with widespread rain-fed agricultural practices — in short, the main grain-producing regions of the world. If the rural population directly affected by desertification was considered to be of the order of 80 million in 1977, later estimates provided a much higher figure of 135 million [Mabbutt, 1987]. ESCAP [1987] gives the figure of 150 million for this region alone! Nearly 650 [850?] million people are living in arid and semi-arid regions of the world and are experiencing various aspects of desertification.

2. THE UNITED NATIONS CONFERENCE ON DESERTIFICATION

The United Nations Conference on Desertification (UNCOD) was held at 1977 at the initiative of the United Nations General Assembly which took its decision on economic, political and humanitarian grounds. The Assembly did not probe the nature of the problem and its magnitude, having been deeply impressed by the African drought tragedy. However, the Conference was preceded by extensive studies conducted by a large number of scientists from different parts of the world, who assembled and discussed all available facts and relevant information in respect of the problem. These materials, including a series of global maps of desertification, were presented as official United Nations documents to the Conference for consideration; they were later published [United Nations, 1977, 1978; Mabbutt, Floret, 1980; Jain, 1986] as valuable sources of information to be used by the world community. Evaluating these materials later, the well- known Africanist, L. Timberlake [1985] stated that UNEP had conducted one of the best UN Conferences both from the point of view of the quality of scientific data and from the point of elaborating the problem.

On the basis of carefully collected and analyzed factual materials, the Conference was able to establish the anthropogenic origin of this negative ecological process; its continued spread in the arid and semi-arid regions of all continents; and its immediate threat to socio-economic development, particularly in the developing countries of Africa, South and South-West Asia, and Latin America.

The Conference has developed and adopted the Plan of Action to Combat Desertification endorsed, a few months later, by the United Nations General Assembly, — a large-scale international action programme and what is considered an appropriate response to the challenge [United Nations, 1978]. The Plan contained concrete recommendations at the national, regional and global levels, directed to combating desertification

where it is developing and progressing and to reclaiming the biological potential in those areas where desertification has already destroyed the ecosystems.

3. IMPLEMENTATION OF THE PLAN OF ACTION TO COMBAT DESERTIFICATION

The results of seven years of international efforts on the implementation of the Plan of Action to Combat Desertification were considered in 1984 by UNEP's Governing council at its 12th session. On the initiative of UNEP, just prior to this session, a comprehensive (4000 page report) General Assessment of the Progress in combating desertification [GAP] was conducted throughout the affected countries [UNEP, 1984]. The generalized results of the assessment were later published [Mabbutt, 1984, 1987; Rapp, 1987] and are available as a valuable source of reference.

According to GAP, desertification threatens the well being of 850 million people and embraces an area of some 3.5 billion hectares, of which 3.1 billion hectares are pasture lands, 335 million hectares are rainfed croplands, and 40 million hectares are irrigated agricultural lands. Desertification causes approximately 21 million hectares annually to loose their productivity, even to the point at which their use becomes totally unfeasible from an economic point of view.

After considering the GAP materials, the Governing Council of UNEP was forced to admit that during the seven-year period, the processes of desertification had continued to spread and to deepen in the developing countries, particularly in Africa [UNEP, 1984]. In his report to the Governing Council at this session, the Executive Director of UNEP, Dr. M.K. Tolba [1984] has emphasized that the creation of an effective barrier to the processes of desertification was one of the main problems in the area of environment protection facing humanity now and called for efforts to find an effective solution in the next two decades.

Further, the Governing Council noted that measures carried out during the seven-year period, had not produced substantial enough results in any of the regions affected by desertification because the Plan of Action had nowhere been implemented in its totality. Moreover, the 1980s had brought new sufferings in the form of persistent and disastrous droughts to the peoples of Africa. In 1984, for example, millions of people in Africa went hungry because of a new drought cycle. Those students who have studied this new disastrous cycle have emphasized that desertification destroys the productive capacity of land and, when the droughts come, the impoverished land collapses [Stiles, Brennan, 1986].

In 1987, in connection with the tenth anniversary of UNCOD, various bodies of the United Nations attempted to analyze and exchange notes on the experiences of combating desertification during this period.

Considering the same problem, and quoting UNEP sources, the World Commission on Environment and Development concluded in *Our Common Future* [WCED, 1987], that desertification is progressing, that the process of desertification affects all the continents of the world, particularly and to the greatest extent the arid territories of South America, Asia and Africa, where up to 18.5 per cent [870 million hectares] of productive lands underwent severe desertification. The Sudano-Sahelian zone of Africa and the countries south of it suffer particularly heavily, as the process of desertification here threatens the well-being of 80-85 per cent of the total population of the area.

Also in 1987, the group of experts of the United Nations Center for Science and Technology for Development studied the status of desertification and the causes of failure in implementing the Plan of Action to Combat Desertification. The group concluded that after 10 years of trials, the Plan needed substantial renovation and reorientation in light of new situations [UNOSTD 1987].

Among the main causes of failure in implementing the Plan of Action, the following were noted:

- continuing uncontrolled population pressure on the fragile natural ecosystems of arid and semi-arid territories, as well as the utilization of natural resources without consideration of their potentialities and natural reproductivity and without alternative programmes of development, coupled with the very limited resources in the majority of the developing countries affected by desertification;

- absence of integrated national plans of action in the majority of the countries affected by desertification, which is the result of giving insufficient priority to the problem at the national level and of not integrating plans to combat desertification into general programmes of socio-economic development;

- absence of an integrated approach to combating desertification in the large regions affected and the substitution for such an approach and a complex of co-ordinated measures of a series of small disconnected projects that do not produce a sufficient impact on the main regional causes of desertification;

- absence of sufficient resources at the disposal of the international community for the implementation of large regional or global programmes to combat desertification, which were recommended by the Plan of Action;

- that fact that neither the major conclusions of the Conference about the causes and consequences of desertification, nor the recommendations of the Plan of Action were made available to the people concerned whose activity is the factor of desertification, and who suffer most — in short, the non-involvement of the rural population of the affected regions;

- underestimation of the danger and catastrophic consequences of desertification by the decision-makers, their inability to understand complex processes of human interaction with nature in a long-term perspective, as well as the consequences of this interaction;

- unwillingness or inability to solve prospective strategic problems that underlie the thousands of current small problems whose solution is attempted instead.

In 1987 as well, a special issue of the international journal "Land Use Policy" devoted to the decade of combating desertification was published [Land Use Policy, 1987] which opened with the review "10 Years After UNCOD" by Dr. M.K. Tolba, in which he considered the results of a decade of implementation of the Plan of Action to Combat Desertification. Noting insufficiency of the measures undertaken, as well as the continuing progress of desertification, Dr. Tolba concluded, that "The result of UNCOD — the Plan of Action to Combat Desertification — is still living and acting document. It will direct UNEP in the nearest years in its struggle against the hazard of land destruction, which is called desertification. UNEP cannot do it alone, however, I call on governments, international organizations, non-governmental organizations and interested people to work with us. The alternative is a decline of food production, continuation of under-development and growth of number of the environment refugees. It is not acceptable."

In addition to Dr. Tolba's review, Jack Mabbutt, in the same issue of the journal, provided a detailed characterisation of the implementation of the Plan of Action at a global scale, mainly on the basis of GAP [Mabbutt, 1987]. The main conclusion, probably, is that "the trends to improvement of the conditions were noted only in insignificant degree, for example in the irrigated lands of the USSR, China and up to a less degree of the USA, in the extension of forests in Southern Europe, USSR, China and USA, in the pastures of the USSR, China and in places in the USA. The developed countries were mainly marked as territories of certain deterioration or stabilization of conditions, while the developing world in Africa, Asia and Latin America was characterized, without exclusion, by the growth of desertification. Moreover, it was shown that the problem of desertification is extended even wider than was supposed at UNCOD: a considerable part of sub-humid tropics is now considered as experiencing a serious threat. The rural population affected by desertification is assessed now as 135 million in comparison with 80 million in 1977. We are not only behind, but now it is demanded from us much more than it was thought earlier. At the present rate, may be only with exception of irrigated lands, the situation will be much worse by the year 2000 — the date established for the implementation of the Plan of Action, than in the year of its elaboration".

In March 1988, at the First Special Session of UNEP's Governing Council, the Second System-wide-medium-Term Environment Programme for the period of 1990-1995, [SWMTEP-II] was adopted and [SWMTEP-I] was adopted in 1983 was for the period of 1984-1989] [Kroumkatchev, 1989; Zonn, 1989]. In the section devoted to arid land and desertification, it was noted that "every year six million hectares throughout the world are reduced to desert-like conditions and nearly 21 million hectares become economically unproductive because of desertification. Nearly one third of all land is at risk from desertification, but the phenomenon is particularly prevalent, and dramatic in arid and semi-arid areas of the world. Efforts to meet rapidly growing needs for food, combined with insufficient attention to the environmental effects of methods in agricultural and pastoral practices have increased the rate of desertification. Factors that contribute to desertification include over-cultivation, overgrazing, deforestation, bush fires, wind and water erosion and soil salinization, which, in turn, result from excessive human and animal pressure and poor management of droughts and pastures. Desertification is closely related to severe droughts which result from climate fluctuations, but are (themselves) aggravated by desertification. It should be noted too, that climatic droughts, by themselves, do not lead to desertification [Kassas, 1987]. Desertification in one area increases the pressure on nearby more productive areas, endangering their productivity and increasing the risk of further extension of the process".

4. DOUBTS AND ARGUMENTS CONCERNING THE ASSESSMENT OF DESERTIFICATION.

At the same time, it is should be noted that some publications requesting certain revisions of the conclusions of UNCOD have appeared recently and that international forums and commissions concerning the global character and seriousness of the danger of present anthropogenic desertification have since taken place. In particular, on the basis of the remote sensing data covering the areas south of the Sahara in Africa, which show periodic "greening" and "yellowing" of the land surface, some experts concluded that the position of UNCOD concerning the extent of desertification was not sufficiently justified and that the global situation was over-dramatized while the cyclic processes of alternation of moist and dry periods were considered and assumed to be directly associated with irreversible changes [Tucker, Justice, 1986; Dregne, Tucker, 1987].

This particular aspect of the problem had been covered by the conference in 1977 and had been specifically considered by many scientists at that time. It was recently given adequate attention by Kassas in 1987 [Kassas, 1987].

Indeed, the periodical "greenings" and "yellowings" of the earth surface, revealed by the settelite images, might have resulted from cyclic atmospheric processes of alternations of relatively moist and dry periods within arid and semi-arid climates. It would, however, be wrong to equate these with actual desertification.

Vegetation decreases its productivity during the periods of droughts; such changes are temporary and reversible. However, in anthropogenic desertification, the soil cover and the geosystem as a whole change irreversibly in the direction of higher aridization. This includes the sub-surface tier of the geosystems. There is an irreversible decrease of the geosystems' ability [soil, subsoil, ground water] to supply the vegetation and, through it, the other organisms with a productive water reserve [Rozanov, 1981]. These changes, due to anthropogenic desertification in arid and semi-arid territories, may take place and have actually been observed even without changes in atmospheric precipitation under stable climatic conditions. A special case of ecosystem aridization may be that in which the total stock of water in the geosystem remains the same or even increases, but the mineralization of water increases sharply, producing the same physiological effect in the end. Such situations appear during catastrophic salinization of irrigated lands and their surrounding areas, lands along the water canals, drainage channels and water reservoirs. The same effect will be brought about by the expansion of shifting sands moving into stabilized vegetated soils, by the outcropping of indurated subsoil horizons as a result of surface erosion, which decreases the soil's water holding capacity sharply.

All these phenomena can be observed in Africa, particularly in the Sudano-Sahelian zone [Radchenko, 1987], and also in the other regions of the world. After the "desert blow" of the late 1960s and the early 1970s, caused by abetled, exacerbated uncontrolled exploitation of natural resources during the preceding decades, Africa was unable to recover, even though the dry periods were interrupted several times by the moister ones. Both the ecological situation and the consequent socio-economic situation in arid regions of the continent continue to worsen because virtually none of the recommendations of the Plan of Action has been implemented here in its totality. Each year the number of African countries requiring practically permanent international food assistance during both dry and wet years continue to grow (see Table 2).

Table 2. Index of per capita food production in some of the regions of the world [Biswas et al., 1987]

Region	1975	1985
Africa	108.35	95.62
Asia	94.85	111.59
South America	95.76	102.22

After the catastrophically dry 1983-1984, when millions of people were hunger stricken, the year 1985 was wet, with a good harvest [Timberlake, 1985]. However, this did not provide freedom from hunger because between 1975 and 1985, although total food production increased by 18.4 percent, the population increased by 34.3 percent, while the per capita food production decreased by 11.8 percent [Biswas et al., 1987]. An FAO study revealed that if such tendencies persist in Africa, by 2010 food self-sufficiency in North Africa will decrease from the present 52 percent to 34 percent and in sub-Saharan Africa from 85 percent to 56 percent while the grain deficit will increase up to 100 million tons per year and its costs will multiply by a factor of six [FAO, 1987].

Another question being discussed in the scientific circles, which is also connected with problems in identification and monitoring of desertification is the difficulty of distinguishing between desertification *per se* and the broad circle of the phenomena related to various forms of soil degradation that are manifest themselves not only in arid areas, but in the most humid ones as well [Rozanov, 1982, 1986a]. These discussions, tend to involve the age-old philosophical dispute about causes and effect. In fact, however, in arid and semi-arid areas, soil degradation always leads to desertification of the land, no matter what the immediate cause or anthropogenic factor of the degradation process may be. The converse is also true: desertification always manifests itself in soil degradation. Causes and effect are perpetually interchanging in this case and are bounded by the unity of the physical processes involved. For these territories, any form of soil degradation is always a symptom and the manifestation of desertification.

PART 1. STATUS OF DESERTIFICATION, 1990

1.1 GENERAL SITUATION

There is no consensus at present concerning the status of desertification in the world as a whole or in its various regions. This is true even of Africa, which is generally considered the most seriously affected continent.

This uncertainty derives from the definition of what desertification is. This subject will be discussed in the second part of this report, which is concerned with methodological matters. At this point, the existing information will be analyzed from the substantive point of view. Some new information will be particularly important in this respect.

There is an enormous amount of information concerning desertification in Africa, South Asia and Latin America. However, this vast fund of data, which appears in various reports and publications, does not cast any new light on the problem because it is largely qualitative and, in some cases, more emotional than factual. With some reservations this information can be used for creating a general picture, but it is hardly sufficient to prove the case beyond all reasonable doubt. However, some new quantitative information, particularly for certain areas hitherto uncovered by widely circulated publications, may provide additional evidence. The case of the USSR, which was recently well studied, may be taken as an illustration of the general situation.

The recent study of desertification in the USSR clearly shows that:

- any attempt to characterize the problem of desertification as "only African" is absolutely groundless and even harmful;
- the process is constantly expanding to embrace new territories and regions of the planet, creating serious ecological dangers for humanity, including those peoples who live far from the regions directly affected;
- once begun, the process develops so intensively that it leaves little time for undertaking effective measures to stop it, if we do not want to face the real global ecological catastrophe threatening one third of the earths land area.

At UNCOD in 1977 the Soviet delegation was able to state proudly on the basis of the case studies that the situation was generally stable in the arid regions of the USSR and that there were only separate local manifestations of anthropogenic desertification to deal with, which would be no problem for so powerful a state [Mabbutt, Floret, 1980]. In 1984, certain "improvements" were reported in the USSR [UNEP, 1984]. Now, however, only five years since the last assessment, the USSR faces the immendy complex problems of the Aral Sea, the Caspian Sea, the Balkhash Lake Basins encompassing huge territories on the plains of Turkmenia, Uzbekistan, Kazakhstan, Kalmykia, Dagestan, Azerbaijan where current desertification is clearly manifest. These are not "separate local manifestations", but the areas that constitute in their totality a very serious problem of the whole arid and semi-arid belt of the country in which very large area land masses are affected by different forms of anthropogenic desertification. It is also important to emphasize that the main causes of desertification here are absolutely the same that were clearly indicated by UNCOD in 1977, namely: uncontrolled utilization of natural resources exceeding the limit of ecological stability of natural ecosystems, followed by their degradation, which is often irreversible; and the utilization of natural resources without appropriate care for their rehabilitation by natural or artificial processes.

1.2 THE CASE OF KALMYKIA

According to remote sensing data, in 1983 there were already more than 500 thousand hectares of shifting sands in only the territory of two districts surveyed in Kalmykia, which occupied up to 30% of the rangelands; they were shown to be expanding by 10% per year, whereas previously they had occupied only two to three percent of the total area in these districts [Vinogradov, 1988]. By 1989, the area of shifting sands had expanded to 800 thousand hectares and continues to grow. As B.V. Vinogradov stated [Vinogradov 1988], within a short time, this had become in the country the largest growing spot of anthropogenic desertification.

The main cause is the overstocking of pastures of low carrying capacity. In the Yashkul district, for example, a selective survey at four points in 1983 revealed the same number of unaccounted sheep as those listed in the official records, while later surveys at 24 points revealed the fact that the number of unaccounted sheep in herds was sometimes by twenty times higher [Vinogradov, 1988]. No pasture can sustain such overgrazing as thus revealed. The Astrakhan gas field, which is being developed nearby, adds to this destruction of rangelands [Bogert, 1990].

There are nearly 100 thousand hectares of irrigated cropland in Kalmykia. Nobody knows how large is the area irrigated additionally by the so called "localised irrigation" based on water supply from various local water sources by varying types of pumps. Practically all irrigated lands are salinized in one or another degree, and this means not only loss of production, but the potential for the growth of salt desert — in short, for the loss of the land. This is the well studied process of silent abandonment of degraded lands and the compensatory development of new croplands: the total area of cropland is not reduced, while the area of the desert grows because of overtaxed pastures that shrink.

This process was revealed and characterized at UNCOD as one of the leading desertification processes, particularly in North Africa and South Asia [United Nations, 1977; Mabbutt, Floret, 1980]. Currently it is developing intensively in the USSR in Middle Asia, Kazakhstan and the Caspian Basin.

The competition for land resources underlies this process. It is widely believed that there is a certain complementarity and a harmony of interests between agriculturists and pastoralists. However, this is far from the truth. In fact, there is a permanent struggle for land between them. This war goes on under any socio-economic conditions or form of land tenure. It exists not only in Africa or Asia with communal land property, but even in the USA with the privately held land [El-Ashly, Gibbons, 1988] and in the USSR with State owned land as well.

Agriculturalists are gradually expanding cropland, including irrigated cropland, particularly in arid territories, in accordance with the needs of socio-economic development. They can expand only into pasture lands, obviously the better ones. The pastoralists are thus forced to retreat with their herds into less productive pastures, creating overloading, overgrazing and finally, desertification. It is generally assumed that the reduction of pastures would be compensated by fodder production in newly reclaimed irrigated lands. However, agriculturalists can make little profit by growing fodder crops. The irrigated cropland was expanded for other, more profitable cash crops such as cotton, rice and sugarcane. The usual result is: degradation and the loss of productive land transformed into desert, and the general decline of the efficiency of the rural economy. The "salt desert" is growing because of degraded irrigated lands and the sand desert is expanding because of the overgrazing of already poor pastures.

The above process is fully confirmed by the example of Kalmykia. According to the results of the repeated remote sensing survey [Ermoshkina et al., 1986], in the Sarpa district in the northern part of the Republic with an area of some 72.5 thousand hectares, the area of pastures has been reduced by 14.7% within 10 years without decreasing the number of sheep; lands along the canals of the Tsarynsk irrigated system became saline throughout the area of 1.7 thousand hectares; large areas of rice fields were abandoned. In the same district in the Ergeni Upland, about 2.9 thousand hectares were reclaimed within 10 years for rainfed agriculture because of pasture lands and 3.5 thousand hectares of exhausted cropland were abandoned at the same time with the net final result of a decrease of pastures by 2.9 thousand hectares, a decrease of cropland by 0.6 thousand hectares, and the growth of desert by 3.5 thousand hectares.

The destruction of natural potential by various economic activities in the development of new territories should be added to the example discussed above. As S.V. Zonn [1986] mentioned, such disturbances are most common around new settlements, industrial and mining enterprises, along irrigation canals and other hydraulic constructions, roads and other communication lines.

The total area of Kalmykia is about 7.6 million hectares. According to the natural geographic regions shown in existing official atlases, it belongs totally to the zone of dry steppes and semi-deserts. However, at present, nearly 13% of its territory has been converted into true desert; this occurred within just the two last decades of unprecedented human impact on the area's natural ecosystems. The process is still continuing as the debates on how to stop it are going on as well.

1.3 THE CASE OF TURKMENIA

The territory of the Turkmenian Republic might be taken as another characteristic example. The largest land resources here are given to arid pastures, the majority of which have very low biological productivity not only because of adverse natural conditions, but largely because of many years of overgrazing without proper care for their rehabilitation. In 1981-1986, about 25.3 million Roubles were spent for pasture improvement in the Republic. Out of this sum, 72% of capital expenditures were allocated for the construction of watering points, mainly the tube wells, 5% for the mechanization of the water supply and 23% for the construction of sheep yards and other production facilities [Guseinov, Altaev, 1988]. It is remarkable that no single Rouble was spent for the improvement of pasture grass cover to increase its productivity and sustainability. At UNCOD, it was proved beyond any doubt that the watering points in arid rangelands without sufficient fodder supply are one of the key areas liable to desertification [United Nations, 1977]. Despite this, this conclusion based on the analysis of the world-wide experience, the Republic's authorities failed to take account of it.

According to the data of the Institute "Turkmengiprozem" [Guseinov, Altaev, 1988], the lands around 3.5 thousand wells are completely trampled and desertified in circles of a diameter of 1.5 to 2.0 km each as a result of overgrazing and fuel gathering for everyday needs by the herders. A simple calculation — 3500 x 3.14 x 0.812 — results in 889.2 thousand hectares, i.e. almost one million hectares. In addition, pastures are substantially damaged by the development of new oil and gas fields, various public works, the construction of roads and by the absence of roads that cause industrial traffic to cut new paths through the land. According to the data of the same institute, the total area of pasture recently desertified and in need of rehabilitation comprises about 2.7 million hectares. All this is taking place at a time when there is a pressing need to stabilize many million hectares of shifting sands inherited from the land abuse of the past, that threatens the surrounding territories that are still productive and broadens the deserts [Babaev, 1986].

The second problem of Turkmenia is soil salinization and land loss due to hydro-technical works and irrigation. Very large losses are connected with the construction of the Karakum Canal, along which many thousands of hectares of land have become water logged and saline. By 1978 when it was extended to 1069 km, the aerial survey showed water logging up to 50 km on both sides of the canal [Vinogradov, 1988], in 10.7 million hectares of waterlogged lands. How many became saline and transformed into salt desert or salt marsh is still to be estimated.

Viewed from the air the landscape around Ashkhabad manifests an abundance of large white spots of newly created (saline soils). The ground waters have risen here substantially because of the canal and, being strongly saline, have saturated the soil with salts given the high evaporation rate of the area's hot arid climate. The area of irrigated cropland in Eastern Karakums is 184.4 thousand hectares, of which only 140 thousand hectares have drainage facilities, 26.3 thousand hectares have become strongly saline and otherwise degraded, while only 4.5 thousand hectares are in a more or less satisfactory state. Almost 90 percent of all irrigated croplands in Turkmenia have been degraded because of secondary salinization [Pankova et al., 1986].

Consequently, because of intensive anthropogenic desertification, there is now a very serious situation in Turkmenia in respect of land resources which, with the present high rate of population growth, will create a very difficult socio-economic situation in the near future. In fact, rapid population growth is taking place in all the areas most seriously affected by desertification [FAO, 1988]. This phenomenon calls for urgent sociological research.

1.4 THE CASE OF THE ARAL SEA BASIN

It has been clearly established that unlimited and uncontrolled water uptake in the river catchments in arid lands is accompanied by land degradation and desertification in lower parts of the river basin [e.g. Minashina et al., 1981; El-Ashly, Gibbons, 1988]. This phenomenon is taking place in the Aral Sea Basin.

From the hydrological and geochemical points of view, the present situation in this case is very clear. In connection with the massive irrigation works and the extensive development of irrigated cotton cultivation, the natural function of the Aral Sea as a major water and salt sink of Middle Asia was anthropogenically eliminated [Kuznetsov, 1976; Kuznetsov, Gryaznova, 1987]. If, by the beginning of the 1960s, about half the water run-off of the southern mountains was flowing into the Aral Sea, the current surface flow into that body of water diminished to almost nothing because of the anthropogenic changes at the plains of the basin. In the Syradarya Basin, between 1971-1980 the removal of river waters by natural systems have decreased from 6.7 to 1.7 cubic km per year, while the technogenic withdrawals increased from 14.0 to 29.7 cubic km per year [Volftsun, Sumarokova, 1985]. The same phenomenon took place in the Amudarja Basin. The surface run-off losses have increased substantially because the free pore space under irrigated and surrounding lands has filled up, causing a massive regional rise of the groundwater table in large areas. The lands of old irrigation in the Hunger Steppe can be taken as an example: here groundwaters are now at a depth of only 2.8 m, that is the depth of the drainage action. About 7.6 cubic km of irrigation water was wasted in this underground saturation, it comprised 16% of the total water uptake during the entire period of irrigation development here [Rubinova, Getker, 1975]. There was a sharp rise in groundwaters in the deltaic area in connection with paddy cultivation, which resulted in the waterlogging of large areas in Kara-Kalpakia, accompanied by many adverse environmental problems, including health hazards.

At present, the water of Syradarya and Amudarja rivers is fully used in their respective basins, mainly for irrigation, and the discharge into the Aral Sea has practically stopped. According to the data of the Middle-Asia Institute of Irrigation, the total annual stock of water resources in the Aral Sea Basin is on average 126.7 km^3. Of this, 44.3 km^3 was used in 1940 for irrigating 3.5 million hectares; 54.1 km^3 in 1960 for irrigating 4.3 million hectares; and 108 km^3 in 1985 for irrigating 7 million hectares. In addition, in 1980, 6.2 km^3 was used for industrial, communal and other needs only in Uzbekistan. The Karakum Canal also takes 8 km^3 annually. At the same time, salty drainage waters are being discharged into the rivers. Within the last 25 years the water level in the sea dropped by 13 m; water salinity increased from 9 to 24-26 g/l; the area of aquatoria decreased by 30 to 35%; the volume of sea water decreased by more than half [Grigorjev, 1987; Kamalov, 1987; Khakimov, 1989]. The draining of the sea continues, the dry zone of the former sea bed has already reached nearly 2.1 million hectares [Grigorjev, 1987] or 2.4-2.5 million hectares [Chernenko, 1987, 1989]. The southern sea bed retreated from 60 to 80 km [Khakimov, 1989]. New sandy solonchak desert is forming on the drying sea bed and at its periphery; this area is currently estimated as 2.6 million hectares [Kamalov, 1987].

Substantial changes are taking place in the Amudarja and Syradarya deltas such as: drying-up of deltaic creeks and lakes, appearance of new water bodies because of discharged waters from irrigation systems, the disappearance of natural marshes, the depletion of cane growth and flood land forests, a sharp drop of ground water table (by 3 to 8 m), appearance of solonchaks and shifting sand dunes [Grigorjev, 1987]. The soil cover of deltaic areas is being substantially transformed towards aridization, salinization and desertification [Zhalbybekov, 1987]. Similar processes are described, by the way, in the deltas of the Ili River flowing into Balkhash Lake, where the aridisation of vegetation in lower delta and its shift to more haloplytic forms in upper delta were observed [Novikova, 1987; Diyarova, 1988]. It is important to note that these degradative processes of intensive anthropogenic desertification are developing in densely populated regions of intensive agriculture.

The desiccating territory around the Aral Sea has become a powerful source of dust-salt material, which is blown away and carried out by wind currents for many hundreds of kilometers. According to earlier studies, a dry belt of up to 50 km was formed by 1975 along the eastern coast of the sea, where large salt and dust aerosols were forming, having been blown out at up to 100 km at the beginning of the process and then expanding their boundaries by 2 to 3 times by 1985; the area of dust zone increased substantially as well [Kondratjev et al., 1985]. The annual outflow of dust varies from 15 to 75 million tons [Kondratjev et al., 1985]. The calculations showed that about one billion tons of salt dust had already blown away from the eastern part of former sea bed [Kamalov, 1987]. Detailed studies have revealed that only salt outflow [without terrigenic material and carbonates] comprises some 2286 t/km^2 as an average at present, and nearly 43 million tons per year from the whole dessicated territory [Rubanov, Bogdanova, 1987]. These salts are precipitating on the surrounding plains, harming the vegetation and salinizing the soils. Sandy massifs are moving to the south at a rate of about 1 km/year, forming at the dessicating sea bed.

The addition of new aerosolic component referred to above affected greatly all atmospheric processes [Kondratjev et al., 1987]. Due to a substantial change in the reflectivity of the drying land [albedo has increased by more than 7 times, and the value of reflected radiation by more than 3 times] the continentality of regional climate has become more continental. The climatic changes towards aridization have expanded up to 400 km affecting the area of nearly 50 million hectares. Consequently, there is a marked decline in the biological productivity of semi-desert pastures, which was low even without these new changes. Annual loss of pasture productivity in the region is assessed as 5 million tons [Kamalov, 1987], but this estimation seems to be too low if one considers the whole territory around the sea currently experiencing desertification.

At the same time, it is necessary to evaluate all adverse processes in the entire basin that are related to the development of irrigated agriculture here and are largely analogous to those described for Kalmykia: the development of the better pasture lands for irrigation; pushing the livestock into less productive pastures; the destruction and desertification of poor pastures and their transformation into sand desert; salinization of irrigated lands, their abandonment and transformation into salt desert; the compensation of land losses by the development of new massifs of better pastures for agriculture, and so on. This is not a closed circle, but rather a spiral, slowly and inevitably expanding under the given economic system. This process will probably be slowed down in connection with the government decision of September 1988 to stop new irrigation developments in Middle Asia [Chernenko , 1989], but will not be totally discontinued, as there are still large land losses due to secondary salinization, which have to be compensated somehow. So new agricultural lands will be developed on account of pastures even without general growth of irrigated cropland area.

It is worth mentioning here, that if some 21 million tons of salts per year had been discharged previously with surface run-off into the Aral Sea, these salts are now accumulating in the plains, particularly in the soils and newly formed ground waters of the region below the irrigation systems and along the canals, in numerous small and large water- and salt-sinks, the largest at present of which are Sarykmysh and Arnasay. According to the available data [Kirsta, 1988], the total annual input of salts to the plains of Turkmenia in the zone of the Karakum Canal is 9-10 million tons and will increase; this will lead to the progressive salinization of large territories if necessary preventive measures are not be undertaken for the removal of salts. It is obvious that such a major regional geochemical redistribution of salts will eventually lead to a deterioration in ecological conditions throughout the entire basin, to a marked growth of secondary salinization of the irrigated and surrounding lands, an example of which may be clearly seen in Kzyl-Orda massif. In short, there is in the Middle Asia, in addition to its water problems, a problem of cultivable land may soon appear in spite of the region's apparently large land reserves [Kuznetsov, Gryaznova, 1987].

The process of desertification in the Aral Basin, as A. Batyrov [1988] has mentioned, is triggered by not only the water deficit. The causes of the regional ecological crisis are numerous. It is predominatly due to the unsound strategy of the distribution of productive forces in the cotton-growing regions of Middle Asia and Southern Kazakhstan, which is directed at water-consuming activities, particularly to the monoculture of cotton. Moreover the hydro-technical systems being constructed are not well designed, which result in the discharge of harmful drainage into rivers, waterlogging and the salinization of irrigated lands.

Thus the anthropogenic desertification is spreading through entire Aral Basin primarily because of the extensive development of inefficient irrigation (the co-efficient of useful action of irrigation systems is only 0.5 to 0.6 as an average [Khamraev, 1988]) and without careful consideration of the regional water balance. It is very difficult to judge how and when this process can be stopped by the measures which are currently being planned, as there appeares to be a very complicated complex of ecological, demographic, social and economic problems that directly affect the dynamics of land resources. There is an obvious imbalance between the natural potential of the territory and the use of its natural resources — the first and the foremost cause of desertification.

1.5 STATUS OF DESERTIFICATION IN MIDDLE ASIA, USSR

The most complete inventory of the status of desertification in the Middle Asia region was conducted recently by the Institute of Deserts of the Turkmenian Academy of Sciences. These are the works of N.G. Kharin and his colleagues on the basis of the analyses of remote sensing data. According to these [Kharin, Kiriltseva, 1988], which cover the plains of Turkmenia, Uzbekistan and Southern Kazakhstan, desertification affects the following areas in different degrees [million hectares]:

Degradation of vegetation by overgrazing	66.4
Degradation of vegetation by undergrazing	0.4
Partial desertification around wells	10.2
Wind erosion	5.9
Salinization of irrigated lands	2.1
Technogenic desertification	11.6
Salinization caused by sea level drop and river training	9.5
Water erosion	1.2
Total desertified area	107.3

It is clear from the above that in the plains of Middle Asia and Southern Kazakhstan nearly 107 million hectares are currently affected by desertification in different degrees, comprising about 60% of the total area, while the remaining 40% is represented mainly by true deserts.

The examples of the status of desertification in the USSR described above, where only ten years ago everything seemed quite satisfactory, show conclusively that the main findings of UNCOD about the global expansion of anthropogenic desertification and its causes remain unchanged, as well as the conclusion of the Governing Council of UNEP that desertification is one of the most serious global ecological problems of our times.

1.6 STATUS OF DESERTIFICATION IN OTHER REGIONS OF THE WORLD

We have devoted much space to the USSR not because other parts of the world deserve less attention, but rather to show that: a) no country of the world, either developing or developed, small or large, has automatic insurance against desertification; b) the problem is global and by no means regional; c) the problem is growing, affecting more and more new areas; d) although there is a large quantity of information concerning desertification in other parts of the world, particularly for Africa, there has been little public discussion of the Middle-Asian Republics of the USSR, wich occupy a huge arid and semi-arid area; this created a false impression that the region was not affected by current land degradation processes taking place elsewhere.

Having established this point, we may now turn to other regions of the world, where these processes have continued and for which information continues to increase.

Without attempting to make a comprehensive survey of current publications on the status of desertification in different regions of the world, we believe that it is feasible to show just general trends on the basis of several fairly well documented examples, bearing in mind that systematic survey data are not available for any part of the world.

Africa

As might well be expected, the majority of publications are concerned with Africa where the situation continues to be most serious. More than 30% of all agricultural land in Africa suffers from desertification, particularly in arid semi-arid and sub-humid territories, to which about 60% of the area of the continent belongs [Gromyko, 1989].
According to other estimates, desertification affects nearly 55 percent of the total area of the continent [Grushevsky, 1989].

According to the earlier study by T.G. Boyadgiev [1984], which was conducted as a part of the FAO/UNEP Project on the Methodology for Desertification Assessment and Mapping, in which the Geographic Information System of FAO was used for modelling, the overall picture of desertification risk in Africa might be presented as follows:

	km^2	% of the total
Total Land	27,850,160	100.0
Zones with 1 to 180 days growing period prone to desertification	9,821,730	35.3
a) Areas subject to moderate, and very severe degrees of desertification risk	7,757,660	27.9
b) Areas with zero to slight degrees of desertification risk	2,064,070	7.4
Zones without growing period for the most part completely desertified, but with localized areas subject to desertification	4,211,700	15.1
Zones with more than 180 days growing period and zones with low temperature, potentially subject to land degradation	13,821,730	49.6

At UNCOD in 1977 the area affected by moderate, high and very high degrees of desertification was estimated as 10,376,634 km^2 or 34.2% of the total land area of the continent, while the area of the extreme desert was estimated as 6,177,956 km^2 or 20.4% of the total.

Thus, we see significant discrepancies in estimates produced in different years and by different authors; none of which was based on actual systematic surveys. The best experienced guess is that approximately one third of the total area of the continent is affected by desertification in different degrees and forms, but that is only a guess. Actual systematic assessment is needed, preferably based on the remote sensing data processed by computer techniques.

Some assessments were made recently in a number of African countries, but on the basis of different methodologies thus giving hardly comparable results. Nevertheless, these data provide certain general information concerning the status of desertification in different parts of the continent.

The latest surveys by the Ministry of Agriculture of Sudan have revealed that 1.6 million ha of irrigated lands (94.1%), 8.8 million ha of rainfed croplands (82.2%) and nearly 97 million ha of rangelands suffer from desertification in that country [Biswas et al, 1987]. Decrease of the intensity of desertification from north to south in Sudan induce permanent out migration of nomads in this direction. This involves a number of additional ecological, social and political problems [Moyhraby et al., 1987].

In northern and north-eastern regions of Nigeria approximately 12.5. million ha. is subject to ecological degradation, while 1.5-2.0 million ha. of agricultural land was put out of agricultural production due to land degradation [Morozov, 1989].

The process of deforestation continues to be one of the leading factors of desertification in Africa. According to the existing data for 1985 [Goncharov, 1989], each year 300 thousand ha of forests disappear, while the compensation of this loss by new forest plantations comprises only 10 thousand ha per year.

In Ethiopia the area of forests was reduced from 16% up to 3.1% within last 20 years; ecologically important forests were depleted in river valleys and at watersheds.

In Sudan, with 45 million m^3 of permissible annual forest cutting, about 75-77 million m^3 are worked out annually including 44 million m^3 for charcoal production and 1.7 million m^3 for expansion of agricultural land [Abu Sin, 1987].

The ratio between the area of annual forest plantation and the area of annual forest depletion in the Sudano-Sahelian zone is only 1:29 [Doyen, 1987]. As I.K. Rozina [1989] has noted, the problem of combating desertification in Africa is directly related to the problem of energy supply to rural areas, where the proportion of fuelwood in total energy consumption amounts to 58%, while the average for the developing countries it is only 20.6%.

The latest study in six countries of Southern Africa, sponsored by UNEP, has revealed a very high degree at the advancement of desertification [Darkoh, 1989]. A highly significant increase of desertification since 1977 was noted for Lesotho, while the increase for Botswana, Madagascar, Tanzania, Zambia and Zimbabwe was slightly lower. The present status of desertification is evaluated as very severe in Lesotho, severe in Botswana, Madagascar, Tanzania and Zimbabwe, and moderate in Zambia.

Unfortunately no assessment was made in Angola and Mozambique, where the situation appears to be serious if not catastrophic, although no relevant data for these countries are available.

Desertification in these Southern-African countries was assessed only qualitatively by various processes involved. According to this survey:

- severe and very severe deterioration of pastures occurs in Botswana, Lesotho and Zimbabwe, with significant and highly significant increases from 1977 in, respectively, Botswana, Lesotho, Madagascar, Tanzania and Zimbabwe;

- severe and very severe deterioration of agricultural land occurs in Botswana, Lesotho, Madagascar, Zambia and Zimbabwe with significant and very significant increases from 1977 in, respectively, Lesotho, Madagascar, Tanzania, Zambia and Zimbabwe;

- severe and very severe water erosion occurs in Lesotho, Madagascar and Tanzania, with significant and very significant increases from 1977 in, respectively, Lesotho, Madagascar, Tanzania, Zambia and Zimbabwe;

- severe and very severe sedimentation of dams and rivers occurs in Lesotho, Madagascar, Tanzania and Zimbabwe with significant and highly significant increases from 1977 in, respectively, Lesotho, Madagascar, Tanzania, Zambia and Zimbabwe;

- severe and very severe wind erosion occurs in Botswana, with significant and very significant increases from 1977 in, respectively, Botswana and Tanzania;

- severe and very severe sand dune encroachment occurs in Botswana, with very significant increase from 1977;

- severe and very severe depletion of forests and woodlands with significant and highly significant increases from 1977 occurs in all six countries surveyed.

Arab Centre for Semi-Arid and Drylands (ACSAD) REGION (of Arab countries of North Africa and South West Asia)

Very serious problems were reported from Mesopotamia, where 1.0 million ha. of irrigated land suffer from very severe salinization; 2.2 million ha. severe salinization, 2.3 million ha moderate salinization and 1.2 million ha. slight salinization, resulting in a total of 6.7 million ha. [Zaletaev, 1989]. In addition, some 3.1 million ha of irrigated land are threatened by salinization. About 0.7 million ha are desertified by wind action, and high degree of wind erosion is noted for additional 1.86 million ha. [Zaletaev, 1989].

There is no recent general assessment of desertification status for the region as a whole. Nor were systematic surveys of the problem conducted in any of the countries of the region.

However, a major effort was undertaken by ACSAD in contributing to the World Map of Human Induced Soil Degradation at an original scale of 1:7,500,000 within the UNEP/ISRIC Project on Global Assessment of Soil Degradation (GLASOD). The map was prepared on the basis of information received from the respective countries of the region (with the exception of Morocco, Mauritania, Somalia and Sudan which were covered by other regional participants of the project, but including Turkey), through detailed questionnaires. This information concerning soil degradation in arid and semi-arid areas of the region could be interpreted as related to the desertification in different forms of its manifestation.

According to the data collected and processed by ACSAD, the following situation occurs in various parts of the region [Ilaiwi, Osman, 1989].

Turkey is mostly affected by the processes of soil erosion. Severe loss of topsoil by water erosion occurs in about 20% of total area, caused by the deforestation of mountain areas. Slight to moderate waterlogging and slight salinization occurs in river valleys due to improper drainage conditions. Although the plains of the Marmara region and the highlands of Central Anatolia suffer only a little from water erosion, a slight to moderate loss of topsoil by wind action following to deforestation and overgrazing takes place in a limited area.

Southwest Asia, which includes Syria, Lebanon, Jordan and Iraq, is most seriously affected by the processes of land degradation. The Mesopotamian plains are probably the world's best known example of human induced soil salinization, which is increasing very rapidly. Large scale soil salinization in the area took place at the beginning of the second half of this century, when motorized water-pumps were introduced into the area, together with summer cash crops — particularly cotton. Recent salinization is caused here by the mismanagement of irrigation water, which raises the water table above the critical limit, as well as eventual salt accumulation due to evaporation. Wind erosion, while strongly affecting the entire area is a major climatic feature of the region, and is especially aggravated in the transitional zones. Mechanized rainfed agriculture in dry steppe lands is the first and most important reason for this, while overgrazing plays the second significant role. Apparently, if no serious measures are taken immediately, the best dry steppe areas will turn to real desert in few years time. Water erosion by gullying and loss of topsoil is taking place in mountainous and upland regions; deforestation, high rainfall intensity and steep slopes are the main reasons.

The Arabian Peninsula, which includes Saudi Arabia, North and South Yemen, Oman, United Arab Emirates, Qatar, Bahrain and Kuwait, is characterized for the major part by extreme aridity. Sand dunes occupy very large areas in Saudi Arabia and other States. Rock outcroppings are also abundant. Arable land is very limited. Wind erosion is largely natural here; with overgrazing, however, it becomes higher. A special form of land degradation occurs in areas where large-scale excavation of good soil for agricultural (e.g. home garden) or industrial (e.g. home construction) purposes has taken place. Deforestation and subsequent water erosion are evident in the south-western part of Saudi Arabia, in Northern and Southern Yemen, and in the eastern and western mountains of Oman, where an agricultural expansion has taken place during the last few years. The ground water used for irrigation is usually saline. No precise information concerning this salinization is available, but salts are observed in the soil of many irrigated farms. In the coastal area, the effect is doubled due to the intrusion of sea water, which has resulted from the lowering of the water table by pumping.

Egypt suffers largely from the salinization of irrigated lands. Severe rapid salinization is found in the northern lowlands of the Delta; it is moderate in the Nile Valley. The main cause is excessive irrigation, accompanied by the absence of efficient drainage systems. The problem is most serious in the oases due to the poor quality of pumped ground water and the difficulties of installing efficient drainage systems in natural depressions.

Libya experiences a moderate loss of topsoil from water erosion as a result of deforestation, which takes place in some parts within Jebel Al-Akhdar, east of Benghazi. Land degradation is found mainly in grazing areas, where a slight to moderate loss of topsoil by wind action is evident as a result of overgrazing. Slight slow salinization is observed in irrigated oases scattered throughout the desert.

Algeria and Tunisia suffer from loss of topsoil by wind erosion caused by rainfed agriculture in the dry steppe areas. Rapid and moderate (if not severe) soil salinization is taking place in all oases due to the introduction of motor pumps to replace the traditional methods of irrigation.

This recent information, not yet quantified spatially, is supplemented by certain data contained in the National Plans of Action to Combat Desertification prepared by the Governments of Syria, Tunisia, Jordan and Yemen Arab Republic with assistance of ACSAD, ESCWA, FAO, and UNEP.

The present status of desertification in these countries was not specifically assessed for these plans, but was estimated on the basis of available information.

Syria. As stated in the National Plan of Action to Combat Desertification for Syria of 1987, the flat central plains of the country, which represent about 50% of the total country's area of 18.5 million ha. are very dry and used mainly for seasonal grazing. The Euphrates and the Orontes rivers are shaping fertile valleys that have some agricultural problems, notably waterlogging in the Orontes valley and salinity and gypsum deposition in the Euphrates. About 4 million ha are cultivated each year, but, in spite of the law that forbids the cultivation of the dry steppe, some 218,000 ha (data for 1985) of the steppe are cultivated annually leading to severe soil degradation.

The main forms of desertification in Syria include:

- water erosion in mountainous ranges,
- wind erosion in the plains,
- salinization and/or waterlogging in the valleys due to over-irrigation and lack of adequate drainage,
- overgrazing in the dry steppe areas.

A significant amount of land has been abandoned because of its salinization and waterlogging in the Euphrates basin. A large area in the coastal plain and in the oasis of Damascus (Ghota) was transformed from agriculturally productive land to urban and industrial areas that could have been established elsewhere. An important part of the forest land in the north-west was destroyed for urban development or by fire or non-renewed industrial wood production. Frequent dust and sand storms have been recorded in the last few years that endanger the cultivated area in the Euphrates valley and, generally human health in Syria, in addition to disturbances on roads, rails and air traffic. In the central part of the badiat (the desert steppe) soils are severely degraded, particularly in the Sokhine, Kabajeb and Shaule regions.

The following generalizations concerning the situation in Syria might be drawn from the measures proposed by the National Plan of Action to Combat Desertification:

- for mountainous regions: soil conservation and erosion control, afforestation and forest conservation;
- for the agricultural plains of the Fertile Crescent: adequate land management, establishment of wind breaks;
- for the desert: management of range and land production, sand dune fixation;
- for marginal lands (sometimes cropped): water harvesting, establishment of green belts;
- for the River Valley: modification of water distribution system to control water losses, adequate drainage system, soil levelling, optimizing of irrigation regime;
- for the oases: conservation of the Ghota and Palmyra oases.

An important case study was recently conducted in the Anti-Lebanon Range north of Damascus under the guidance of Prof. Dr. Y. Barkoudah of the University of Damascus [Rahali, 1987]. The study was conducted by comparing the aerial photographs taken in 1940, 1958 and 1982 for the same area (c. 500,000 ha.) with a ground survey of the present situation. On the basis of this study some conclusions have been drawn as follows:

Changes in Land Use 1940 — 1982

	1940 %	1958 %	1982 %
Forest	24	14	12
Cereals cultivation	-	20	15
Fruit trees	-	10	7
Shrub land	-	20	30
Rocky shrub land	-	6	7
Bare skeletal land	-	4	9
Other lands	-	26	20
Total	-	100	100

This study established that the area of cultivation is not increasing and may be even decreasing but certainly permanently shifting to better lands leaving desert behind. The present progress of technology and mechanization of farming have led to the expansion of cultivation onto lands that were previously difficult to cultivate. Therefore desertification is progressing with the progress of technology without proper care for the natural resource base.

As noted by another study [Ilaiwi, 1988], "during the last years a dramatic acceleration of the degradation was realized with consequent increase in frequency, duration and severity of sand and dust storms in the eastern parts of the country. They affect not only the quality of life in the cities and villages of the Euphrates and Khabour rivers, but also plant production in cultivated areas and the steppe. Large areas in the steppe could be identified, where already the final steps towards desertification have been reached. Moving sand dunes cover houses, railway tracks and roads. Smaller sand dunes trapped by shrubs may be found in an area as large as one third of the steppe".

Jordan

The United Nations mission related to the National Plan of Action to Ccombat Desertification for Jordan visited the country in 1986 and reported that 99% of the total area of the country is subject to various degrees of different processes of desertification [ESCWA/UNEP/FAO, 1987].

The following changes in land use connected with desertification were reported by the mission on the basis of an analysis of figures from FAO Production Year Book 1976, 1983, 1984, 1985 for the Jordan (thousand ha):

	1961-1965	1980-1984	% change
Total area	9,774	9,774	-
Land area	9,718	9,718	-
Arable land	1,056	373	- 64.7
Permanent crops	121	38	- 68.6
Permanent pasture	100	100	-
Forest and woodland	125	40	- 68.0
Other land	8,316	9,167	+ 10.2

Yemen Arab Republic

A UNEP/ESCWA joint mission visited this country in November 1987. The mission findings agreed with the picture illustrated by General Assessment of Progress in 1984, i.e. that the situation in the YAR had deteriorated, particularly in the Tihama, Marib and Al-Jawf. According to the conclusion of the mission, "the overall implications of desertification for the YAR and for its agricultural resources potential in particular, are distressing. Crop yields are declining, rangelands and forests are constantly undergoing degradation, the good topsoil is being continuously removed from agricultural lands by erosion, soils and groundwater in many localities are becoming salinized, underground aquifers are being depleted and the destructive effect of shifting sand dunes on cultivated lands and on settlements is increasing. The projection of desertification trends into the future augurs for the worse".

According to the 1981 estimate [FAO 1981a], 97.9% of the total land surface of the Republic is affected by desertification, mostly by severe and very severe erosion (60% of the total area of the country), while 3.38 million ha of land are affected by salinization. Of the total area 92.8% is at high or very high risk of desertification, the remaining 7.2% being hyper-arid climatic desert.

Between 1970 and 1980, arable land decreased from 2.692 million ha to 2.440 million ha; the total amount of cultivated land, both rainfed and irrigated, dropped in 1984 to only 1.515 million ha. If these figures are correct, this means that the annual rate of the cultivated land loss between 1970 and 1980 was 17 thousand ha per year while between 1980 and 1984, it incresed to 185,000 ha. per year, thus becoming 10 times higher. Grazing intensity increased at the same time from 1.43 to 1.69 head/hectare to 2.87 head/hectare.

Tunisia

The National Plan of Action to Combat Desertification for Tunisia does not present new information concerning the status of desertification in this country but rather reiterates the data collected for UNCOD in 1976 by Floret et al., according to which the following was on record:

Slightly affected areas	18,200 km^2	17.2%
Moderately affected areas	42,200 km^2	39.7%
Strongly affected areas	12,500 km^2	11.7%
Extreme deserts	33,300 km^2	31.4%
the total area	**106,200 km^2**	**100.0%**

Other relevant observations:

The Government of Saudi Arabia, with the assistance of FAO, is now completing the preparation of a map at a scale of 1:2,000,000 that would show the desert conditions in the Kingdom based on information from the General Soil Map of the Kingdom at a scale of 1:250,000. This map will show the degree of severity of the various desert conditions, i.e. salinity, erosion by water and wind, rock denudation and their combinations as well. Therefore this map would provide all the necessary basic information for the assessment of the status of desertification in the Kingdom on a detailed scale.

Two project proposals related to the desertification assessment that will include Saudi Arabia, Syria, Iraq and Algeria are now being developed by ACSAD:

- Monitoring of the desertification processes for their early detection and assessment, including wind and water soil erosion, soil salinity risk, changes in biomass production with the long-term objective of qualitative and quantitative assessment of environmental change is in process. The technology envisaged for the assessment will be based on the use of remote sensing data;

- Monitoring of the processes of soil and vegetation deterioration or rehabilitation in the Syrian dry steppe is also contemplated, including the elaboration of conservation and improvement measures; this monitoring will also rely on the use of the satellite remote sensing data.

ACSAD is now seeking to strength its capability, in both hardware and software, to utilize these advanced technologies for desertification assessment and monitoring.

Another activity of ACSAD in respect of the assessment of the desertification status in the region concerns water problems. A number of different studies were conducted both at regional and national levels. The major effort has resulted in the publication of the Hydro-geological Map of Arab Countries and Adjacent Areas at a scale of 1:5,000,000 [ACSAD/UNESCO, 1988]. This map is complemented by much more detailed maps of water resources 1:1,000,000 which are currently being prepared and will be published as soon as the sheets are ready [ACSAD, 1984]. An assessment of the water situation in the region was also published in 1988 [ACSAD/UNESCO/IIHEE, 1988]. All these hydrological studies could contribute greatly to the general assessment of desertification status in the region. However, this has not yet been done for various reasons and must be done in the future, particularly with respect to changes in water quantity and quality. There is an ongoing project of ACSAD to monitor droughts and water resources in the region.

As an intergovernmental regional organization, ACSAD is engaged in many other activities related to desertification, particularly activities that place strong emphasis on research, training and exchange of information components of a general strategy to combat desertification. These activities, however, are beyond the scope of the present report.

East and South Asia

The situation reported from the eastern and southern parts of Asia is not much better than that of the ACSAD Region.

According to ESCAP data [1987], desertification in the Asian and Pacific Region affects nearly 70 million hectares of rainfed cropland and about 16 million hectares of irrigated cropland.

In this region, lie more than half of all the world's irrigated lands that suffer from waterlogging and salinization. In the Indus Valley the major problem is presented by growing alkalinization against the background of general salinization or even a decrease of salinity in some places. This is due to the adverse impact of sodium alkaline groundwater and irrigation waters on cultivated soils.

ESCAP recently published a regional review and assessment of desertification [ESCAP, 1987], which is result of the evaluation undertaken by the Intergovernmental Meeting on a Regional Network of Research and training Centres on Desertification Control held at ESCAP Headquarters in September 1986.

Although this review does not provide any new concrete information in addition to that published by H. Dregne in 1983 and collected by UNEP for the 1984 global assessment, there is an indication that the problem is very serious in the region and is now recognized as a major threat to both the environment and to the well-being of some 150 million people in the Asian and Pacific region. Mounting landuse pressures that contribute to desertification stem from rapid population growth, the subsistence struggle, income disparities and, at times, motives of short-term commercial gain. The review indicates that desertification is extensive in all the main types of land use, probably affecting more than 860 million ha. of productive land: 65% of rangelands, 50% of rainfed croplands, and 14% of irrigated lands. Generally speaking, these figures are very rough and unreliable, probably too low. A reliable new assessment is clearly indicated for the region as a whole, carried on the basis of surveys using existing quantitative methodologies, particularly remote sensing techniques.

In China, the territory affected by desertification was roughly estimated in assessments prior to 1984, carried out by the Institute of Desert Research, Academia Sinica, Lanzhou. According to the publications of this Institute [Zhu Zenda, Liu Shu, 1983; Zhu Zenda et al., 1986; Une Collection..., 1988], there are two categories of desertified lands in China; those that were desertified during millennia of land use, and those desertified during last few decades of intensive land use and which are affected by the ongoing processes of desertification. Unfortunately, these publications do not contain clear indications of the methodology used for such a distinction. However, the area affected is classified by these studies, in million hectares as follows:

Historically desertified lands	12.0
Recently desertified lands	5.0
Slightly (latent) desertified lands	15.8
Total area of lands affected by desertification	32.8

The studies contain a very interesting classification of the severity of desertification. Four classes of the degree or intensity of desertification are distinguished on the basis of two criteria:

	Percentage of area occupied by shifting sands	Percentage of growth of the area of shifting sands from a fixed time
1. Latent desertified lands	<5	<5
2. Ongoing desertified lands	6-25	6-20
3. Severe desertified lands	26-50	21-40
4. Most severely desertified lands	>5	>40

The above area of 32.8 million ha constitutes 3.4 percent of the total area of the country, or 24.7 percent of the area of the Chinese deserts. According to these estimates, almost one quarter of all the deserts of China are the man-made deserts. The process is continuing and the area of the deserts is expanding.

Recently published data of a survey in China show that within the last 15 years, the area of desertified lands has increased by 3 million hectares, with an average annual increment of 200,000 hectares,

and that a still larger area is affected by present day desertification [Zhao Quiguo, Li Qingkui, 1988]. Quoting *The Beijing Review*, the Moscow newspaper Pravda of 22 June 1987 informed its readers that the present area of deserts in China is about 130 million ha. and that almost whole of this territory was actively cultivated in ancient times. It is expected that if the present process of desertification is not arrested, more than 7 million more hectares will be converted into desert by the end of this century.

Central and South America

The high rates of land loss due to desertification were earlier reported from this region as up to 100-200 thousand ha. per year in Mexico alone [Medellin-Leal, 1978]. A seminar on desertification in Brazil has reiterated the estimation of the area affected by strong desertification as 2 million km^2; this estimation was done for UNCOD in 1977 [Ministerio..., 1984]. Apparently massive soil erosion is progressing in the region and is the major physical process leading to and resulting from desertification. However, no new systematic data on desertification assessment have yet appeared.

1.7 GLOBAL ASSESSMENTS

In respect of the global assessment of the status of desertification, the existing estimations are approximate and not very reliable because of a variety of factors, among them, the diversity of methodological approaches of different authors and the absence of unity in evaluating of the diagnostic criteria of desertification. It is not always easy to distinguish facts from emotions or estimates from impressions, while the quantitative data are very scarce at the global level. Even the area of deserts is estimated very roughly by the geographers, the appropriate figures varying from 3.1 to 5.8 billion hectares as indicated in the Introduction to this paper. Therefore one would expect a certain diversity in spatial assessments of this phenomenon, which is very difficult to quantify.

The first quantitative spatial assessments of desertification were made on the basis of the UNCOD materials (see Table 3). However, later on, these results were reconsidered by different authors. If, in 1978 the total area affected by desertification was estimated at 3.8 billion hectares [Mabbutt, 1978], five years later the figure was increased to 4.7 billion hectares [Dregne, 1983], the increase is being attributed to the inclusion of the areas of true hyper-arid deserts into the total area by H. Dregne, which were excluded by J. Mabbutt.

Table 3 Territories Affected by Desertification [Mabbutt, 1978]

	Arid Zone		Semi-arid Zone		Sub-humid zone		Total Area
Degree of the risk of desertification	million km^2	% of the zone	million km^2	% of the zone	million km^2	% of the zone	million km^2
Very severe	1.1	6.4	2.2	12.1	0.2	1.2	3.5
Severe	13.4	77.3	4.4	13.6	0.6	4.3	16.4
Moderate	2.1	12.1	12.5	69.4	3.2	23.3	17.8
Total	16.6	95.8	17.1	95.1	4.0	28.8	37.7

It is feasible to separate the present processes of desertification of arid lands, which is now increasing at a certain rate, and their desertified state as a result of past natural or anthropogenic processes which led historically to the formation of present day deserts or semi-deserts that were formerly productive steppe, savanna or wooded land.

Such an approach was used by H.E. Dregne [1983, 1986]. According to his studies, the territories undergoing slight desertification are the most common in the world as Table 4 indicates. This category of landscapes includes true deserts, where current anthropogenic processes have only a slight impact on biological productivity and soils, as these areas were already completely desertified in the past by the joint action of natural [climatic] and anthropogenic processes.

As to the extent of desertification in different regions, Dregne's figures show significant diversity. Severe desertification affects nearly 30% of the arid territories in Spain, 27% of those in North America, 22% of those in South America, 20% of those in Asia, 18% of those in Africa, and 8% of those in Australia. The share of moderately desertified land varies from 11% in Africa to 70% in Spain.

Table 4 Present Desertification in Arid Territories of the World [Dregne, 1986]

Degree of Desertification	Area, million hectares	Percent of the Total Area of Arid Territories
Slight	2,452	52.1
Moderate	1,377	29.3
Severe	870	18.5
Very Severe	7	0.1
Total	**4,706 *)**	**100.0**

*) Total area of arid territories of the world, including pasture, forest, cultivated and other lands, including true deserts.

Pasture lands are those most affected by the desertification: up to 80% of all the arid pasture lands of the world are moderately affected by desertification, but in a number of the cases, severely and very severely. For example, in both South and North Americas, about 610 million ha of pasture lands or (84% of their total area of 729 million ha.) are affected by soil degradation processes; more than 70% of pasture lands of Australia suffer from various kinds of anthropogenic soil erosion; and all pasture lands of Africa are affected by desertification.

The impact of anthropogenic desertification on the ecosystems of arid territories is particularly strong in the Western part of the Sahelian zone of Africa (Burkina Faso, Chad, Gambia, Mali, Mauritania, Niger and Senegal) [World Bank, 1985]; It is most extensively manifest in the territories with annual rainfall from 200 to 500 mm.

According to H. Dregne's estimation, the following proportion of lands put to different uses is affected by desertification from a moderate to a very high degree : 21% of irrigated lands, 77% of rainfed cropping lands, and 82% of pasture lands.

H.E. Dregne [1986] has used the following criteria for recognizing the degrees of desertification:

Slight	State of vegetation from perfect to good	Erosion is absent or negligible	Salinization of irrigated lands is absent	Decrease of yields by less than 10% annually
Moderate	State of vegetation is satisfactory	Moderate wash- out, small gullies, separate hummocks	Salinization of irrigated land is moderate	Decrease of yields by 10-15% annually
Severe	State of vegetation is bad	Strong sheet wash-out, many gullies, sometimes blown-out soils	Salinization of irrigated land is strong	Decrease of yields by 50-90% annually
Very severe	Vegetation is mainly absent	Spots with blown-out soil, many deep gullies	Thick salt crust on almost impermeable soil of formerly irrigated lands	Decrease of yields by more than 90% annually

Table 5 Soil degradation under desertification of agricultural lands in arid territories of the world, million ha [Rozanov et al., 1989]

Forms and degrees of soil degradation	Rainfed cropping lands	Irrigated lands	Pasture lands	Total
Slight wind erosion	66.4	-	536	602.4
Moderate wind erosion	43.0	-	340	383.0
Strong wind erosion	25.2	-	306	331.2
Subtotal	134.6	-	1,182	1,316.6
Slight water erosion	60.2	34.2	157	251.4
Moderate water erosion	44.2		114	158.2
Strong water erosion	48.8		109	157.8
Subtotal	153.2	34.2	380	567.4
Slight salinization	-	47.6	-	47.6
Moderate salinization	-	40.4	-	40.4
Strong salinization	-	17.4	-	17.4
Subtotal	-	105.4	-	105.4
TOTAL	**287.8**	**139.6**	**1,562**	**1989.4**

According to more recent estimates (Rozanov et al., 1989), the following areas in arid territories, excluding true deserts, are affected by desertification (see Table 5):

Irrigated lands	140 million ha or 63%,
Rainfed croplands	288 million ha or 62%,
Pasture lands	1562 million ha or 96%,
Total	**1990 million ha or 86%**

The main forms of soil degradation under desertification in arid territories are due to wind and water erosion of pasture and rainfed croplands and the salinization of irrigated lands. Similarly rainfed agricultural lands are destroyed almost to the same extent by wind and water erosion. Irrigated lands, however, largely suffer from secondary salinization and only to a small extent from water erosion, while wind erosion is the most disastrous factor for the pasture lands.

1.8 CONCLUDING COMMENTS

To conclude this part, it follows that there is no doubt that the anthropogenic desertification of the arid territories of the world is currently one of the most dangerous global environmental threats, because of consequences for the main resource base for the human development now and in the future. It is caused not only by the immediate economic activities of human beings in the desert prone lands, but is also intensified by climate changes that will result in both global warming and aridization, which are also caused by human action-world wide.

Therefore, combating increasing desertification is the immediate task of the entire human race, delay may well exact a price that we will be unable to pay afterwards. As indicated by Y. G. Mashbits [1988], anthropogenic desertification became an important part of the first priority global programme of natural resources utilization and the fight against socio-economic underdevelopment in many countries of the world, which is inseparable from arresting the advancement of desert-like conditions and implementing realistic and effective measures for combating desertification.

The above short review of the available latest information concerning the present status of desertification in the world shows without any doubt that:

- The process is still active and progressing in all arid territories of the world, and is intensified particularly by the implementation of large-scale development programmes and technologies that do not incorporate components for the protection of the environment and the rational use of natural resources;

- UNEP is fully justified in its struggle against desertification as a first priority environmental issue that should receive the full moral, technical and financial support of the international community.

PART 2. METHODOLOGIES USED FOR DESERTIFICATION ASSESSMENT

2.1 METHODOLOGICAL BACKGROUND CUM DEFINITION OF DESERTIFICATION

The definition of desertification that was adopted by the UNCOD [United Nations, 1977, 1978] remains valid and is widely used throughout the official documentation as well as in current general or scientific publications. However, several modifications or alternative definitions were later developed (e.g. Dregne, 1978, 1983, 1986; Rozanov, 1981, 1982, 1986; Sabadell, 1982; World Bank, 1985, etc.) with a view to determining the most precise. The original UNCOD definition appeared useful for general purposes of understanding the problem, its scope and extent at the global level. This definition, in all its modifications, was also appropriate for attracting the attention of the international community and the Governments and international organizations concerned about the very serious ecological and socio-economic consequences

of this widespread process of natural resource degradation and loss through human-induced abuse of the arid lands.

In spite of all the differences among current definitions, it is generally recognized that desertification is a marked decline or total loss of the potential ability of the ecosystems in arid territories to sustain the biological productivity of land. This decline was attributed mainly to the diminution of the ability of the geosystems to supply the natural or cultivated vegetation of arid territories with sufficient water for normal growth and productivity under these ecological conditions.

However, for the practical purposes of desertification assessment, mapping, monitoring and counter-measures, particularly at the local level, none of these definitions appear to be sufficiently operative, they lack the quantitative aspect, on the one hand, and, on the other, an unequivocal indication of what is to be assessed, mapped, monitored and fought. This lack of operability has led to differences in the methodologies used by different scientists and national and international institutions concerned with desertification assessment in different parts of the world, as well as at different times.

The following list of currently used or proposed definitions of desertification, which is based mainly on recent review of the subject by Prof. R.S. Odingo (1989) and by the staff employed for the Kenya Pilot Study [Government of Kenya, UNEP, 1989], which, however, is probably incomplete is very instructive and provides a fair picture of the state of art that has eventually resulted in the diversification of methodologies for desertification assessment and mapping and ultimately in the present uncertain situation.

According to various authorities, **desertification is defined as:**

1. **Rapp, Le Houerou, Lundholm, 1976:** *The spread of desert-like conditions in arid or semi-arid lands. Desertification or the degradation of arid and semi-arid ecosystems is a step-by-step decomposition of the plant and animal communities.*

2. **United Nations Conference On Desertification, 1977:** *The diminution or destruction of the biological potential of the land that can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems and has diminished or destroyed the biological potential, i.e. the plant and animal production, for multiple use purposes at a time when increased productivity is needed to support growing populations in quest of development.*

3. **Dregne, 1977:** *The impoverishment of arid, semi-arid and sub-humid ecosystems by the combined impact of man's activities and drought. It is the process of change in these ecosystems that can be measured by reduced productivity of desirable plants, alteration in the biomass and the diversity of the micro- and macro- fauna and flora, accelerated soil degradation, and increased hazards of human occupancy.*

4. **Kharin, et al. 1984:** *A complex of physiographical (natural) and anthropogenic processes, causing the destruction of arid, semi-arid and sub-humid ecosystems and the degradation of all forms of organic life, which, in turn, results in the diminished natural-economic potential of these territories.*

5. **Rozanov, 1981:** *A natural or man-induced process of irreversible changes of soil and vegetation of dryland in the direction of aridization and diminution of biological productivity, which in extreme cases, may lead to total destruction of biological potential and conversion of land into desert.*

6. **Sabadell et al, 1982:** *The sustained decline and/or destruction of biological productivity of arid and semi-arid lands caused by man-made stresses, sometimes in conjunction with extreme natural events. Such stresses, if continued or unchecked, may lead to ecological degradation and ultimately to desert-like conditions.*

7. **FAO/UNEP, 1984:** *A comprehensive expression of economic and social processes as well as those natural or induced ones which destroy the equilibrium of soil, vegetation, air and water, in the areas subject to edaphic and/or climatic aridity. Continued deterioration leads to a decrease in, or*

destruction of the biological potential of the land, deterioration of living conditions and an increase of desert landscape.

8. **Dregne, 1983:** *The impoverishment of terrestrial ecosystems under the impact of man, it is the process of deterioration in these ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro- and macro-fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy.*

9. **Kassas, 1988:** *A process of ecological degradation by which economically bio-productive land becomes less productive. In extreme instances the final scene is a desert-like landscape incapable of sustaining communities that once depended on it.*

10. **Warren, Agnew, 1988:** *The notion that the extent of deserts —dry areas with few plants —is increasing, usually into the semi-arid lands.*

11. **World Bank, 1988:** *A process of sustained land (soil and vegetation) degradation in arid, semi-arid and dry sub-humid areas, caused at least partly by man. It reduces productive potential to an extent which can neither be readily reversed by removing the cause nor easily reclaimed without substantial investment.*

12. **World Resources Institute, 1989:** *The deterioration of soil, severely reduced productivity of desirable plants and declining diversity of flora and fauna because of the activities of both people and livestock.*

13. **Government of Kenya, UNEP, 1989:** *A complex of natural and mainly man-induced land degradation processes which lead to the decline of biological productivity of arid, semi-arid and sub-humid lands and in turn, results in the diminished natural and economic potential of these lands.*

Thus, due to a certain diversity in desertification definitions and corresponding methodologies for its assessment, the global picture has become rather vague and much disputed. Certain controversial results of the assessment have appeared in various official documents and publications. As indicated earlier, in some scientific, political and management circles it is thought that the situation with desertification have been exagerated at UNCOD and in other international forums; that the problem is not global, but rather regional or local; that it is only an African problem; that it does not exist as such, etc. By contrast, some observers have expressed the view that the main forms of desertification (sand dune encroachment, deterioration of rangelands, forest depletion, deterioration of irrigation systems, deterioration of rainfed agriculture (Hendry, 1986), are not specific to the desertification process, but occur in any geographical zone of the world under the impact of inappropriate human activities.

In addition to the variety of opinions, some of the assessors were unable to detect any consistent trend in changes [e.g. Olsson, 1985; Tucker, Justice, 1986; Dregne, Tucker, 1988]. L. Olsson [1985], in his integrated study of desertification in semi-arid areas of Sudan by remote sensing, GIS and spatial models, has observed that "it has not been possible to find a consistent trend of a degrading landscape. The conditions vary with the climate condition. An area with appropriate land-use in a year with adequate rainfall may suffer from crop failure and show signs of over-exploitation another year". To counter this assertion, we need only mention that nobody assesses desertification by a one-year crop failure, which can occur anywhere due to regular droughts.

Whatever opinions may exist, there is a solid fact of growing desert that was substantiated by the most recent data in Part 1 of this report. The point that the main forms of desertification are non-specific is hardly relevant. As soon as land degradation does occur within an arid territory, it will always eventually lead to desert-like conditions or to true desert.

The root problem is that there is no precise definition of what desert is. We cannot blame the geographers for not being able to define clearly the term desert, as this term historically was so loosely applied to so many different ecosystems, e.g. absolutely lifeless internal parts of the Sahara or very green

Arizona (in spring) with plenty of cacti and mesquite bush, shifting barkhan sands of Karakums or savanna-like Kalahari forms with abundant acacias. Thus, we are forced to be vague about deserts or desertification at the global level, as no clear-cut boundaries exist in the natural landscapes. But we cannot remain vague when dealing with concrete local problems at the farm level. This dilemma must to be solved and can be solved if properly considered on the basis of the available knowledge.

In spite of all the above difficulties, we are able to identify certain indicators of desertification or the intensification of desert-like conditions and to quantify them for the purpose of the assessment.

According to M.K. Tolba [1989], the desertification is characterized by the following indicative processes:

> *"impoverishment and reduction of vegetation cover, involving an initial loss of biological productivity and exposing the soil surface to accelerated water and wind erosion, leading to reduction in soil organic matter and nutrient content and to a deterioration of soil structure and soil hydrological properties, with crusting and compaction causing further loss in fertility and possibly leading to salinization or alkalinization or to the accumulation of other substances toxic to plants or animals. These processes are commonly linked with deterioration in the dependent human livelihood systems, including adverse changes in the productivity of irrigated and rainfed agriculture and livestock industries, over-exploitation and diminution of natural resources including water and woody vegetation, decline and abandonment of settlements, deterioration in nutritional and health standards, and in social services, and socio-economic stress including enforced migration and social and political strife".*

From this general list of characteristics, some measurable parameters can certainly be selected and classified.

No unity in defining or assessing desertification on a global scale can be expected unless some kind of compromise can be found on how to proceed in these matters. While accepting the possibility of a variety of approaches at the local level, we shall be able to expect some positive results in assessing the actual situation correctly only in developing some definite international methodology that would be adopted and strictly followed throughout the world.

2.2 THE METHODOLOGY DEVELOPMENT AT A GLOBAL LEVEL

The first attempts to assess desertification quantitatively and to show the areas affected on the global map were undertaken in 1976-1977 at the request of the Secretariat of the UNCOD. Within a year a number of maps were produced for presentation at the Conference.

A *World Map of Desertification* was jointly compiled by the UN organizations concerned at a scale of 1:25,000,000 [FAO/UNESCO/WMO, 1977]. Actually, the map delineated arid territories of the world by different degrees of aridity according to the climatic indexes, and the inherent risk of desertification, but not its real status. This map was supplemented by a series of experimental maps produced by independent scientists at the same scale, showing the status of desertification (H. Dregne), climate aridity indexes (D. Henning and M.F. Phlohn) and the world scheme of aridity and drought probability (V. Kovda and B. Rozanov) [UNCOD, 1977].

At the same time, FAO produced an experimental map of desertification for North Africa and South-West Asia showing the desertification hazard and risk on the basis of interpretation of the data taken from the World Soil Map at a scale of 1:5,000,000. This map was demonstrated at the Conference, but never published for general use.

After the Conference, in response to the recommendation of UNCOD, UNEP undertook, jointly with FAO, to develop a methodology for assessing and mapping of desertification. In considering the urgent need for action, UNCOD recommended the preparation of detailed maps at the national and regional levels with emphasis on assessment at the country level and the production of maps of immediate use to the countries concerned.

This work began in 1979 as a part of implementation of the Plan of Action to Combat Desertification. The main technical responsibility was given to FAO which carried out this undertaking step by step through several approximations under the guidance of periodic expert consultations. The results of this work were periodically published as technical reports [FAO/UNEP/UNESCO, 1979; FAO, 1980, 1981, 1982]. After the first consultations in 1980 and 1981, the draft provisional methodology was transmitted to the participating agencies, countries and national institutions for field tests and the production of experimental maps at various scales at farm, district/province and country/region levels. The methodology was tested in Australia, Burkina Faso, Mexico, Pakistan, Sudan, Syria, Tunisia, USA (Texas) and the USSR (Turkmenia). In addition, a limited pilot study was undertaken on the use of remote sensing data in digital format in the Hodna region in North-Central Algeria. An evaluation of the tests of the draft methodology was carried out at the third expert consultation. The conclusions and recommendations of this consultation formed the basis for the final documents that were published in 1984 by FAO/UNEP as *Provisional Methodology for Assessment and Mapping of Desertification* and *Map of Desertification Hazards and Explanatory Note* (this "map" actually represented a series of component analysis maps for Africa at a scale of 1:25,000,000 with some methodological notes on their preparation).

The Provisional Methodology published in 1984 in its final version was based on the consideration of natural and human induced processes leading to desertification, the following of which were selected for practical purposes:

i. degradation of vegetative cover,

ii. water erosion,

iii. wind erosion,

iv. salinization,

v. soil crusting and compaction,

vi. reduction in soil organic matter,

vii. accumulation of substances toxic to plants or animals.

Given the fact that the above criteria could be quantified , it was proposed to consider the following aspects of desertification to be shown on the maps:

- the Status of Desertification: the state or conditions existing in a particular land area at the time of observation, compared to conditions which existed in the past;
- the Rate of Desertification: the changes that have occurred per unit of time;
- the Inherent Risk of Desertification: the vulnerability of the landscape to desertification processes;
- the Hazard of Desertification: the evaluation of the conditions considering the status, rate and inherited risk of desertification by dominant determinative processes, including human and animal pressures on the environment.

An evaluation of the effects of desertification processes was then proposed to combine and codify the information in classes to denote the severity of the assessment factors by processes and by aspects: slight, moderate, severe, and very severe. The desert, as the ultimate stage of desertification, was taken as the final reference point.

Characterizing the Provisional Methodology as a whole, its authors rightly stated that "evaluation of desertification effects is difficult, mainly because of the lack of sufficient data to assess the amount of land degradation that has occurred. Heavy reliance has to be placed on the observations and evaluations of experienced persons and on extrapolations of data collected on small areas to larger areas. Mathematical and conceptual models, such as the Universal Soil Loss Equation for water erosion, can be highly useful tools to construct desertification estimates. Models, however, must be tested against experimental data. The absence of a large source of reliable data imposes a serious limitation on the verification of the validity of land degradation models. Consequently, they must be used with caution" [FAO, 1984].

This observation provides the probable explanation as to why this Provisional Methodology was never implemented in its original form and full volume. Presumably, no organization could undertake so huge an amount of costly work to obtain so unreliable an end product, at least at the global, regional or country levels.

As far as the author of the present report knows, neither UNEP nor FAO attempted to proceed further on a global scale after 1984. Similarly, to the author's knowledge there were no attempts anywhere in the world to adopt this Provisional Methodology in its original form and to use it for actual assessment and mapping of desertification.

However, the effort and funding did serve a number of purposes. Certain elements of the Provisional Methodology were later utilized for developing national or regional approaches, e.g. by N.G. Kharin in the USSR, by the Government of Kenya and UNEP for the Kenya Pilot Study of Baringo and Marsabit districts and by M.B.K. Darkoh in the UNEP-sponsored study in Southern Africa, or for use in other activities, e.g. by ISRIC in the world soil degradation assessment (GLASOD).

The main objective of the Kenya Pilot Study was "to review the FAO/UNEP (1984) methodology in the assessment and mapping of desertification and to provide recommendations that would assist in its application at local, national and regional levels" as well as "to develop a cost-effective standardized method for the assessment and mapping of desertification through a simplified methodology that could be used, with appropriate modifications, by any country affected by desertification".

The initial evaluation of the Provisional Methodology by the Study Project showed that "most of the indicators and methods proposed could only be used in assessment and mapping of desertification at a local and pilot level. It would be very expensive and time consuming to use most of the proposed indicators and methods at the regional or national level." The major criticism was that the application of the proposed methodology was impractical. The lack of sufficient data was a major handicap and the cost of acquiring such data could be very high. Consequently, it was decided that a simpler, more refined methodology should be developed and tested in a pilot study project in Kenya.

The detailed data for the selected areas on climate, landforms, soil, vegetation, animal numbers, and human populations, were collected for the selected desertification indicators using available statistical information, remote sensing techniques and field surveys. The data were then evaluated for use at the local level and utilized in a GIS to develop generalized models that could be used for the assessment. Five models were developed: water erosion, wind erosion, range carrying capacity, vegetation degradation, and human population.

For the purposes of this assessment the aspects of desertification (risk, status, rate and hazard) proposed in the Provisional Methodology were found adequate and have been adopted with slight modifications. The ratings of the four aspects of desertification were expanded from four to five points: none, slight, moderate, severe, very severe. However, in some cases it was found practical to use only a two or three point rating.

Many interesting approaches were developed in this study for utilizing different methods for determining of various parameters of desertification. Five model maps were produced, showing the status of water erosion, wind erosion, vegetation degradation, range carrying capacity and human population density (dwellings per km^2). A final desertification hazard map was generated by overlaying the results of the above analysis and summing up the individual status scores.

The results of the study showed that in the Baringo area within 32 years, 11% of the area was improved, 14% of the area became degraded, 70% remained the same; and 5% of the area was under cultivation. Generally in Marsabit no significant degradation occurred during the 16 years except for Logologo and a little for Illaut.

Another attempt to develop the methodology was undertaken by the UNEP in co-operation with the Government of France on the basis of comparing aerial photographs taken in 1950 with the SPOT 1987 imagies for a transect from 10°50' to 15°40'N from the northern boundary of Guinea through Mali and Mauritania in West Africa. The comparison was made with the assistance of ground checks in selected areas along the transect. The first results of testing the new methodology were recently reported [PNUE/Ministere des Affaires Etrangeres, France/Ministere de la Cooperation Francaise, 1989].

It is too early to draw definitive conclusions concerning the validity and the merit of new methodologies developed in Kenya and in the latter project. However, their comparative analysis should be undertaken as soon as possible by an expert. Due to time constraints, it was impossible to do this within the present report.

In his attempt to assess the desertification status in six countries of southern Africa, which was sponsored by UNEP, M.B.K. Darkoh [1989] has distinguished the following processes indicative of desertification:

i. deterioration of pasture;
ii. deterioration of soil fertility in agricultural land;
iii. erosion by water;
iv. erosion by wind;
v. sand encroachment, sand dune invasion;
vi. sedimentation of dams and rivers;
vii. waterlogging and/or salinization;
viii. depletion of forest/woodland.

For the degrees of desertification, the following criteria were developed :

Very severe: reduction of land to completely unproductive status as represented by moving sand dunes, widespread large gully systems, or salt-crusted, virtually impervious soils in previously irrigated areas;

Severe and Moderate: different degrees of change to less desirable vegetation, the extent of accelerated soil erosion and denudation, or loss of crop yield through reversible salinization of irrigated soils;

Slight: little or no degradation of the plant cover or soil has occurred.

The whole assessment process was done by questionnaires in a purely qualitative manner.

The second main reason for failure to utilize in full the Provisional Methodology was probably that, while it provided a good tool for analysing the individual processes involved into desertification, it still gave little idea of how to measure desertification as such and how to show it on the map as a complex phenomenon with all its attributes and degrees and rates of advancement. This certainly reflects the above described difficulties involved in defining desertification.

Partly because of this and because of shortage of funds and other pressing needs, as well the agencies concerned have engaged themselves in a series of other activities that try to approach the problem from other angles.

The FAO, supported by UNEP, was and is particularly active in this respect. In keeping with its mandate to develop food and agriculture and to promote rural development, FAO is involved in implementing programmes and projects to improve agriculture in dry desert-prone regions which are especially vulnerable to droughts and food shortages. FAO activities in promoting better resource management in arid and semi-arid areas include the development of land, water, rangeland and livestock resources, arid-land forestry, and drought control. Within the framework of the Plan of Action to Combat Desertification, FAO has made a significant contribution to executing the recommendations of UNCOD [FAO, 1986].

The major FAO policy in this respect is aimed at integrating environmental issues into the agricultural and rural development processes. FAO therefore makes efforts to consolidate and expand further programmes promoting environmentally sustainable development [FAO, 1988]. This policy is fully consonant with the recommendations of the World Commission on the Environment and Development, which were made published in its report *Our Common Future* [WCED, 1987]. This policy of FAO is particularly relevant for the areas affected or likely to be affected by desertification, that is, for the arid and semi-arid territories of the world.

As to methodology, in addition to the development of the Provisional Methodology for desertification assessment and mapping, FAO has been engaged in several major activities.

The first is the development of a methodology for soil degradation assessment, based on existing data and on the interpretation of environmental factors influencing the extent and intensity of soil degradation (such as climate, topography, vegetation, soil characteristics, soil management and land use). Within the joint FAO/UNEP/UNESCO project, the Soil Degradation Map of Africa North of the Equator and the Near and Middle East was prepared showing present and potential soil degradation. First, the methodology was published [FAO/UNEP/UNESCO, 1979], then used in a series of two maps, each consisting of three sheets at a scale of 1:5,000,000 : the Provisional Map of Soil Degradation Risks and the Provisional Map of Present Soil Degradation Rate and Present State of Soil [FAO/UNEP/UNESCO, 1980].

The second methodological approach was developed by FAO within its project on Agro-Ecological Zones, which has covered in full only the developing countries of the world [FAO, 1978, 1980, 1981], The purpose of this methodology is assessing the potential agricultural use of the world's land resources.

The overall methodology of the assessment comprises the following activities:

i. Review and refinement of the proposals of the evaluation in conjunction with identification of the basic data and assumptions to be used;

ii. Selection of alternative land uses (crops, level of inputs, etc.) for consideration;

iii. Determination of climatic and soil requirements of the selected alternative land uses;

iv. Compilation of inventory of the land (climate and soil) and mapping units (agro-ecological zones) with particular respect to (iii);

v. Matching of the requirements (iii) with the land inventory (iv) and calculation of anticipated production potential in the different agro-ecological zones recognized;

vi. Estimation of production costs, and identification of the various suitability classes to be employed and their differentiating parameters;

vii. Classification of the land into various suitability classes for the selected alternative land uses, and presentation of results.

The basic intent of this methodology was to draw, from the existing information an initial approximation of the present and potential use of the world's land resources and thereby provide the physical data base necessary for planning future agricultural developments.

The third methodological approach was developed by FAO, in collaboration with UNFPA and IIASA, within the study on the potential population-supporting capacities of lands in the developing countries [FAO/UNFPA, 1980; FAO/UNFPA/IIASA, 1982]. Data on soils and climates from 117 developing countries were collected and compared with the growth requirements of 15 major crops, as well as and grassland pasture to assess potential food production and the number of people this could support. The world map at a scale of 1:10,000,000 was produced showing the main ecological zones with the potential land carrying capacity in terms of possible rate of persons per one hectare of the land.

The methodology applied in this study was elaborated further and detailed in the Assessment of Population Supporting Capacity for Development Planning in Kenya [FAO/IIASA, 1989]. The data base of this study related to information on soils, climate, vegetation, population, livestock, etc. is stored within the GIS of FAO and is available for the interpretation in respect of desertification. However, such an interpretation was never made, as it was not specifically envisaged by the parties concerned.

Similar studies were conducted for several other developing countries, including Bangladesh and Mozambique. All the pertinent background environmental information of these studies is also available in FAO GIS.

Several methodological materials were produced as guidelines for land evaluation for rainfed agriculture [FAO, 1983] and for extensive grazing [FAO, 1989].

Another joint FAO/UNEP activity in this area concerns the ecological monitoring of lands affected or likely to be affected by desertification. It also has a strong methodological aspect and includes the systematic collection of a time series of data on the biological and physical processes relevant to the sustained productivity of an ecosystem. Assessments are carried out to determine the demands being made on the land, as well as its capacity to support human and animal life, and the expected future productivity and stability of the land and its vegetation under different forms of management [FAO, 1989].

The FAO Conference (1981) at its 21st session adopted a World Soil Charter, which established a set of principles for the optimum use of the world's land resources, improvement of their productivity and their conservation for future generations. To this end, also, the Governing Council of UNEP in 1982 adopted the World Soils Policy. Both documents create a solid international basis for the rational and sustained utilization of the world's land resources.

However, all the methodological efforts described above related to the desertification assessment have not led so far to the reliable actual quantitative assessment of the existing situation, either in statistics or in maps at the global or even regional levels. Nor were they applied to any particular country as a whole, not because the agencies concerned were unwilling to do so, but because the necessary funds were lacking, or because other needs seemed to be more pressing and also because of methodological uncertainties.

The above international methodological efforts were then taken over by other bodies of the international community, particularly by ISSS and ISRIC within two large projects, GLASOD and SOTER, which are concerned with the present status of the land resources of the world and soil degradation problems.

The UNEP/ISRIC project GLASOD is now at an advanced stage and should soon be completed. An appropriate methodology for the assessment and mapping at a scale of 1:10,000,000 was developed at the initial stage of the project taking into account all previous methodologies, particularly those developed by the FAO described above. The following forms of soil degradation are distinguished:

- water erosion (on-site and off-site);
- wind erosion (on-site and off-site);
- loss of nutrients;
- pollution and acidification;
- salinization;
- discontinuation of flood induced fertility;
- other chemical problems;
- sealing and crusting of topsoil;
- compaction;
- deterioration of soil structure;
- waterlogging;
- aridification;
- subsidence of organic soil;
- biological deterioration.

The causative factors of soil degradation also have to be considered in the evaluation process, namely: a) over-grazing of pasture land, b) deforestation, c) over-intensive annual cropping. Five degrees of each of the above processes are distinguished. Recent past average rates of soil degradation will also be taken into account.

An even more detailed methodological approach was utilized in the preparation of the initial documentation for SOTER whose aim is "... to utilize emerging information technology to produce a world soils and terrain digital database containing digitized map unit boundaries and their attribute data, and supported by a file of chosen point data ..." [UNEP/ISRIC, 1989].

Both projects are contributing to more comprehensive and accurate understanding of the present status of world's soils and the processes of their degradation.

Finally, considering all the methodologies for desertification assessment at a global scale, which have been or are being developed by various international organizations under different project titles, particularly by UNEP, FAO and the ISSS (ISRIC), we should refer briefly to the use of new techniques connected with remote sensing and information collection, storage, and processing.

Although technologies hold much promise and are currently the only tools for assessing the existing environmental situation reliably and quickly, they are still not applied practically for various reasons, both technical and organizational, for the assessment of desertification as such.

The Global Environment Monitoring System (GEMS) promotes the remote sensing techniques for environmental monitoring. It encourages the use of data from earth resources technology satellites, complemented by data from systematic reconnaissance flights using light aircraft, and the appropriate field work. To accommodate this approach and to engage in effective monitoring, the computerized Global Resource Information Data Base (GRID) has been established within UNEP. GRID utilizes ARC-INFO software and NASA'S ELAS software and has two main operating centres, GRID-Control in Nairobi and GRID-Processor in Geneva. The global data base permits rapid assessment of large areas and so provides a diagnosis of unhealthy trends for the environment, including desertification. More detailed monitoring can be done cost-effectively using satellite and aircraft techniques. The necessary field work provides the final details and permits planning and remedial action.

However, as far as the actual application of this technology is concerned, "... there is no agency yet responsible for routine inspection of the data for signs of environmental change, damage or human impact on the environment. On an individual basis, country by country and project by project, such examination is done to a limited extent, and significant work has been sponsored by UNEP, which reports that about 20%

of the world's desert and semi-arid zones has now been assessed using satellite remote sensing technology [Gwynne, Falconer, 1987].

Another facility is provided by the FAO/GIS. This computer-based information system, which can store, manipulate, display and produce geographic (spatial) information, integrated with statistical and textual data, represents one of the most useful and powerful analytical tools of resource planners and managers [FAO, 1986]. With the methodology for desertification assessment and mapping developed in 1984, it became possible through GIS to compile the desertification maps at different scales and levels of generalization, including mapping at the country level at a scale of 1:1,000,000, if the following maps at the same scale are available: a) soil constraint map, b) water action, c) wind action, d) salinization, e) animal pressure, f) population pressure, g) composite degradation hazard map. In short, what GIS provides is a means of converting spatial data into digitized form that can be displayed, manipulated, modified and analyzed and reproduced quickly in a new format, available for either visual display or hard copy reproduction.

The above capability of FAO/GIS was utilized for the Desertification study in Africa, Integrated terrain units in Africa, Agro-Ecological zoning in the developing world. A considerable data base is already accumulated by GIS although it is still insufficient for the world coverage with the required accuracy.

Unfortunately, neither of these capabilities of UNEP and FAO was utilized for actual quantitative assessment of desertification either at a global or national scale anywhere not because of lack of interest on the part of the organizations concerned, but, because of the lack of funds.

Therefore the present situation concerning both methodology for the assessment and the actual quantitative assessment of desertification at the global scale is still unsatisfactory. This suggests that efforts to develop an appropriate methodology for assessment of desertification per se, as it is currently defined (as an integrated natural or human induced phenomenon of ecosystem degradation), have been unsuccessful because this phenomenon cannot be measured as a unified whole and therefore cannot be mapped with sufficient reliability and accuracy. Moreover it suggests that there should be an alternative approach to the solution of the methodological problem.

It should also be noted that several major international activities are now being considered by various international and regional agencies, which have components related to the desertification assessment and mapping. These projects should be implemented on the basis of an appropriate methodological background that must be developed in advance.

A large project, for example, is being discussed at the initiative of the Government of France within the agencies of the UN System on ["L'Observatuire du Sahara et du Sahel: La necessite de completer et de reforcer le dispositif existant de lutte contre la desertification en Afrique du Nord et dans la region Soudano-Sahelienne"]. ACSAD, in co-operation with UNEP and ESCWA, is developing the National Plans of Action to Combat Desertification for the countries of the region of its concern (NPACDs for Syria, Jordan, Yemen Arab Republic and Algeria have already been completed by 1989). All these and related activities will certainly require a methodology for desertification assessment and monitoring, preferably on the basis of computerized data from the remote sensing.

2.3 METHODOLOGY DEVELOPMENT AT THE NATIONAL LEVEL

In the great majority of the countries affected, there appear to be no serious attempts to assess the status of the desertification at a national level in a comprehensive form after 1977. However, several different methodological approaches were developed in various countries both for local or national and global studies of the magnitude of the problem.

1. One of the first attempts to assess the global magnitude of desertification was undertaken by Professor M. Kassas in 1957 at Cairo University, Egypt, when he compared the areas of the deserts shown by climate, soil, and vegetation maps. The larger area of desert revealed by soil and vegetation maps in comparison with the climatic deserts was attributed to the process of human induced desertification.

2. At the Texas Technical University, USA, Professor H.E. Dregne tried to solve the methodological problem by several approximations starting from his world map of the status of Desertification at a scale of 1:25,000,000 presented to UNCOD in 1977 [Dregne, 1977]. The results of his further efforts to refine the methodology were also later made public [Dregne, 1983, 1986].

   In his methodological approach, H. Dregne distinguishes four degrees of desertification: slight, moderate, severe and very severe. The following criteria for these classes of severity of the precess were selected:

   - State of vegetation: perfect to good, satisfactory, bad, no vegetation;
   - State of soil erosion: absent or negligible, moderate, strong, very strong;
   - State of salinization of irrigated lands: absent, moderate, strong, very strong;
   - Decrease of crop yields: by less than 10%, by 10-50%, by 50-90%, by more than 90%.

   These degrees of desertification were then determined for different categories of land use by countries, by continents and for the entire planet within the climatic boundaries of hyper-arid and semi-arid territories.

   As a senior consultant, H. Dregne was involved in the development of the Provisional Methodology for Assessment and Mapping of Desertification [FAO, UNEP, 1984], to which he contributed substantially. However there has been no further development of this approach.

3. At the United States National Aeronautics and Space Administration (NASA), there was an attempt to study the desert encroachment on the basis of satellite remote sensing techniques [Tucker, Justice, 1986; Dregne, Tucker, 1988]. The spatial extent of deserts in different periods of time was compared for Africa north of the Equator using the National Oceanic and Atmospheric Administration (NOAA) A Very High Resolution Radiometer (AVHRR), satellite data of the same area taken at two different periods. This approach made it possible to assess the problem in very general terms without any specification of the processes involved. Moreover, the authors concluded that, the extent of desertification in this part of the world, as revealed by numerous ground studies, was greatly over-estimated while periodic shifts of the desert boundary to the north or to the south were connected with periodic cycles of atmospheric precipitations.

   In spite of the great potential capability of this methodological approach, its greater use must await further experimentation before it is perfected.

4. A more specific approach was utilized by Professor B.V. Vinogradov at the Institute of Experimental Morphology and Ecology of Animals, USSR, in a study of desertification in Kalmykia [Vinogradov, Kulin, 1987; Vinogradov, 1988], in which he compared the space images of the same area separated by an interval of 10 years and supplemented by appropriate ground surveys. The results of the study have already been described above.

5. The same methodology was applied by the Institute of Geography of the Academy of Sciences of the USSR also in Kalmykia, though for a different area [Ermoshkina et al., 1986]. The land use pattern of the area was quantitatively compared over an interval of 10 years, using the remote sensing images; spatial changes in land use were then calculated. Appropriate field work (Ground Truth) was organized for the interpretation of the remote sensing data.

6. In another study, conducted by the Dokuchev's Soil Institute, USSR, a technology was developed for the assessment of the degree of salinization of irrigated lands using remote sensing data, from

both satellites and aircraft, supplemented by ground surveys [Pankova et al., 1986]. The study provided detailed information on the degrees of salinization of irrigated lands in all the Republics of Soviet Middle Asia.

7. At Moscow State University, a methodology was developed for the assessment of the present degree of aridization of world's soils and the probability of soil drought and secondary salinization under irrigation [Kovda et al., 1976, 1977, 1978, 1981]. This methodology was based on the qualitative estimate of the degrees of soil aridization from the data on secondary accumulation of soluble salts, gypsum, calcium carbonate and iron/manganese concretions in various soils of the world. These data, together with the available statistical information on drought probability, were then compared with the soil map of the world at various scales up to 1:25,000,000. The latest version of the world map based on this methodology will soon be published in the *Atlas of World Natural Resources and Their Utilization*.

8. Another methodology for desertification assessment was also developed at Moscow State University based on the available statistical information concerning the degrees (slight, moderate, strong) of soil degradation by wind and water erosion and by the salinization of land under different uses (rainfed agriculture, irrigated agriculture, ranges) in different ecological (physico-geographical) zones [Rozanov, 1981, 1982, 1986; Rozanov et al., 1989]. The results of global or regional assessments were presented in the form of statistical tables characterizing the areas affected.

9. A very comprehensive and detailed methodology for the assessment of desertification was developed at the Institute of Deserts of the Turkmenian Academy of Sciences, USSR, partially utilizing the scheme proposed by FAO/UNEP Provisional Methodology of 1984 [Kharin et al., 1984, 1988]. The methodology provided for the use of data from the satellite remote sensing, aerial photographs and ground surveys for the interpretation of the space/air images. The results of the application of this methodology to the assessment of desertification in the Middle Asian Republics and Kazakhsfan have been described in an earlier section of this report. the desertification map of the area at a scale of 1:2,500,000 was prepared for the areas affected.

10. A comparable methodology for desertification assessment was developed at the Damascus University by Professor Y. Barkoudah using aerial photographs taken in the same area in different years [Rahali, 1987]. The comparison of the images was also supplemented by ground surveys for better interpretation.

The methodologies employed in various countries for presenting original materials to UNCOD or, subsequently, for the General Assessment of Progress, were more descriptive in form and therefore not pursued later on. To the best of the author's knowledge, the ten different approaches listed above represent the major choices used throughout the world for desertification studies. A comparison of the ten is presented in Table 6.

Table 6. Comparison of various methodologies used for desertification assessment by different authors

Author(s), Year(s)	Input: data used, sources of information	Criteria selected	Scale of original application	Output: form presentation
1. Kassas, 1957	Global climate, soil and vegetation maps	Extension of desert areas as shown on the maps	Global	Global figures
2. Dregne, 1977, 1983, 1986	Global maps and statistics	State of vegetation, state of soil erosion,state of salinization, decrease of crop yields	Global, continental, regional	Statistical tables, small-scale maps
3. Tucker et al., 1986, 1988	NOAA (AVHRR)	Vegetation density and productivity	Regional	Small-scale maps
4. Vinogradov, 1987, 1988	Satellite images of different times plus ground surveys	Land use pattern	Local	Statistics, large-scale maps
5. Ermoshkina et al., 1986	Satellite images of different times plus ground surveys	Land use pattern	Local	Statistics, large-scale maps
6. Pankova et al., 1986	Satellite images, aircraft remote-sensing, ground surveys	Degree of soil salinity	Regional	Statistical tables
7. Kovda et. al., 1976, 1977, 1978, 1981	Small scale soil maps, statistics, soil descriptions	Accumulation of soil secondary new formations, degree of soil aridity	Global	Small-scale maps
8. Rozanov et. al., 1981, 1982, 1989	Statistical information	Water and soil erosion, salinization	Global, regional	Statistical tables
9. Kharin et al., 1984, 1988	Satellite images and aerial photographs, ground surveys	Status of vegetation, wind and water erosion, salinization, soil destruction	Regional	Medium-scale maps, statistics
10. Rahali, 1987	Aerial photographs of different times, ground surveys	Land use pattern	Local	Large-scale maps, statistics

2.4. CONCLUDING COMMENTS

The short analysis of the present state of the art in respect of the methodology for assessment of desertification given above reveals three major points, namely:

(i) The methodologies for the assessment of desertification that are currently used throughout the world at both the global and regional levels (either through international efforts or by various national institutes and individual scientists), are all far from satisfactory and cannot provide precise and reliable information on the status, trends and rates of desertification at the global level, although some of the methodologies can be successfully utilized for the assessment of the process at the local level, [e.g. Vinogradov, 1987; Ermoshkina, et al. 1986; Rahali, 1987].

(ii) The shortcomings of these methodologies stem largely from those of the present definition of the desertification or, rather, the absence of precise measurable parameters of this general phenomenon. This is particularly true in respect of the utilization of new satellite remote sensing technology, which is one of the reliable methods. Even then there is need to define more precisely what has to be measured and how the results of the measurement should be interpreted. Here, the measurable parameters selected for the assessment of desertification by different authors vary greatly and therefore differ widely in their resulting estimates.

(iii) To obtain a reliable and precise picture of the status of the desertification in the world or in a specific large region, it would be imperative to:

(a) redefine desertification in precise terms of measurable parameters, and

(b) to develop an internationally acceptable system of methods of measuring the parameters of desertification, preferably utilizing modern techniques of satellite remote sensing which are currently available both internationally and nationally.

CONCLUSIONS

The review of current publications and reports of various international institutions concerning the present status of desertification, particularly those containing concrete results of field studies, observations and actual assessments conducted at the local or regional/provincial levels, as well as global assessments using different methodologies, shows very definitely that:

(a) In spite of all the efforts undertaken internationally, regionally or nationally since the UNCOD, desertification continues to destroy the natural resource base of arid and semi-arid territories of the world, embracing larger and larger areas and spreading into new regions at an accelerated rate.

(b) The driving forces or the anthropogenic causes of the process of desertification are still the same as those described by UNCOD. Generally, it is expressed in the form of the irrational land use, wasteful use of the natural resources in these lands, beyond their carrying capacities against a background of the absence of occupational alternatives for the peoples inhabiting the regions.

(c) Although the total land area affected or likely to be affected by desertification is large and growing throughout the world, its total dimensions are not yet known with the necessary degree of accuracy and reliability. Accurate and reliable figures concerning the status, extent, and rate of desertification, which could be used adequately to compare different localities and regions and summarized by countries, regions, continents and for the whole world, do not exist.

22. Dregne H.E., 1977. The Status of Desertification. World Map at a Scale of 1:25,000,000. United Nations, UNCOD, A/CONF.74/31.

23. Dregne H.E., 1978. Desertification : Man's Abuse of the Land. J. Soil and Water Conservation, Vol. 33, 11-14.

24. Dregne H.E., 1983. Desertification in Arid Lands. Hartwood Acad. Publ., London.

25. Dregne H.E., 1986. Extension and Distribution of Desertification Processes. In : Reclamation of Arid Territories and Combating Desertification. A Comprehensive Approach. CIP, Moscow, 10-16.

26. Dregne H.E., Tucker C.d., 1988. Desert Encroachment. Desertification Control Bulletin, UNEP, No. 16, 16-19.

27. El-Ashly M.T., Gibbons D.C., Eds., 1988. Water and Arid Lands of the Western United States. A World Resources Institute Book. Cambridge Univ. Press, Cambridge.

28. Ermoshkina M.A., Lotov R.A., Mazikov B.M., 1986. Study of Natural Resources of Kalmykia on the Materials of Satellite surveys. Pochvovedenie, No. 3, 147-157 (in Russ.).

29. ESCAP 1987. Desertification in Asia and the Pacific: A regional Review and Assessment. ESCAP, Bangkok.

30. ESCWA, UNEP 1988. National Plan of Action to Combat Desertification in the Yemen Arab Republic.

31. ESCWA, UNEP, FAO, 1987. National Plan of Action to Combat Desertification in the Hashimite Kingdom of Jordan. Baghdad.

32. FAO, 1978. Report on the Agro-Ecological Zones Project. Vol. 2. Results for South-West Asia. World Soil Resources Report 48/2. FAO, Rome.

33. FAO, 1980. Report on the Agro-Ecological Zones Project. Vol. 4. Results for South East Asia. World Soil Resources Report 48/4. FAO,Rome.

34. FAO, 1981a. Provisional Methodology for Desertification Assessment and Mapping. FAO, Rome.

35. FAO, 1981b. Report on the Agro-Ecological Zones Project. Vol.3. Methodology and Results for South and Central America. World Soil Resources Report 48/3. FAO, Rome.

36. FAO, 1983. Guidelines : Land Evaluation for Rainfed Agriculture. FAO soils Bulletin 52, FAO, Rome.

37. FAO, 1984. Land, Food and People, Based on the FAO/UNFPA/ IIASA Report "Potential Population-Supporting Capacities of Lands in the Developing World". FAO, Rome.

38. FAO, 1986a. FAO and the Environment. FAO, Rome.

39. FAO, 1986b. FAO's Activities in Combating Desertification. FAO, Rome.

40. FAO, 1987. Production YearBook 1986. FAO, Rome.

41. FAO, 1988a. Guidelines. : Land Evaluation for Extensive Grazing. FAO Soils Bulletin 58. FAO, Rome.

42. FAO, 1988b. The State of Food and Agriculture 1987-1988. FAO, Rome.

43. FAO, 1990. The Conservation and Rehabilitation of African Lands. An International Scheme. Draft. FAO, Rome.

44. FAO, IIASA, 1989. Assessment of Population Supporting Capacity for Development Planning in Kenya. Working papers 1-8. FAO, Rome.

45. FAO, UNEP, 1983. Methodology for Compilation of Desertification Hazard Map of Africa at a Scale of 1:5,000,000. FAO, Rome.

46. FAO, UNEP, 1984. Map of Desertification Hazards. Explanatory Note. FAO, Rome.

47. FAO, UNEP, 1984. Provisional Methodology for Assessment and Mapping of Desertification. FAO, Rome.

48. FAO, UNEP, UNESCO, 1979. A Provisional Methodology for Soil Degradation Assessment. FAO, Rome.

49. FAO, UNEP, UNESCO, 1980. Provisional Map of Present Degradation Rate and Present State of Soil for Africa North of the Equator and the Near and Middle East, 1:5,000,000. FAO, Rome.

50. FAO, UNEP, UNESCO, 1980. Provisional Map of Soil Degradation Risks for Africa North of the Equator and the Near and Middle East, 1:5,000,000. FAO, Rome.

51. FAO, UNESCO, 1985. Carrying Capacity Assessment with a Pilot Study of Kenya. FAO, Rome.

52. FAO, UNESCO, WMO, 1977. World Map of Desertification. FAO, Rome.

53. FAO, UNFPA, 1980. Land Resources for Populations of the Future. FAO, Rome.

54. FAO, UNFPA, IIASA, 1982. Potential Population-Supporting Capacities of Lands in the Developing World. FAO, Rome.

55. Goncharov L.B., 1989. On Use of Land and Water Resources in Africa. Problemy Osvoenia Pustyn, No. 3, 10-13 (in Russ.).

56. Government of Kenya, UNEP, 1989 A methodology for Assessment and Mapping of Desertification. Report of the Kenya Pilot Study. UNEP, Nairobi.

57. Grigorjev A.A., 1987. Large-Scale Changes of Nature in Aral Basin According to Observations from the Satellites. Problemy Osvoenia Pustyn, No.1, 16-22 (in Russ.).

58. Grigorjev A.A., 1989. Desertification : An Aspect of the Ecological Problem. Problemy Osvoenia Pustyn, No. 3, 3-5 (in Russ.).

59. Grushevsky A., 1989. Desertification and Deforestation in African Countries. Problemy Osvaenia Pustyn, No. 3, 10-13 (in Russ.).

60. Guseinov R.G., Altaev A.A., 1988. Assessment of Capital Expenditures for Reclamation of Pastures. Problemy Osvoenia Pustyn, No. 5, 24-28 (in Russ.).

61. Gwynne M.D., Falconer A., 1987. Remote Sensing and Geographic Information System for Monitoring the Environment and Combating Desertification. In : Chagas C., Canuto V., Eds. Study Week on Remote Sensing and its Impact on Developing Countries. Pontifica Academia Scientiarum, Citta del Vaticano, 371-384.

62. Hendry P., 1986. The Desert's Challenge and the Human Responce. Dimentions and Perceptions. CERES, FAO, Vol. 19, No. 2, 17-21.

63. Henning D., Phlohn M.F., 1977. World Map of Climate Aridity Indexes. United Nations, UNCOD, A/CONF. 74/31.

64. Ilaiwi M., 1988. Desertification in the Northern Part of the Syrian Steppe and the Protection of Economic Establishments from Moving Sands. ACSAD/Ministry of Agriculture, Syria, Damascus.

65. Ilaiwi M., Osman A., 1989. Human Induced Soil Degradation Map of the World, Region II. (ACSAD Contribution to the GLASOD Project). ACSAD, Damascus.

66. Jain J.K., Ed., 1986. Combating Desertification in Developing Countries. Scientific Publishers, Jodhpur.

67. Kamalov S.K., 1987. Aral sends SOS. Priroda i Chelovek, No. 10, 30-33 (in Russ.).

68. Kassas M., 1977. Arid and Semi-arid Lands: Problems and Prospects. Agro-Ecosystems, Vol.3, No. 3, 185-204.

69. Kassas M., 1987. Drought and Desertification. Land Use Policy, Vol.4, No. 4, 389-400.

70. Kassas M., 1988. Ecology and Management of Desertification. Earth '88: Changing Geographic Perspectives.

71. Khakimov F.I., 1989. Soil Amelioration Conditions of Deltas under Desertification. Pushino. (in Russ.).

72. Khamraev N.R., 1988. Problems of Development and Improvement of Water-Economy System of Amudarja Lowland. Problemy Osvoenia Pustyn, No. 1, 11-16 (in Russ.).

73. Kharin N.G. et al., 1984. Explanatory Note to the Map of Anthropogenic Desertification of Arid Territories of the USSR at a Scale of 1:2,500,000. Ylym, Ashkhabad (in Russ.).

74. Kharin N.G., Kiriltseva A.A., 1988. New Data on Areas of Desertified Lands in Arid Zone of the USSR. Problemy Osvoenia Pustyn, No. 4, 3-7 (in Russ.).

75. Kirsta B.T., 1988. Supply of Salts by the Karakum Canal to the Plains of Turkmenistan. Problemy Osvoenia Pustyn, No. 1, 17-23 (in Russ.).

76. Kondratjev K. Y., Grigorjev A.A., Zhvalev V.F., Melentjev V.V., 1985. Complex Studies of Dust-Storms in Aral Basin. Meteorologia i Hydrologia, No. 4, 17-23 (in Russ.).

77. Kondratjev K. Y., Zhvalev V.F., Karpov I.V., 1987. Studies of the Impact of Desertification Processes on the Atmosphere. Problemy Osvoenia Pustyn, No. 1, 3-9 (in Russ.).

78. Kovda V.A., Onishenko S.K., Rozanov B.G., 1976. On the Probability of Droughts and Secondary Salinization of Soils of the World. Bilogicheskie Nauki, No. 2, 27-38 (in Russ.).

79. Kharin N.G., Petrov M.P., 1977. Glossary of Terms on Natural Conditions and Desert Development. Ylym, Ashkhabad.

80. Kovda V.A., Onishenko S.K., Rozanov B.G., 1977. On Probability of Droughts and Secondary Salinization of World's Soils. In : Warthington B., Ed. Arid Land Irrigation in Developing Countries. Pergamon Press, Oxford, 237-238.

81. Kovda V.A., Rozanov B.G., 1977. Scheme of Aridity and Drought Probability. World Map at a Scale of 1:25,000,000. United Nations, UNCOD, A/CONF. 74/31.

82. Kovda V.A., Rozanov B.G., 1978. Land Aridization, Drought Probability and Probability of Soil Salinization under Irrigation. Problems of Soil Science, Nauka, Moscow, 3-13.

83. Kovda V.A., Rozanov B/G., 1981. Regional Frequency and Occurrence of Droughts. In : Kovda V.A. Soil Cover, its Improvement, Utilization and Conservation. Nauka, Moscow, 55-62 (in Russ).

84. Kroumkatchev L., 1989. The First Special Session of UNEP's Governing Council. Problemy Osvoenia Pustyn, No. 5, 58-62 (in Russ.).

85. Kuznetsov N.T., 1976. Geographical Aspects of the Future of Aral Sea. Problemy Osvoenia Pustyn, No. 2, 17-25 (in Russ.).

86. Kuznetsov N.T., Gryaznova T.H., 1987. Use of the Many-Purpose Aircraft-Laboratories in the Development and Evaluation of Validity of Long-Term Physico-Geographical prognoses. Problemy Osvoenia Pustyn, No. 1, 10-15 (in Russ).

87. Land Use Policy, 1987. Special Issue on Desertification. Vol. 4, No. 4.

88. Mabbutt J.A., 1978. The Impact of Desertification as Revealed by Mapping. Environmental Conservation, Vol. 5, 45-56.

89. Mabbutt J.A., 1984. A New Global Assessment of the Status and Trends of Desertification. Environmental Conservation, Vol. 11, 103-113.

90. Mabbutt J.A., 1987a. A Review of Progress Since the UN Conference on Desertification. Desertification Control Bulletin, UNEP, No.15, 12-23.

91. Mabbutt J.A., 1987b. Implementation of the Plan of Action to Combat Desertification : Progress since UNCOD. Land Use Policy, Vol. 4, 371-388.

92. Mabbutt J.A., Floret C., Eds., 1980. Case Studies on Desertification. UNESCO, Paris, Resources Research XVIII.

93. Mashbits Y. G., 1988. Desertification in the Developing Countries : Character and the Ways of Solving the Problem. Problemy Osvoenia Pustyn, No. 5, 83-86 (in Russ.).

94. Meckelein W., 1980. Desertification in Extremely Arid Environments. Stuttgart.

95. Medellin-Leal F., Ed., 1978. La Desertification en Mexico, Instituto de Investigacion de Zonas Deserticas, Universidad Autonoma de san Luis Potosi, San Luis Potosi.

96. Mendez R., 1981. Combating Desertification in the Sudano-Sahelian Region. Desertification Control Bulletin, UNEP, No. 5, 2-8.

97. Milanov S.O., 1987. Ecologo-Economic Aspects of Natural Resources Utilization in Eastern Karakums. Problemy Osvoenia Pustyn, No. 6, 29-35 (in Russ.)

98. Minashina N.G., Buylov V.V., Derevencha M.E., Duchovny V.A., Gogolev I.N., Rozanov B.G., 1981. Irrigated Soils, their Utilization and problem of Rising the Productivity of Irrigated Agriculture. Reports of the General Symposium of the VI Congress of the All-Union Society of Soil Science, USSR, 68-89. Tbilisi (in Russ.).

99. Ministerio do Desenvolvimento Urbano e Meio Ambiente, Secretaria Especial do Meio Ambiente, 1984. Seminario Sobre Desertificacao no Nordeste. Documento Final. Brasilia.

100. Morozov V.P., 1989. Nigeria : An Experience in Combating Desertification. Problemy Osvoenia Pustyn, No. 4, 14-18 (in Russ.).

101. Moyhrabi A. et al., 1987. Desertification in Western Sudan and Strategies for Rehabilitation, Environmental Conservation, No. 3, 227-231.

102. Odingo R.S., 1989. Review of UNEP's Definition of Desertification and its Programmatic Implications. UNEP, Nairobi.

103. Novikova S.S., 1987. Vegetation of Dry Beds of Ancient Delta of Ili River. Problemy Osvoenia Pustyn, No. 3, 21-28 (in Russ.).

104. Oldeman L.R., Ed., 1988. Guidelines for General Assessment of the Status of Human-Induced Soil Degradation. Working Paper and Preprint 88/4. ISRIC, Wageningen.

105. Olsson L., 1985. An Integrated Study of Desertification. Department of Geography, University of Lund, Sweden.

106. Pankova E.I., Golovina N.N., Ventskevich S.D., Panadiani E.A., 1986. An experience of Assessment of Soil Salinization in Irrigated Lands of Middle Asia on the Materials of Satellite Survey. Pochvovedenie, No. 3, 138-146 (in Russ.).

107. PNUE, Ministere des Affaires Etrangeres Frances, Ministere de la Cooperation Francaise, 1989: Developpement d'Une Nouvelle Methode d'Evaluation et de Suivi de la Desertification des Regions Saheliennes et Soudaniennes 1952-1987. IGN France, ORSTOM, Paris.

108. Radchenko G.F., 1987. Problems of Desertification in Arid and Semi-Arid Regions of the Developing Countries on the Example of the Sahel. Progress, Moscow (in Russ.).

109. Rafikov A.A., 1989. Problems of Nature Conservation in Arid Lands of Uzbekistan. Problemy Osvaenia Pustyn, No. 4, 38-46 (in Russ.).

110. Rahali M., 1987. Desertification on the Borders of the Syrian Desert. Department of Botany, Damascus University Damascus.

111. Rapp A., 1987. Reflections on Desertification 1977-1984 : Problems and Prospects. Desertification Control Bulletin, UNEP, No. 15, 27-33.

112. Rapp A., Le Houerou H.N., Lundholm B. Eds., 1976. Can Desert Encroachment be stopped? SIES, Stockholm.

113. Republique Tunisienne, Ministere de l'Agriculture, UNEP, 1985. Strategie Nationale de Lutte Contre de Desertification.

114. Rozanov B.G., 1981. Principles of Diagnostics and Assessment of Desertification Processes. Abstracts of Papers of the International Symposium "Combating Desertification Through Integrated Development", 27-29 Tashkent.

115. Rozanov B.G., 1982. Assessing, monitoring and Combating Desertification. Trans. 12th Int. Congr. Soild Sci., New Delhi, India, 8-16 February 1982, Vol. 4, 56-58.

116. Rozanov B.G., 1986. Land Resources of Arid Belt of the USSR, their Rational Utilization and Conservation. Problemy Osvoenia Pustyn, No. 5, 22-28 (in Russ.).

117. Rozanov B.G., 1986. Soil Degradation Processes Leading to Desertification. Trans. 13th Int. Congr. Soil Sci., Hamburg, FRG, 13-20 August 1986, Vol.3, 1257-1258.

118. Rozanov B.G., Targulian V.O., Orlov D.S., 1989. Global trends in Soil Changes. Pochvovedenie, No. 5, 5-18 (in Russ.).

119. Rozina I.K., 1989. Energetics and Problem of Desertification in Africa. Problemy Osvenia Pusytn, No. 4, 3-8 (in Russ.).

120. Rubanov I/V., Bogdanova I.M., 1987. Quantitative Assessment of Salt Deflation in the Drying Bottom of Aral Sea. Problemy Osvoenia Pustyn, No. 3, 9-16, (in Russ.).

121. Rubinova F.E., Getker M.I., 1975. Water Balance of the Hungry Steppe : Change in Its Structure Under the Impact of Hydrotechnical Construction at Present and in the Perspective. Tashkent (in Russ.).

122. Sabadell J.E., Risley E.P., Jorgenson H.T., Thornton B.S., 1982. Desertification in the United States. Dpt. of the interior, Bureau of Land Management, Washington, D.C.

123. Stiles D., Brennan R., 1986. The Food Crisis and Environment Conservation in Africa. Food Policy, Vol. 11, No. 4, 298-310.

124. Syrian Arab Republic, Ministry of State for Environment; UNEP's Regional Office for West Asia; ACSAD, 1987. Plan of Action to Combat Desertification in Syria. Damascus.

125. Timberlake L., 1985. Africa in Crisis. Earthscan, London.

126. Tolba M.K., 1984. Harvest of Dust. Desertification Control Bulletin, UNEP, No. 10, 2-4.

127. Tolba M.K., 1984. General Assessment of the Implementation of the Plan of Action to Combat Desertification in 1978-1984. Report of the Executive Director to the Governing Council of UNEP. UNEP, Nairobi.

128. Tucker C.d., Justice C.O., 1986. Satellite Remote Sensing of Desert Spatial Extent. Desertification Control Bulletin, UNEP, No. 13, 2-5.

129. UNCOD, 1977. Status of Desertification in the Hot Arid Regions : Maps and Explanatory Note. A/CONF. 74/31.

130. Une collection a Instruire Cours du Controle Desertique pour l'Instruction Internationale, 1988. Centre Internacional de l'Education et la Recherche sur le Controle Desertique, Lanzhou.

131. UNEP, 1984. General Assessment of Progress in the Implementation of the Plan of Action to Combat Desertification 1978-1984. UNEP, Nairobi.

132. UNEP, ISRIC, 1989. SOTER Report 4e : Proceedings of the Second Workshop on a Global Soils and Terrain Digital Database and Global Assessment of Soil Degradation.ISSS, Wageningen.

133. United Nations, 1977. Desertification : Its Causes and Consequences. Pergamon Press, Oxford.

134. United Nations, 1978. United Nations Conference on Desertification : Round-up, Plan of Action and Resolutions.

135. United Nations, ESCAP, 1989. Desertification in Indus Basin due to Salinity and Waterlogging, Bangkok.

136. UNOSTD, 1987. Report of the Panel of Experts on "The Application of Science and Technology to the Study, Prevention, Monitoring and Combating of Drought and Desertification". UN, New York, A/CN.II/AC.I/VII/3.

137. Vinnikov K.Y., 1986. Sensibility of Climate. Hydrometeoisdat, Leningrad (in Russ.).

138. Vinogradov B.V., 1988. Checking from the Space. Kommunist, NO. 3, 65-67 (in Russ.).

139. Vinogradov B.V., Kulin K.N., 1987. Aero-Space Monitoring of Desertification Dynamics of Black Lands in Kalmykia According to Repeated Surveys. Problemy Osvoenia Pustyn, No.4, 45-53 (in Russ.).

140. Volftsun I.B., Sumarokova V.V., 1985. Dynamics of the Anthropogenic and Natural Losses of Amudarja and Sysrdarja Rivers for a Long-Term Period. Meteorologia i Mydrologia, No. 2, 24-29 (in Russ.).

141. Warren A., Agnew C., 1988. An Assessment of Desertification and Land Degradation in Arid and Semi-Arid Areas. IIED Paper No.2

142. World Bank, 1988. Desertification in the Sahelian and Sudanean Zones of West Africa. World Bank, Washington, D.C.

143. World Commission on Environment and Development, 1987. Our Common Future. Oxford Univ. Press, Oxford.

144. World Resources Institute, 1989. The World Resources 1988-89. Basic Books Inc., New York.

145. Zaletaev V.S., 1989. Irrigation and Desertification : Ecological Controversies. Problemy Osvoenia Pustyn, No.3, 45-48 (in Russ.).

146. Zhalbybekov B., 1987. Transformation of Soil Cover of the Sea-Side Delta of Amudarja River in Connection with Anthropogenic Desertification. Problemy Osvoenia Pustyn, No. 2, 26-33 (in Russ.).

147. Zhao Qiguo, Li Qingkui, 1988. Intensive Cultivation of Major Soils in China. Soil Research Report No. 18. Institute of Soil Science, Academia Sinica, Nanjing.

148. Zhu Zenda, Liu Shu, Wu Zhen, Di Xinmin, 1986. Desets in China. Institute of Desert Research, Academia Sinica, Lanzhou.

149. Zhu Zenda, Liu Shu, 1983. Combating Desertification in Arid and Semi-Arid Zones in China. Institute of Desert Research, Academia Sinica, Lanzhou.

150. Zonn I.S., 1986. Land use and Water Resources in Arid Territories. In : Reclamation of Arid Territories and Combating Desertification : A Comprehensive Approach. CIP, Moscow, 24-34.

151. Zonn I.S., 1989. Strategy of UN System in the Area of Environmental Conservation of Arid Lands and Desertification for 1990-1995. Problemy Osvoenia Pustyn, No. 5, 51-57 (in Russ.).

152. Zonn S.V., 1986. Black Lands of Kalmykia. In : Reclamation of Arid Territories and Combating Desertification : A Comprehensive Approach. CIP, Moscow, 130 -132.

GLOBAL ASSESSMENT OF DESERTIFICATION: STATUS AND METHODOLOGIES — ADDENDUM

Professor Boris G. Rozanov
Head, Chair of General Pedology
Faculty of Soil Science
Moscow State University, USSR

for
Desertification Control Programme Activity Centre
United Nations Environment Programme

March 1990

FOREWORD: NEED FOR AND NATURE OF THE ADDENDUM

The UNEP DC/PAC Report of February 1990 on the "Assessment of Global Desertification: Status and Methodologies" was prepared in January 1990 for the discussion at the Ad-Hoc Consultation on the same subject which took place in Nairobi from 15 to 17 February 1990.

During the Consultation, several important documents were made available by the participants from various parts of the world and from different organizations. These documents are listed below.

In addition, the Minutes of the consultation provided still more information and valuable comments and conclusions pertinent to the matter under consideration, particularly on the methodological aspects. These materials are reviewed in the Addendum.

Furthermore, after the Consultation, Professor B. Rozanov was charged with a mission to UNEP/ROAP and ESCAP in Bangkok as well as to IDRAS in Lanzhou, China, to collect the latest information on desertification status in the ESCAP region. The sources of information obtained during this mission are also listed below.

All the above materials are reviewed in the Addendum. Final conclusions and recommendations were made on the basis of the original Report, additional information obtained at and after the consultation, as well as on the basis of the discussion of the problem by the experts at the Consultation. They constitute the final part of the Addendum.

This Addendum should be viewed as a part of the Report and both documents must be considered together.

Nairobi, March 1990

TABLE OF CONTENTS

PART 1. STATUS OF DESERTIFICATION 1990

ACSAD REGION

Saudi Arabia

According to the Brief on Various Desert Conditions in Saudi Arabia/National Soil Survey ..., 1989 the Kingdom of Saudi Arabia is, by and large, a country of severe aridity and is, therefore, a desert. Thus, no present day desertification is taking place here in any appreciable extent. However, there are slight to moderate variations in natural conditions among certain regions. This variability could be a basis for differentiation of diverse conditions of aridity.

The current assessment of the desert conditions of the country at a scale of 1:2 million is based on soil indicators including soil salinity, soil erosion by water and wind, and rock denudation by combined action of soil erosion and retarded soil accumulation due to aridity. The data on soils were taken from the General Soil Map of the Kingdom of a scale 1:250,000 [**MIAW, 1985**]. However, it was impossible to modify the descriptions of the map units by changes, if any, induced by large-scale irrigation that has been spreading in the Kingdom since the mid-seventies. So, it is just a generalization of the existing soil data. It was not possible even to estimate the present risk of secondary salinization, which requires long-term monitoring of the process.

The following forms of desert conditions were delineated on the map, showing major soil degradation processes:

Soil Salinity	- none to very slight - slight - moderate - moderate with gypsum accumulation - severe with gypsum accumulation
Soil Erosion by Water	- none to very slight [on slopes <5%] - slight [on slopes up to 8%] - moderate [on slopes up to 35%] - severe [on slopes >35%]
Sand Blowing	- none to very slight [non-sandy soils or moist sands] - slight [dry sands on plains] - moderate [dry sands on plains plus small dunes] - severe [dry sands on plains plus high dunes]
Flooding	- none to slight [less than once in 100 years] - slight [1 to 5 times in 100 years] - moderate [5 to 50 times in 100 years] - frequent [more than 50 times in 100 years]
Rock Denudation	- none to very slight [less than 10% of the area] - slight [11 to 30 % of the area] - moderate [31 to 50% of the area] - severe [more than 50% of the area]

Naturally, it would be impossible to say anything concerning the present status of desertification in the country on the basis of these data, particularly because of the absence of quantification of various areas so far.

AFRICA

Kenya

The final report on the Kenya Pilot Study [FP/6201-87-04], which was jointly undertaken by the Government of Kenya and UNEP with a view of testing the FAO/UNEP 1984 Methodology at a local level, shows the situation in Baringo and Marsabit districts in north-eastern part of the country.

The Baringo study area was about 3,600 km². It is situated around Lake Baringo in a transitional natural zone with annual precipitations nearly 600 mm rising up to 1900 mm in the surrounding mountains. The main land use in this area is livestock keeping with some irrigated agriculture for production of vegetables, fruits and maize.

The study area in Marsabit was about 14,000 km². Two rainy seasons are marked here: long rains from March to May and short rains from October to December; other months are dry. In low lying areas, annual precipitations are less than 250 mm, while increasing up to 800 mm in the surrounding mountains. The main area is under extensive pastoralism with some mixed farming in the lower plateau of Mt. Marsabit.

The methodological aspects of this study were discussed earlier in the Report, while the substantial results on the desertification status in the area are presented in this Addendum.

The following changes were observed in the study areas:

Period	**Baringo 1950-1981**	**Marsabit 1956-1972**
Areas improved to better vegetation class, %	11.0	0.0
Areas degraded to worse vegetation class, %	14.0	20.5
Areas mainly unchanged, %	69.7	79.5
Expansion of agricultural area %	5.3	negligible
Total Area, %	**100.0**	**100.0**

Therefore, according to this study, in the Baringo area, 14 % of 3,600 km², that is about 50,400 hectares, experienced degradation of vegetation within the last 30 years, which can be attributed to human-induced desertification due to overgrazing in connection with the growth of population.

In the Marsabit area, which appeared more desert-prone, 20.5% of 14,000 km² that is about 287,000 hectares experienced the same change within 16 years.

Thus, the rates of vegetation degradation in the study areas are different: 1,680 hectares/year in Baringo and 19,000 hectares/year in Marsabit. With the present rate, if it is determined correctly, it becomes dangerous.

Unfortunately, the report on the study does not contain quantitative characteristics of soil degradation and therefore does not provide the full picture of desertification in the pilot areas. Thus it would be better to say about the trends of desertification, because the present process of vegetation degradation could be arrested and reversed under proper management system.

Mali

Two pilot studies were sponsored by UNEP in Mali in order to test the FAO/UNEP 1984 Methodology and to obtain reliable first-hand information related to the actual status of desertification in this part of the Sahelian region.

Table 1. Desertification in Yelimane and Kayes Districts of Mali, km² [Kharin, 1990]*)

Desertification	Desertification Class				Total	%
	Slight	Moderate	Severe	Very Severe		
		YELIMANI DISTRICT				
Vegetation degradation	-	89	1622	1204	2929	40
Wind erosion	-	-	142	-	149	3
Water erosion	-	-	-	-	-	-
Soil compaction	-	-	764	13	777	16
Unsuitable land **)	-	-	-	-	1945	41
Total	-	**89**	**2539**	**1217**	**4790**	**100**
		KAYES DISTRICT				
Vegetation degradation	499	3322	8619	1718	14158	64
Wind Erosion	-	-	20	780	800	4
Water Erosion	-	1627	810	51	2488	11
Soil compaction	-	520	3614	520	4654	21
Total	**499**	**5469**	**13063**	**3069**	**22100**	**100**
		TOTAL FOR THE STUDY AREA				
Vegetation degradation	499	3411	10245	2922	17077	61
Wind erosion	-	-	169	780	949	3
Water erosion	-	1627	810	51	2488	9
Soil compaction	-	510	4378	533	5431	20
Unsuitable land **)	-	-	-	-	1945	7
Total	**499**	**5558**	**15602**	**4286**	**26890**	**100**

*) Totals and percentages are recalculated as the original table of the source contains some mistakes.
**) Absolute deserts of the past [natural climatic desert].

In the study sponsored by UNEP and the French Government and conducted by the Institut Geographique National of France in co-operation with the Universite de Reims and ORSTOM, three separate areas were chosen for comparing the situations in 1952-1957 and 1987 on the basis of remote-sensing photo-images. The results are as follows (p.101).

The conclusion from this study is that land degradation in this area under desertification is slowly progressing, however with different rate in its different parts, as can be judged on the basis of the increment of bare soil: 16.5 hectares/year in Nara, 143 hectares/year in Mourdian, and 8 hectares/year in Yanfolila. This land loss can be attributed to the growth of population and cultivated land: the more land is annually cultivated the more it is lost to the desert.

As for the vegetation, the authors of the study, **[Guyot, 1990]** have observed that, "the global trends are not one-way oriented and, if in some instances one may notice a shift downwards in the vegetal cover, e.g. from tree savanna to shrub savanna, in some other places, where the environment remained relatively untouched by human activities, the change has been reversibly orientated, e.g. from shrub savanna to tree savanna or even open forest".

In another study **[Kharin, 1990; UNEP/UNEPCOM/Institute of Deserts, 1990]** the investigations were sponsored by UNEP and conducted by the Institute of Deserts, USSR, with participation of specialists from Mali. The test area occupied 26,890 km^2 with population of 3,673,000. The average annual precipitations vary from 400 to 800 mm in different parts of the area, with only two climatic seasons: wet from May to September and dry from November to April.

Degradation of the vegetative cover is the most widespread form of desertification of arid ecosystems here. It is caused by overgrazing, cutting trees and shrubs for fuel and construction, as well as by cultivation of fallow lands. Under the impact of desertification, the biological productivity here decreased by 75%. Very serious degradation of vegetation is accompanied by intensified water and wind erosion which consequently results in total degradation of arid ecosystems when the biological productivity is approaching zero point.

As in case of the French study, in various parts of the test area the situation varied [Table 1].

According to the data of Table 1, practically the whole study area is affected by desertification, especially by severe degradation of vegetative cover, with exception of the true desert which is considered to be natural climatic phenomenon here and constitutes about 7% of the total area being a fringe of the Sahara.

If we compare the results of these studies conducted by the French and Soviet Institutes, it would appear that the factual data seem to be more or less similar, e.g. 2.9% of a bare soil in the first area and about 7% in the second, but the interpretation of the results are different due to differences in the methodological approaches.

In the first case the vegetation change is not considered as an indicator of desertification, while in the second one it is taken as an indicator of severe desertification. The bare soil is considered as resulting from desertification within last 30-35 years in the first case, while it is regarded as a natural long existing desert in the second. In the first case the processes of wind and water erosion and soil compaction are not assessed at all, while in the second case they are taken as indicators of moderate and severe desertification on about 32 percent of the total study area.

Thus, the comparison of these two case studies does not provide a clear picture of the desertification status in Mali. Clearly, the unification of the methodology is imperative.

Result of UNEP/Government of France pilot project [Guyot, 1990]

	NARA	MOURDIAH	YANFOLILA
Total area, hectares	60,241	69,622	67,888
Annual isohyeth, mm	400	800	1,200
Bare soil increment, hectares	+473	+4,994	+270
--------------------, times	10	357	27
Crops of the year increment, hectares	+1,911	+6,110	+4,272
Settlements area increment, hectares	1.8	2.3	2.4
--------------------, times	+77	+43	+259
Steppe herbacée, hectares	-55	-220	-
Steppe arbustive et buissonante, hectares	+232	-	-
Steppe arborée, hectares	-965	-	-
Savane herbeuse, hectares	-92	-2	-968
Savane arbustive, hectares	+13,941	+5,682	-8,561
Savane arborée, hectares	-15,565	-14,243	-20,493
Savane boisée, hectares	+48	-2,090	+23,873
Les bowé, hectares	-	+657	-
Forêt claire, hectares	-	-132	+662
Bowal, hectares	-	-	-171
Bowal arborée, hectares	-	-	-181
Galerie forestiere, hectares	-	-	+234
Prairie marécageuse, hectares	-	-	-1,038
Dominant vegetation in 1952-1957	Savane arborée on 64.1% of the total area	Savane aborée on 73.3 % of the total area	Savane aborée on 42.7% of the total area
Dominant vegetation in 1987	Savane arbustive on 44.1% of the total area	Savane arborée on 53% of the total area	Savane boisée on 62.7% of the total area

Tunisia

In a study conducted for UNESCO MAB, **H.N. Le Houerou and R. Pontanier [1987]** noted the process of rangeland decrease in connection with the growth of arable land in Tunisia, which was described earlier in the Report as one of the main causes of desertification in marginal lands, particularly in the dry steppes.

Within a century from 1880 to 1980, the cropland for cereals [approximately 40% corn and 60% barley] had increased from about 400 thousand hectares to 2,000 thousand hectares and area of dryland tree crops [70% olives] increased from 200 thousand hectares to 1,600 thousand hectares making the total growth of cultivated land from 600 to 3,600 thousand hectares, that is by six times. At the same time, the area of grazing lands has decreased from 10,000 thousand hectares to 6,000 thousand hectares. It means, that about one million hectares in Tunisia were lost to the desert within this century due to the process of cultivation of marginal lands. The same process was described in the Report for the USSR and Syria. Now it is very strongly developing in China: Rangeland - Cultivation - Desert.

If we note the limited cultivable land resources in Tunisia as well as limited rangelands, the loss for the country is rather heavy and irreversible. The average rate of desertification would then come up to 10,000 hectares per year, which is quite heavy for a country which is not so rich in land resources, the desert occupying a large portion of its total area.

ESCAP REGION

As **Dr. B. Spooner [1988]** observed, human conditions in areas vulnerable to desertification in the ESCAP region differ in a number of obvious ways from the other regions. He cites particularly the long and relatively stable technological history of production systems, as in the use of pastoralism and oasis agriculture in Iran, Afghanistan and Pakistan, Mongolia and Western China, of agriculture in India and South-East Asia. In addition, modern industrial irrigation was first developed in what is now Pakistan and Northern India, and the major technologies for control of salinization and waterlogging have been developed in Pakistan. The ESCAP region is also the major region with examples of desertification through deforestation in the sub-humid tropics and ESCAP was instrumental in getting this form of desertification included in the global definition. According to the author's view, the most challenging aspect of the desertification problem in the ESCAP region is the sheer breadth of cultural and social diversity of the human populations that require assistance in desertification control, from Iran to the Pacific and from Mongolia to Indonesia.

According to the estimations for 1982, **[UN ESCAP, 1987]**, the desertification status in the region varies in its different sub-regions [Table 2]. The most severely affected rangelands are concentrated in China and Mongolia, while the percentage of the areas affected is highest in South Asia and USSR. In the last two subregions there is the highest percentage of the affected rainfed croplands as well, while the soil salinity problem in irrigated lands is apparently most serious in Australia.

Of course, the above estimations are rather unreliable being based on very different sources of information in respect of various subregions. They just show the general situation in the region with a certain indication of regional geography of the problem areas. Clearly, more detailed information is required. In 1987, the ESCAP/UNDP Programme on strengthening of regional network of research and training centres on desertification control in Asia and the Pacific [DESCONAP] was originated, and, hopefully, it will bring new data soon.

Afghanistan

According to the **Afghanistan Country Report [1988]** at the first DESCONAP meeting in Chiang Mai, Thailand, out of 54.7 million hectares of pastures in the country, 30 m. hectares are in relatively good condition, but 24.7 m. hectares are desertified to various degrees. These are mainly located close to

Table 2. Estimated extent of land affected by desertification in the Asia and the Pacific Region in 1982 (million hectares) [UN ESCAP, 1987]

Subregion	Rangelands			Rainfed Croplands			Irrigated Lands			Forest and Woodlands	
	total area	affected by desertification	%	total area	affected by desertification	%	total area	affected by desertification	%	total area	% change
South Asia	240	225	94	57	49.5	87	52	11.5	22	84	-19
South East Asia	-	-	-	52	?	?	15	-	-	260	-15
China & Mongolia	400	300	74	99	7.5	8	45	3.7	9	143	+20
Australia	450	150	33	39	12	31	1.2	0.4	40	39	-9
USSR [M.As. & Kaz.]	150	125	83	25	17.5	70	8	2.2	28	?	?
Total	**1240**	**800**	**65**	**274**	**86.5**	**50**	**121**	**17.8**	**14**	?	?

habitations and have been heavily overgrazed during the last decade adding to the rapid advancement of desert. Barely 20% of the forest land has well stocked forest.

M.A.Nazim [1988] agrees, that the official figure of 1.9 million hectares of forests, 2.9 percent of total country area, has now become questionable. Certain portion of the existing forest seems to be gradually disappearing because the only source of energy being used in the country is fuelwood, bushes and charcoal. Desertification has assumed such disturbing proportions in the country that special attention of the Government is being continuously drawn to the need for its solution. In the course of the past eight years, the process of desertification is on an increasing scale.

An attempt to assess the desertification status in northern Afghanistan was also recently made by the Desert Institute of the USSR **[Kalyenov, Kharin, 1990]** by way of interpretation of air and space photo-images without ground surveys. An intensive process of desertification has been detected in the area. Vegetation degradation by extensive pastoralism and consequent eolian deflation are the most characteristic types of desertification in sandy territories. The wind erosion is also very active in arid territories composed of surface clay and loess deposits.

China

The extensive studies of desertification status in China were recently undertaken by the Desert Institute of the Academia Sinica at Lanzhou. It is planned, that the Desertification Map of China will be produced and published by the end of 1990 at a scale of 1:4,000,000. There are already certain experimental maps for the case studies at scales of 1:50,000; 1:100,000; and 1:300,000, showing various forms of desertification, their rates, and risks. The studies are based on remote sensing data and ground surveys.

According to **Professor Zhu Zhenda and his colleagues [1988]**, desertification is the process of environmental change through which desert-like landscape appeared on an original non-desert land due to excessive human activities and influences of natural conditions in arid and semi-arid zones during a historical period; desertification-prone lands is the territory influenced by desertification.

Within the desertification-prone areas, desert-like landscape appeared due to the following:

- the landscape of sand desert extended and enlarged at the periphery of sand desert, that is on the original desert-steppe and steppe zones where vegetation was luxuriant in the historical period;

- desert condition was strengthened in the interior of sand desert, that is the sand desert caused by natural factors has been further enlarged in the historical period.

90% of desertification-prone areas of China occur in desert-steppe and steppe zones surrounding the deserts. In arid desert zone in the west of China such areas are scattered in the oases at the lower reaches of rivers in the interior or at desert periphery, or distributed in the areas where sand dunes encroach and move towards the desert periphery under wind forces.

In fragile arid and semi-arid ecosystems, desertification is easily caused by the impact of human activity. The phenomena of desertification, in which the occurrence of shifting sands is regarded as one of the major indicators, generally start from the settlements, farmlands, water wells and springs and enlarge in a spotty pattern. As a result, a mixed landscape of shifting sands, and semi-fixed dunes is formed.

Professor Zhu Zhenda considers that China's desertification problem, in addition to shifting-sand damage resulting from eolian force action, includes water erosion in mountainous areas. However, all estimations of the desertification status in China, both cartographical and statistical, include to present, only sand areas affected by wind action, and do not include either water erosion, or salinization damage. Therefore, in China till now, desertification is only the eolian activity in sandy areas. This should be kept in mind while comparing the data on China with the same for other regions of the world. It means that all data on desertification in China are much lower than that of the actual situation.

According to the Chinese studies, the desertification-prone lands in China occupy 334,000 km^2, of which 176,000 km^2 have been already desertified and 158,000 km^2 belong to so called latent desertification-prone lands, or slightly affected areas at high risk. Of these total lands:

29% are in the western part of N-E China with the spread of desertification in marginal lands and blow sands in dry-farming areas;
42% are in central Inner Mongolia and adjacent areas with the intensification of desert-like conditions in marginal area of the steppe;
29% are in the other places with dune encroachment at oases periphery, reactivation of fixed sand dunes and blow-sand disasters.

Of the total desertification problem in the country, 42.2% is classified as desertification of sandy steppe and 52.3% as reactivation of fixed sand dunes and encroachment of shifting sands.

The main causes of desertification are classified as follows:

25.4% due to over-cultivation of marginal steppe land;
31.8% due to collection of fuelwood;
5.3% due to sand dune encroachment under wind force;
37.5% due to misuse of water resources, destruction of vegetation, technical problems.

According to the degree of desertification, the area affected is classified as follows:

Most severely desertified lands	34,805 km^2	Mobile dunes occupy dominant percentage of the area and densely distributed; annual growth of shifting sand more than 3%; should be fully protected; very difficult to recover.
Severely desertified lands	60,677 km^2	Shifting sands in patches and interspersed with fixed and semi-fixed dunes; annual growth of shifting sand 2-3%; should be closed to grazing, but can be used for hay production.
Lands affected by on-going desertification [moderately desertified]	80,960 km^2	Sand sheets and sand mounds, soil erosion and surface roughness; annual growth of shifting sands 1-2%; can be used for grazing with proper careful management.
Land at high risk of desertification	158,000 km^2	Shifting sand in small scale and blown out sands; annual growth of shifting sands less than 1%; can be used with appropriate management.

Thus, the area affected by desertification is classified in following way:

Already desertified land	176,442 km^2	52.7%
- most severely	34,805 km^2	10.4%
- severely	60,677 km^2	17.9%
- moderately	80,960 km^2	24.4%
Lands at high risk	158,000 km^2	47.3%
Total land affected	334,442 km^2	100%

Comparison of aerial photos of 1950s and 1970s has revealed that 39,000 km^2 of desertified land increased since last 25 years, that is about 1560 km^2 per year was desertified due to cultivation of sandy steppe and reclamation of fixed dune areas, to the collection of fuelwood, overgrazing and reactivation of sand dunes.

The desert in China is growing with an alarming speed. **Wang Dongtai [1990]** quotes the data of the Desert Institute, according to which in Baokang County north of Beijing in Hebei Province 24.7% of the land was desert in 1970s while by the 1980s desert constituted 38% of the Country's land. Fengning County was covered with grass 40 years ago, but by the 70s 16.2% of the Country's land was covered by sand and by 80s 25% of the Country's land was desert. Two major deserts of China's north are expanding: one is around the northern part of Beijing threatening the capital of the country.

The following concept and the definition of desertification is adopted in China:"...under fragile ecological conditions in arid, semi-arid and some parts of sub-humid zones, degradation of environment similar to sandy desert characterized by blown sand and wind drifts appeared on the original non-desert lands due to excessive activities and the disequilibrium of ecosystem. The so-called degraded environment similar to sand desert-like is not limited on the arid desert zone from the view point of natural zone, it refers to similar features of eolian landform of sand desert in consideration of surface landscape and its similarity of ecological environment in desert environment... The final result of degradation refers to the occurrence of eolian landform on surface which is similar to that of sand desert, it refers also to the reduction of biomass production and the loss of available land resource due to quick sand encroachment" **[Zhu Zhenda et al., 1988]**.

In Northern China there is a vast distribution of desertification-prone lands which are characterized by remarkable eolian landform and wind drifts. Particularly in the marginal area [transitional zone of the dry-farming system and steppe] in semi-arid zone, desertification prone lands occupy 64 % of the total land area of the region. Taking Horqin Steppe as an example, desertification prone lands increased and occupied 53.8% of the total land area of the region at the end of 1970s from the former 20% at the end of the 1950s. Even on Xilin Gol Steppe, desertification-prone lands around grazing plots, drinking wells and along traffic roads spread in manners of linear or spotted development. Taking Sonid Zuoqi County as an example [not including Otindag Sandy Land in the South of Sonid Zuoqi], desertification-prone lands were increased and occupied 8% of the total land area of the County at the end of the 1970s from the former 2% in the 1950s. In Ulan Qarb Prefecture, (Inner Mongolia), farm land impacted by desertification hazards occupied 46% of the total area of dry-farming.

"In consideration of the above real facts in China, we termed the process of environmental degradation, during which eolian land-form appeared on the surface and land productivity declined, the process of desertification and the lands impacted by the process is titled desertification-prone lands. Several years practices indicate that the adaptation of the above concept of desertification accelerated in fact the extent of scientific results in the field because the definition is unequivocal, the extent is concrete, measures are effective and acceptable to local people" **[Zhu Zhenda et al., 1988]**.

"...desertification is a process of environmental degradation which indicated by the eolian activities and drifting sands caused by dis-accordances between excessive human activities, resources and environment on the basis of certain sand material sources under the dynamics of serious drought and frequent wind" **[Ibid.]**.

"...by desertification we mean in fact the sand desertization". The intensity of desertification is measured by *"the increase percentage of drift sands in the total land area of the region and the annual growth rate of sand surface caused by blowouts"* **[Ibid.]**.

Therefore, the total area of China affected by desertification is under- estimated at present. It does not for example include the stony deserts or desertified areas, but also the newly formed salt deserts as well. A new assessment is on the way and should be accomplished by the end of 1990. It is planned to be more comprehensive.

Inida

Among the values and beliefs that have affected recent desertification in India, some relate to population growth [e.g. fragmentation of families and land holdings, which become uneconomic] to social security [e.g. large number of children and large herds as a security against famine and similar risks], or to economic and agronomic processes **[Bharara, 1988]**.

A preliminary reconnaissance made in few of the western districts of Madhya Pradesh by **Dr. H.K. Jain [1988]** has shown that the process of xerification has already set in these areas and if an immediate action is not taken up then the whole region would be converted into desert within a period of three to four decades. It would be a result of the combined pressure of adverse and fluctuating climate, and excessive exploitation by man. It was also shown that these districts are now experiencing dry sub-humid to semi-arid type of eco-climate which were falling under moist sub-humid to marginal humid type of eco-climatic zone just a couple of decades ago. Khargone, Jhabua, Rajgarh and Guna districts appear to have been worst-hit by the process of xerification and are on the verge of becoming desertified areas. Thick dry deciduous forests existed in these districts three to four decades ago which have now been converted into bald country

with round basalt pebbles and stones constituting the uppermost layer; one cannot see soil anywhere in the terrain. With 8 to 9 months of dry season and with 800-1000 mm of annual rainfall occurring from July to September, the erosion destroys soil very quickly when protective vegetation is degraded by man, leaving desert behind. Consequently, the livestock production is decreasing and large numbers of people have migrated and are migrating to adjoining areas for labour work, still more increasing the pressure of the population upon the land in areas where soil still exists.

According to data of CAZRI **[ICAR, CAZRI,1988]** all available evidence suggests that the Rajastan desert had not and is not advancing towards the east, but that fresh sand deposition is still going on towards the west, the desertic conditions have further deteriorated in the recent past. The situation is assessed as follows:

		% of the Total Area of Western Rajasthan
Natural Land Vulnerability		
Desertified area	9,290 km²	4.35
High to Medium Vulnerable	162,900 km²	76.15
Medium to Slight Vulnerable	41,962 km²	19.50
Total	**231,882 km²**	**100.00**
Desertification Hazards		
Desertified area	9,290 km²	4.35
High	135,292 km²	63.26
Medium	67,400 km²	31.51
Slight	1,900 km²	0.80
Total	**231,882 km²**	**100.00**

J. Venkateswarlu [1989] states that the productive area is shrinking in India as hectare/capita:

1951	1971	2000
0.33	0.29	0.18

Due to this shrinkage, additional, mostly marginal lands were brought under cultivation between 1951 and 1983 amounting up to 24 million hectares. As was earlier mentioned in other parts of the Report, this is a potential for further desert growth. Deforestation adds to this potential danger: 4.3 million hectares of forests disappeared between 1951 and 1980. The soil loss is alarming: taking 5t/ha soil loss due to erosion as "tolerable", at least 58.08 million hectares of arable land and 6.31 million hectares of forest areas are subject to greater soil loss needing immediate attention. Flood-prone area has increased at the same time from 25 million hectares in 1950 to 40 million hectares in 1980. The salt-affected soils comprise some 7.0 million hectares.

Latest estimations have revealed that the priority soil conservation measures are needed in connection with:

Soil erosion	58.08	m. ha
Flood control	9.00	m. ha
Waterlogging [in irrigated areas]	0.70	m. ha
Salinization	3.90	m. ha
Deforestation	10.00	m. ha

However, the control measures are difficult to introduce because the net benefit from soil conservation is not beyond 15% in the form of additional yield which is not viable. The effects are to be considered over a long term. The farmer at the micro-economic level tends not to consider this as his priority programme, even if he understands the problem.

Indian scientists consider that the large-scale irrigation projects are responsible for ever increasing waterlogging and salinization. In this process the loss in agriculturally useful area is estimated to be 10 million hectares. As of today [1989], 7 million hectares is estimated to be affected by various degrees of salt infestation. In 37 major river valley projects in the country some 0.74 million hectares are estimated to be affected by salt infestation. Out of 31.7 million hectares of Thar desert spread over the states of Haryana, Rajasthan and Gujarat, some 1.3 million hectares are affected by desert. In addition about 22.8 million hectares has become highly vulnerable to desertification. The Thar desert is highly populated, arid and is overgrazed by livestock. Soil loss occurs here through both wind and water erosion.

In addition, the NCDBA estimated that 2.7 million hectares in the north-eastern states are under shifting cultivation out of the total 4.36 million hectares in the country. Such a system leads to enormous soil loss due to erosion.

On the other hand, **P. Singh [1989]**, considers that, out of the total geographic area of India [328.6 million hectares], about 175 million hectares is affected by soil erosion and land degradation and about 260 million hectares faces varying degrees of drought. Various forms of land deterioration are as follows:

Area subject to water erosion	111.3	m.ha
Area subject to wind erosion, including 7 m.ha area infested by sand dunes	38.7	m. ha
Area degraded through:		
- waterlogging	6.0	m. ha
- alkalinization	2.5	m. ha
- salinization, including coastal sands	5.5	m. ha
- ravines and gullies	3.97	m. ha
- shifting cultivation	4.36	m. ha
- riverine processes and torrents	2.73	m. ha

A campaign is being implemented in India for the development of wastelands **[Eswaran, 1989]**. The wastelands are defined as degraded lands which produce nothing, or far less biomass [crops, grasses, trees, etc.] than is possible by using currently known technology. In India, the extent of wastelands is about 130 million hectares, of which, about 93.7 million hectares are outside the forest areas. For the non-forest area these lands include:

Saline and alkaline lands	7.17	m. ha
Wind-eroded lands	12.93	m. ha
Water-eroded lands	73.60	m. ha
Total	**93.70**	**m. ha**

All the above data, although somewhat controversial in different information sources, show very clearly the dangerous status of Indian land resources, particularly due to different forms of desertification, that is land degradation due to human impact in arid, semi-arid and dry sub-humid zones.

Indonesia

Indonesia does not technically fall within the properly defined arid countries. However, according to the concept developed in ESCAP, the country is included into the scope of the desertification problem as an indication that land degradation is rampant. According to the First Assistant Minister for Population and the Environment, **Indonesia, [1988]**, the desertification here "can be meant as a deforestation process on the forest lands and land degradation occurred on both agricultural and rural areas". The total area affected by such processes is rather large, but it is doubtful that it should be included into the global assessment of lands affected by desertification.

Iran

The present land use pattern in Iran is characterized by the following figures **[Ganji, Ali Farzaneh, 1990]**:

Type of Land Use	Area, million hectares	% of the Total
Rangelands	90.7	55
Deserts, desertified and degraded lands	34.6	21
Forests	12.2	7.4
Agricultural lands	23.8	14.4
Cities, lakes, etc	3.7	2.2
Total	**165.0**	100

Most of the country consists of arid and semi-arid lands [about 80% of the total area of the country] in which the average annual rainfall is less than 300 mm, and potential evapo-transpiration is many times higher. Land degradation and soil erosion in the interior plateau of Iran have been closely associated with man's settlements and his activities. There are many evidences to prove this occurrence during the past centuries. But the land degradation and desertification have accelerated during the last century and especially during the last 25 years, because of:

- doubling of population during last 20 years;
- increase of herds and overgrazing;
- conversion of rangelands into croplands with increase of dry farming;
- uncontrolled use of inappropriate farm machinery;
- fuel gathering;
- irregular exploitation of water resources and mismanaged irrigation;
- cutting of forests [from 18 million hectares 30 years ago to present 12.2 million hectares];
- outmigration of labour force from rural areas to cities.

Until 25 years ago, damages associated with sand movement and dune encroachment were increasing annually. Villages by the hundreds were being abandoned because they were actually buried by sand.

Awareness of the increasing severity of sand encroachment developed about 1958. Major activities to stop sand movement started to be implemented in 1965-1966. Till present, about 3 million hectares of moving sands and desertified areas have been rehabilitated. The sand dune fixation programme included:

transplantation	898,526 hectares
broadcast seeding	2,027,676 hectares
petroleum mulching	177,330 hectares
palisade construction	9,556 km

According to the ESCAP data **[UN ESCAP, 1988]**, the steady increase in village population has resulted in demand for more arable land, and the area of range and forest has decreased drastically.

According to **Ali Akbar Mahboubi [1989]**, the rangeland of Iran is 100 million hectares, and it provides forage for 60 million livestock units out of the total of 120 million units of the country. This overgrazing puts a heavy burden on the rangeland which should only feed 16 million animal units.

The forests of Iran have also been over-exploited. Of the total 3.8 million hectares of the northern forests, only 1.8 million hectares has remained. Soil erosion through rain and wind is of extensive dimension.

Approximately 12 million hectares are covered with sand, of which, one half is highly active and does damage to the inhabitants of the marginal lands. Up to now, only 1.113 million hectares of the sandy land has been brought under conservational measures, such as the extension of vegetation. There are 8.180 million hectares of swamps and gullied land in Iran which need also some rehabilitation measures.

As for the state of the rangelands, the following figures are indicative:

Good pastures	19 m. ha
Medium pastures	25 m. ha
Poor pastures	56 m. ha
Total	**100 m. ha**

With the exception of the northern strip of the country, most of the Iranian arable lands are more or less saline. The area of highly saline and water-logged land is about 1.18 million hectares. With construction of dams in some places like Khozestan and development of irrigation networks, secondary salinization has intensified.

The erosion hazard is also appreciable. It is estimated that about 1 billion tons of soil is annually lost by erosion.

Mongolia

According to **G. Dembereldetj [1989]**, semi-deserts and deserts occupy about one third of the country area. Comparison of old maps with satellite pictures since 1970s showed that sand boundaries were expanded by several kilometers in some areas. However, no reliable data on desert expansion are yet available.

A study conducted by the Soviet scientists, **[Kharin, 1990]** showed that the present range management practice leads to a severe desertification in desert-steppe and desert zones of the country. Specific site-related criteria for the assessment of desertification in Mongolia were developed by the study team. No quantitative information on the results of the study is yet available.

Nepal

Nepal is also included by ESCAP in the zone benefiting from anti-desertification activities. **S. Bhattaraj [1988]**, noted that "although Nepal does not fall under the true definition of desertification, i.e., the total destruction of biosphere potential and conversion of the land into sand or rocky desert, but it falls under the category of desertification which leads to the loss of agricultural productivity of the soil, increase of runoff and subsequent loss of soil nutrients as a result of reduction of plant biomass, etc. With this, Nepal cannot be separated from other countries of the region in the context of potential vulnerability to desertification".

The assessment of current situation in the country has revealed the annual loss of 240 million m^3 of soil through Nepal's major rivers and this is equivalent to 1.7 mm of topsoil per year. About 47% of soil erosion is attributed to natural processes, while the remaining 53% is human induced. About 5% of erosion problems are due to construction of hill roads, other causes being connected with forest clearing, shifting cultivation and overgrazing.

Pakistan

Describing the current status of desertification in Pakistan, **M. M. Ashraf [1988]** states that "desertification is a serious problem of Pakistan where almost three fourths of the land is either affected or likely to be affected by this process".

By and large, Pakistan is an arid/semi-arid country with 68 million hectares of the land areas lying in regions receiving less than 300 mm annual rainfall. Out of the total area of the country, 51.5% is arid, 36.9% is semi-arid, 5.4% is sub-humid and 6.2% is humid. The present land-use pattern of the country is characterized by the following figures:

Cultivation	20.54 m. ha	23.3%	[including 14 m.ha of irrigation]
Culturable waste	11.19 m. ha	12.8%	
Not available for cultivation	23.25 m. ha	26.4%	
Area under forest	4.58 m. ha	5.2%	
Unclassified area	28.42 m. ha	32.3%	
Total	**87.98 m. ha**	**100.0%**	

The main problems of desertification in Pakistan are:

- abandonment of irrigated croplands affected by water-logging and salinization [Punjab];
- abandonment of villages, traditional irrigation systems and croplands desertified by deterioration of ground water aquifers or lowering of the ground water table [Baluchistan];
- siltation of rivers, irrigation systems and reservoirs;
- land slides in hilly areas;
- disappearance of physical infrastructure of rangelands under shifting sand dunes.

More than 90% of agricultural land in Sind province is affected by salinization. The land affected by the salinity increases by 40,000 hectares every year. The economic costs of water-logging and salinity are estimated at US$ 140 million per year [$ 25/hectare/year].

The following figures show the soil salinization problem in the country in thousand hectares:

Province	Area Surveyed	Slightly Saline	Moderately Saline	Strongly Saline	Total Surfacely Saline	
Punjab	9968	698	399	299	1396	14%
Sind	5411	1028	595	974	2597	48%
North-West Frontier	550	50	11	11	72	13%
Baluchistan	352	60	18	14	92	26%
Total	**16281**	**1836**	**1023**	**1298**	**4157**	**26%**

Alongside with water logging and salinization of irrigated lands, water erosion presents serious problems as well. The Potwar plateau has been particularly subjected to the processes of soil erosion: there are about 1.3 million hectares of gullied land here.

The rangelands in Pakistan constitute a substantial part of the country's natural resources:

Province	Total Area m.ha	Range area, m.ha	% of Ranges
Punjab	20.63	9.70	47
Sind	14.09	9.28	65
N-W Frontier	10.17	5.68	55
Baluchistan	34.72	32.43	93
Northern Areas	7.04	3.50	50
Azad Jammu & Kashmir	1.33	0.60	45
Total	**87.98**	**61.19**	65

Most of the rangelands are presently in a depleted condition, are subject to improper management and subjected to over grazing due to uncontrolled growth of livestock numbers without any regard to the carrying capacity of pastures. The current production of rangelands is estimated as 25.4 million tons of dry matter in comparison with the potential of 75.73 million tons. At the same time recent increase of the livestock in the country is as follows, million heads:

1972	1976	1981
53.8	68.0	91.8

Therefore, the desertification problem in Pakistan is rather serious, affecting both cultivated lands and rangelands.

Philippines

According to C.C. **Tomboc [1988]**, symptoms of environmental deterioration leading to desertification are clearly seen in the country:

- uncontrolled destruction of natural forests;
- zero vegetative cover in some provinces like Cebu;
- alarming growth of the population;
- formation of sand dunes in the north of the country;
- intrusion of saline water into the aquifer due to massive withdrawal of fresh water for the burgeoning population, industrial expansion, prawn industry, etc.;
- erratic climatic condition (changing climatic patterns).

However, as in case of other humid areas of the ESCAP region, it is questionable whether this observed land degradation could be classified as desertification.

Thailand

Thailand is a monsoon humid country with a pronounced dry season of several months. Thus, desertification is possible here, particularly in the northern interior regions. However, the situation is not very clear here. The present day situation may be illustrated by the following figures characterizing the land-use pattern of the country:

Year	Population million	Arable land & permanent crops m. ha.	Agricultural land ha. per capita	Forest m. ha	Forest ha. per capita	Waste lands m. ha.
1960	25.520	7.943	0.311	25.230	1.028	17.227
1984	50.584	19.054	0.386	15.403	0.305	16.032
1986	52.546	20.224	0.386	14.905	0.284	16.248

It is clear, that the destruction of forests is progressing in Thailand, on account of which the cropland is growing for the needs of expanding population. However, unlike in other parts of the world, the agricultural area per capita of population is still not decreasing here and the area of wastelands is apparently not growing as well. It is rather strange, and the situation should be properly studied. It is particularly strange with so big rate of deforestation as could be seen from the following figures on the forest area in Thailand:

Year	Area, km^2	% of the total country's area	Average annual rate of deforestation (km^2)
1961	273,579	53	-
1973	221,707	43	4,323
1976	198,417	39	7,763
1978	175,434	34	11,492
1982	156,686	31	4,687
1985	149,053	29	2,544
1988	143,804	28	2,354

With the above rate of deforestation, land degradation is usually very much accelerated. However, it is not seen in this case from the land-use pattern figures. Either the country is very much advanced in the area of land protection and conservation, or the statistics is not appropriate. It has to be studied.

USSR: Middle Asia and Kazakhstan

A "Map of Man-Made Desertification of the USSR Arid Lands" was prepared at a scale of 1:2,500,000 using on the FAO/UNEP 1984 Methodology with certain criterial changes and adaptation to the scale and local conditions. The explanatory note to this map was recently published **[Turkmen SSR Academy of Sciences, Desert Institute, 1988]**.

The map shows the status of desert environment and human impacts as observed in 1985. The changes in the environment that have occurred during last 20 years were estimated.

The following processes of desertification were identified within the territory of Middle-Asian republics of the USSR covering the major portion of the arid belt of the country:

1. degradation of vegetation caused by overgrazing;
2. degradation of vegetation around desert wells due to concentration of livestock at watering points;
3. degradation of vegetation caused by under-grazing identified in the areas with dense cover of desert moss;
4. wind erosion;
5. water erosion;
6. salinization of irrigated lands;
7. soil salinization caused by sea level lowering and by the withdrawal of the river flow;
8. technogenic desertification caused mostly by heavy vehicles.

Several aspects of the desertification were distinguished on the map, namely: status, rate, inherent risk, domestic animals pressure, population pressure, desertification hazard as an integrated indicator. Specific criteria for each of the aspects were developed on the basis of the data and the experience gained by the Institute of Deserts, Ashkhabad. These criteria are somewhat different from those suggested by the FAO/UNEP 1984 Methodology in the quantitative aspects.

The statistical data on the desertification assessment basing on this map were published earlier and have been briefly discussed in the appropriate part of the Report and thus do not need to be repeated.

Vietnam

The available data show accelerated deforestation in Vietnam leading to land degradation as in cases of Indonesia, Nepal, Philippines and Thailand, although it has rather remote relationship to the desertification.

The forest area in Vietnam has decreased drastically during recent decades, with annual rate of deforestation of about 160,000 hectares:

1943	14.3 million hectares;
1983	7.4 million hectares.

On account of this process, the degraded lands on denuded hills extended for 13.9 million hectares, or 35% of the country's area.

The status of the existing forests is also far from satisfactory:

2.7 m. ha	forests with timberwood stock up to 140 m^3/ha;
3.0 m. ha	forests with timberwood stock less than 50 m^3/ha;
1.1 m. ha	bamboo groves;
0.6 m. ha	other mixed forests of no economic value;
7.4 m. ha	total forest area.

The same general situation is observed here as in the majority of the countries of South and South-East Asia: accelerated deforestation and consequent land degradation due to human-induced accelerated soil erosion by water action under monsoon climate. However, it is doubtful that this phenomenon should be classified as desertification, particularly with the definition which was adopted by the Ad-Hoc Consultation in February 1990.

PART 2. METHODOLOGIES USED FOR DESERTIFICATION ASSESSMENT

As was already stated in the main Report, different methodologies were employed by the organizations and individual scientists for the assessment of the status of desertification in different parts of the world or for the world as a whole, naturally, with different end-results. Additional material reviewed in the Addendum has confirmed this observation.

It is quite natural that no uniform methodology can be utilized for the assessment at various levels: global, regional or sub-regional, national or provincial, and local. The degree of detail and the parameters and indicators of the process would be very different depending on the level and scale of the assessment, particularly if it is made on the basis of actual mapping at various scales. The same is true for the accuracy and the reliability of the assessment results. However, one and the same basic methodology should be employed for one level and scale of the assessment throughout the area assessed, and the main philosophy of the assessment should remain the same throughout various levels and scales. Unfortunately, this is not the case, as it was clearly revealed by the analysis of published materials and during the discussions at the Ad-Hoc Consultation in Nairobi **[UNEP DC/PAC, 1990a]**.

In simple words, it all goes back to the main question of what is to be assessed, what is desertification and what is not. Vague, un-operational definition of desertification adopted by UNCOD in 1977 has resulted in all subsequent difficulties in this respect.

At the Ad-Hoc Consultation, these differences in the approaches to desertification assessment appeared particularly in presentations of the case studies from different regions, although all of them started from the basic FAO/UNEP 1984 Methodology from which they all deviated into various directions, apparently due to different local conditions and, mainly, due to the differences in understanding and the perception of the process and its consequences or manifestations.

Of course, all the nations and organizations are free to adopt that assessment methodology for their internal use which would be most suitable for their conditions and purposes. However, the diversity in approaches and actual methodologies is leading at present and will continue to lead in the future to great difficulties in composing the global picture.

The existing desertification assessment methodologies, although innumerable by their details, might be classified into certain general cases in order to understand the global situation and to come out with some remedial proposals.

1. There are certain countries, e.g. Australia and the United States of America, as was stated by R. Perry and H. Dregne at the Ad-Hoc consultation, which do not use the term "desertification" for their internal purposes, even in arid territories, because of its vague concept, but rather employ such concepts as "range deterioration", "soil degradation", "soil loss", "land degradation", etc. They have developed monitoring systems to determine changes in soil and vegetation which permit them to assess the current situation and to undertake necessary remedial measures at a proposed time in order to control degradation processes. Of course, these arrangements are not always adequate in real life due to a number of social, economic and technical reasons, and the degradation of natural resources does take place in these countries, as elsewhere, but, theoretically speaking, they are prepared and equipped to cope with the problems and to provide appropriate data concerning the situation in their territories for the world-wide assessment if provided with globally accepted definition of what is to be assessed in measurable parameters.

2. A number of countries, e.g. Indonesia, Philippines, Vietnam and some others in the ESCAP region or some countries in Equatorial Africa, do use the term "desertification" but not in its original concept. They employ it for describing land degradation resulting from deforestation or shifting cultivation and subsequent water erosion under very humid climates, which has nothing to do with the aridity or desert conditions. Accordingly, the data from these parts of the world enlarge artificially the global picture of desertification.

3. In China, the term "desertification" is presently applied only to wind erosion in sandy areas. The existing maps and statistical data produced by IDRAS at Lanzhou show only this phenomenon in relation to both soil and vegetation degradation. By the end 1990, IDRAS is planning to change this position, as the author of this report was informed by Prof. Zhu Zhenda, Director of IDRAS. Water erosion, soil salinization and other forms of land degradation will be included into the assessment. Therefore, the status of desertification in China is presently underestimated, but after 1990 the data might be changed. It should be kept in mind while composing the global pictures.

4. Several countries, e.g. Afghanistan, India, Iran, Pakistan and some others, use for the assessment of desertification the existing data of land-use surveys with certain indications of deterioration of natural resources, particularly soil and vegetation. These data are interpreted in terms of the desertification hazard but do not usually contain any indication of the degree or rate of the process or its actual manifestation pattern. These interpretations are often made without proper background information and should be regarded as qualitative estimations.

5. Some countries, e.g. USSR, attempted to make actual surveys basing on the FAO/UNEP 1984 Methodology. However, the original methodology was substantially changed in the course of the assessment, particularly in respect of quantification of the parameters. Therefore, the ratios between different degrees of desertification, i.e. slight, moderate, severe and very severe, should be considered with utmost care, bearing in mind the national specifications. Moreover, as far as the USSR is concerned, only its Asian part is covered by the present assessment, while the northern and western parts of the Caspian basin are left out.

6. Several case studies were recently undertaken by various bilateral or multilateral agencies, with assistance from UNEP or otherwise, in a number of developing countries, e.g. Afghanistan, Kenya, Mali, Mongolia, in order to test the FAO/UNEP 1984 Methodology at a local level. Unfortunately, all of them came out with different results of the assessment because of these or those

methodological adjustments and innovations introduced in the course of the assessments. It is necessary to undertake some research before comparing them with each other.

Thus, the problem of the methodological unity still remains unsolved at a global scale, mostly due to the vagueness of the original definition of desertification.

This problem was extensively discussed at the Ad-Hoc Consultation in Nairobi. The participants came to the conclusion that the new definition is required in order to obtain a more reliable global picture of areas affected by desertification. The following definition was adopted:

- Desertification/Land Degradation, in the context of the assessment, is land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact.

Land in this concept includes soil and local water resources, land surface and vegetation or crops.

Degradation implies reduction of resource potential by one or a combination of processes acting on the land, including water and wind erosion, sedimentation and siltation, long-term reduction in amount or diversity of natural vegetation, crop yields, soil salinization and sodication.

It was further decided that the assessment should provide estimates for the effects of each of the processes involved based on explicit criteria.

The information on the status of each process should form part of the assessment, which should not merely present an aggregate severity class for undifferentiated desertification/land degradation.

It was then suggested that the World Map of Soil Degradation (GLASOD) at a scale of 1:10,000,000, which will be completed and published by mid 1990 by the international efforts, could be taken as a basis for preparation of the World Desertification Map at the same scale in order to assess the global situation in unified terms of actual mapping with an accuracy permitted by the scale.

The World Desertification Map will be accompanied by an Atlas showing the situation at various levels, including regional, national and local, with a view to promoting the unified methodological approach throughout the world.

The Map and the Atlas will be created by UNEP with assistance from the UN agencies, such as FAO, WMO and others. It will be computed using the existing GIS databases of various agencies, including GEMS.

PART 3. CONCLUSIONS AND RECOMMENDATIONS

1. The United Nations Conference on Environment and Development will be organized in June 1992. According to the appropriate UN General Assembly resolution concerning the Conference, the global problem of desertification should be considered among the others basing on new data collected specifically for this purpose. In order to provide these data, UNEP has to undertake immediately new up-to-date assessment of the status of desertification in various parts of the world. All the materials to be presented to the Conference should be ready by end 1991 giving the time space of one and a half year for actual work. The matter is aggravated by the fact that the preparatory work must include four although closely interrelated but rather specific areas: (i) assessment of the status of desertification; (ii) evaluation of the existing Plan of Action to Combat Desertification from the point of view of its validity at present, 15 years since UNCOD; (iii)

general assessment of progress in implementation of the PACD; (iv) financial and institutional aspects of anti-desertification programmes.

2. Bearing in mind the fact that the degree of accuracy of the data depends primarily on the scale of the assessment, taking into account the available data and time constraints, it would be advisable to present to the world community at the Conference only a general picture of the status of desertification in the world by several slices of different accuracy and credibility:

(i) for the global level - the Desertification Map of the World at a scale of 1:10,000,000 showing general global pattern of desertification or rather the areas affected, probably without any attempt to distinguish the processes, degrees, rates, etc.; this map should be based on the GLASOD data within the limits of arid, semi-arid and dry sub-humid areas supplemented with additional indicators as required; this work might be accomplished by UNEP with the assistance of other relevant UN agencies;

(ii) for the regional level - the Desertification Map of Africa at a scale of 1:5,000,000 could be produced basing on the existing GIS databases of GEMS and FAO; this work might be accomplished by FAO;

(iii) for the national level - the Desertification Map of China at a scale of 1:4,000,000 could be compiled jointly by IDRAS and DC/PAC basing on the version which is now being prepared in China; another map for Kenya can be produced at a scale of 1:1,000,000 basing on the existing in formation by the Government of Kenya with certain international assistance;

(iv) for the local level - certain examples of existing desertification maps, e.g. Horqin Sand Land of China (beautifully published with Chinese and English legends), could be included into the collection.

Being supplemented by the World Atlas of Thematic Indicators of Desertification, the above cartographic materials will constitute a solid basis for the UNEP Report on the status of desertification 1992.

3. In addition to the UNEP Report, the Governments could be requested to present the results of their own assessment of the status of desertification within their respective territories, or, alternatively, the centrally obtained results of global assessment at a scale of 1:10,000,000 could be verified by the Governments through a series of regional working meetings; the second alternative seems to be preferable although rather delicate.

4. The global figures for the areas affected or likely to be affected by desertification should be taken from the new world map at a scale of 1:10,000,000 which can be presented by the continents through direct measurements. It might not be advisable to try to obtain new figures of global annual losses as there are and there will be no reliable new data for such an estimation. However, certain examples of annual losses for the areas having reliable data can be included into the Report.

Bearing in mind the amount of work to be produced within the short time, the closest collaboration of UNEP [DC/PAC, GEMS], FAO, WMO and other relevant organizations of the UN system seems to be imperative in order to accomplish the task.

LIST OF THE DOCUMENTS USED FOR THE ADDENDUM

1.	Afghanistan Country Report, 1988	Reports of the First Consultative Meeting of the Regional Network of Research and Training Centers on Desertification Control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.
2.	Ashraf M.M., 1988	Status of Desertification in Pakistan. Ibid.
3.	Bharara L.P., 1988	Social Policy for Desertification in Rajastan. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 26-28.
4.	Bhattaraj S., 1988	Status of Desertification Problems and their Control Measures in Nepal. Reports of the First Consultative Meeting on the Regional Network of Research and Training Centers on Desertification Control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.
5.	Dembereldeij G., 1989	Meteorological aspects of Desertification in Mongolia. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in the Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.
6.	Dregne H., 1989	Informed Opinion: Filling the Soil Erosion Data Gap. *Journal of Soil and Water Conservation*, July-August 1989, 303 to 305.
7.	Eswaran V.B., 1989	Peoples Participation in Wastelands Development. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in the Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.
8.	First Assistant Minister for Population and the Environment, Indonesia, 1988	Desertification in Indonesia. Reports of the First Consultative Meeting of the Regional Network Research and Training Center on Desertification Control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.
9.	Ganji M.R., Farzaneh Ali, 1990	Desertification and its Control in the Islamic Republic of Iran. Bureau of Sand Dune Fixation and Combating Desertification, Forestry and Range Organization, Ministry of Agriculture, Islamic Republic of Iran, Tehran.
10.	Guyot L., 1990	Development of a New Method for Assessment and Monitoring of Desertification in Sahelian and Sudanian Regions 1952-1987. UNEP, Nairobi.
11.	ICAR/CAZRI, 1988	Progress in Arid Zone Research 1952-1987. Reports of the First Consultative Meeting of the Regional Network of Research and Training Centers on Desertification Control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.
12.	Iran Country Report, 1988	Ibid.
13.	Jain H.K., 1988	Desert: At the doorstep of Malwa Plateau. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 29 to 31.
14.	Kalyenov G.S., Kharin N.G. 1990	Explanatory Note to the Map of Present Status of Desertification in Northern Afghanistan. Desert Institute, Ashkhabad.

15. Kharin N.G., 1990 — Explanatory Note to the Desertification Map of Arid Areas in Mongolian Peoples Republic, 1:2,500,000. Desert Institute, Ashkhabad.

16. Kharin N.G., 1990 — Regional Assessment of Desertification, USSR/Mali. Desert Institute, Ashkhabad.

17. Le Houerou H.N., Pontanier R., 1987 — Les Plantations Sylvo-Pastorales dans la Zone Aride de Tunisie. Notes Techniques du MAB. 18, UNESCO, Paris.

18. Mahboubi Ali Akbar, 1989 — Desertification in Iran. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.

19. National Soil Survey & Land Classification Project [NSSLCP], Land Management Department, Ministry of Agriculture & Water, Kingdom of Saudi Arabia, 1989 — A Brief on Various Desert Conditions in Saudi Arabia. NSSCLP, Riyadh.

20. Nazim M.A., 1988 — The Desertification Situation in Afghanistan. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 12 to 15

21. Pham Quang Do, 1989 — Some features of Soil Degradation in Vietnam. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in the Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.

22. Singh P., 1989 — Range Management and Sylvipastoral Systems to Control Sand Drifts. Ibid.

23. Soil and Agricultural Division [SACD], Water Quality Bureau, Japan Environment Agency, 1990 — Desertification Control Activities in Japan SACD, Tokyo.

24. Sombroek W., Oldeman, W., 1990 — World Soils and Terrain Digital Database "SOTER". ISRIC, Wageningen Netherlands.

25. Spooner, B., 1988 — Socio-economic aspects of Desertification control in Asia and the Pacific. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 21 to 25.

26. Tomboc C.C., 1988 — Outline of the Situation Report, Republic of the Philippines. Reports of the First Consultative Meeting of the Regional Network of Research and Training Centers on Desertification control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.

27. Turkmen SSR Academy of Sciences, Desert Institute, 1988 — Explanatory Note to the Map of Man-Made Desertification in the USSR Arid Lands, 1:2,500,000. Desert Institute, Ashkhabad.

28. UN ESCAP, 1987 — Desertification in Asia and the Pacific: A Regional Review and Assessment. ESCAP, Bangkok.

29. UN ESCAP, 1988 — Reclaiming the desert in the Islamic Republic of Iran. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 7 to 11.

30. UNEP DC/PAC, 1990 — Global Assessment of Desertification: World Atlas of Thematic Indicators of Desertification [Proposal document of 11 February 1990]. UNEP, Nairobi.

31. UNEP DC/PAC, 1990 — Minutes of the Ad-Hoc Consultation on the Assessment of Global Desertification: Status and Methodologies, 15 to 17 February 1990, Nairobi, Kenya. UNEP, Nairobi.

32. UNEP/UNEPCOM/ Desert Institute, 1990 — Recommendations on Application in the Sahelian Zone of FAO/UNEP Provisional Methodology for Desertification Assessment and Mapping. CIP, Moscow.

33. Venkateswarlu J., 1989 — Resource Inventory, Monitoring of Desertification and Its Control and Drought Management - Country Report, India. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.

34. Verkateswarlu J., 1989 — Soil Degradation Processes-Retrospect and Prospect. Ibid.

35. Wang Dongatai, 1990 — Greening to Stop Desert Dust. China Daily, 5 March 1990, p.3

36. Watershed Management Division, Royal Forest Department, Ministry of Agriculture and Co-Thailand, 1989 — Forest Development and Conservation Practices in Thailand. Expert Papers of the Regional Meeting of Experts, Local Level Government Officials and NGOs on Desertification Control in the Asia and Pacific Region, 11 to 17 December 1989, Jodhpur, India.

37. Zhu Zhenda, 1988 — Occurrence and Development of Desertification - Prone Lands and the Impacts on Environment and Renovative Ways to Control the Problem. IDRAS, Lanzhou.

38. Zhu Zhenda, 1988 — Some Concerns on China's Desertification Control and suggestions. Reports of the First consultative Meeting of the Regional Network of Research and Training Centers on Desertification Control in Asia and the Pacific, 5 to 7 September 1988, Chaing Mai, Thailand.

39. Zhu Zhenda [Ed.], 1988 — Desertification Maps of Daqinnggou and Keerquin [Horqin] Steppe, Inner Mongolia, China, 1:50:000 [7 maps showing different aspects of desertification status, progress and trends]. IDRAS, Lanzhou.

40. Zhu Zhenda [Ed.] 1988 — Map of Desertification Hazard in Horqin Sandy Land, 1:300,000. IDRAS, Lanzhou.

41. Zhu Zhenda [Ed.], 1988 — The Map of the Status of Desertification in Horquin Sandy Land, 1:500,000. IDRAS, Lanzhou.

42. Zhu Zhenda, Di Xinmin, Lin Shu, Wu Zhen, 1988 — Deserts and Desertification Indicators in China. *ESCAP Environment News*, Bangkok, Volume 6, Number 3, 16 to 20.

43. Zhu Zhenda, Di Xinmin, Wang Yimou [Eds.], 1988 — Map of Developmental Degree of Desertification in Daqin Tala 1958-1974, 1:100,000 [two maps showing progress of desertification]. IDRAS, Lanzhou.

44. Zhu Zhenda, Liu Shu, Di Xinmin, 1988 — Desertification and Rehabilitation in China. ICERD, Lanzhou.

45. Zhu Zhenda, Liu Shu, Wu Zhen, Di Xinmin, 1986 — Deserts in China. IDRAS, Lanzhou.

46. Zhu Zhenda, Zou Benggong, Di Xinmin, Wang Kangfu, Chen Guangting, Zhang Jixian, 1988 — Desertification and Rehabilitation in China: Case Study in Horquin Sandy Land. IDRAS, Lanzhou.

REPORT OF THE KENYA PILOT STUDY (FP/6201-87-04) USING THE FAO/UNEP METHODOLOGY FOR ASSESSMENT AND MAPPING OF DESERTIFICATION

Government of Kenya (GOK)
Department of Resource Surveys and Remote Sensing (DRSRS)
and
United Nations Environment Programme (UNEP)

February 1990

PREFACE

This report presents the results of the joint Government of Kenya (GOK) and United Nations Environment Programme (UNEP) project on the Evaluation of the FAO/UNEP Provisional Methodology for Assessment and Mapping of Desertification. The objectives of the project were:

1. To evaluate the FAO/UNEP (1984) methodology for use in the assessment and mapping of desertification and recommend a simplified methodology that could be used elsewhere with appropriate modification.

2. To strengthen the capability of Government of Kenya agencies to undertake desertification assessment, the planning of control measures and good land management; and

3. To contribute towards the preparation of a World Thematic Atlas of Desertification.

Many persons contributed at various stages to the completion of this report. This included staff of UNEP-DC/PAC, UNEP-GEMS/PAC and from the civil service of the Government of Kenya. Technical staff members of the Department of Resource Surveys and Remote Sensing (DRSRS, formarly KREMU) and project consultants greatly contributed towards the preparation of this report.

The most significant contributors and their fields were:

Mr. W.K. Ottichilo, Technical Coordinator
Mr. R.K. Sinange, Vegetation Expert
Mr. J.H. Kinuthia, Climate Expert
Ms. M.K. Kamar, Soils Expert
Mr. H.A. Mwendwa, Human Ecology Expert
Mr. J. Grunblatt, Systems Analyst

Assisted by:
Mr. S. Oduor, Vegetation
Mr. F. Msafiri, Vegetation
Mr. F. Waliaula, Vegetation
Mr. P.W. Wargute, Human Ecology
Mr. D.K. Ronoh, Human Ecology
Mr. S.M. Ng'ang'a, Data Analyst
Mr. P. Aoko, Cartography

It is hoped that the methodology and desertification indicators proposed in this report plus the conclusions arising from the study will form a basis for the assessment and mapping desertification in similarly affected countries.

TABLE OF CONTENTS

LIST OF MAPS AND TABLES

EXECUTIVE SUMMARY

This report presents the results of the joint Government of Kenya (GOK) and United Nations Environment Programme (UNEP) evaluation of the FAO/UNEP (1984) Provisional Methodology for Assessment and Mapping of Desertification. The main objective of the project was to evaluate the FAO/UNEP (1984) methodology for use in the assessment and mapping of desertification and to provide recommendations that would assist in its application at local and national levels. This entailed the choosing of appropriate desertification indicators and the identification of methods that could be used for data collection, and analysis in a rapid and cost effective manner. The project was undertaken at a pilot level in two study areas. The study areas were located in Baringo and Marsabit districts of Kenya.

Initial evaluation of the FAO/UNEP methodology showed that most of the indicators and methods proposed could only be used in assessment and mapping of desertification at the local, or pilot level. It would be very expensive and time consuming to use most of the proposed indicators and methods for assessment and mapping of desertification at regional or national level. It was also noted that most countries do not have detailed data to the level proposed in the methodology. Recent, past, or long-term data, required for determination of rate of desertification, is also lacking.

In this study, detailed data was collected on selected desertification indicators using a combinaton of remote sensing techniques and field surveys. The detailed data was then evaluated for use at local level. Selected data elements and other ancillary data were used in the geographic information system (GIS) to develop generalized models that could be used in the assessment and mapping of desertification at regional or national level. Five models were developed. These are:

1. Water Erosion Model
2. Wind Erosion Model
3. Range Carrying Capacity Model
4. Vegetation Degradation Model
5. Human Population Model

These models can be used in assessment of desertification at a national level using basic data on climate, landform, soil, vegetation, animal numbers, and human population. Based on the experience gained in this study, it is recommended that in areas where the basic data required for the models does not exist, remote sensing techniques - particularly the use of satellite imagery and systematic reconnaissance flights (SRF) can be used in the baseline resource inventory. The use of remote sensing is relatively cost-effective, rapid and the information can be obtained on a periodic basis and consequently these remote sensing techniques should further be used in the long - term monitoring and assessment of desertification.

Lastly it is recommended that socio-economic data should be included in any assessment of desertification since desertification processes are largely induced by human activities.

1. INTRODUCTION

1.1 THE GENERAL OUTLINE OF THE PROBLEM

Desertification is not a recent process. It has been proceeding - sometimes rapidly, sometimes slowly-for more than a thousand years (Dregne 1983). It commonly appears as degradation of plant, animal, soil and water resources and general loss of biological productivity in areas under ecological stress (FAO/UNEP, 1984). In fragile ecosystems such as those on desert margins, this degradation can severely reduce the capacity of the area affected to support human life.

Until recently, attention was not focused on desertification in part because the desertification process was an insidious one that went unrecognized in the early stages or was seen as a local problem affecting only a small population (Dregne, 1983). In addition, new land was always available to start over again. As long as remedial action could be deferred by moving to the new frontiers, land conservation had little appeal. It was not until the 20th Century - when easy land expansion came to an end - that governments and people finally realized that continued careless degradation of natural resources threatened their future (Dregne, 1983).

More than one-third of the earth's land area belongs to the sub-humid, semi-arid and arid climatic zones where the process of desertification has intensified in recent decades (Mabbutt, 1984). According to the estimates available, desertification threatens the future of more than 785 million people, or 17.7 percent of the world's population who live in these drylands (United Nations Conference on Desertification (UNCOD) 1977, Mabbut 1984). Of this number between 60 and 100 million people are affected directly by decreases in productivity associated with the current desertification process.

It is also estimated that between 50,000 and 70,000 square kilometers of useful land are going out of production every year, through desertification. The World Map of Desertification, at a scale of 1:25,000,000 prepared for the UN Conference on Desertification in 1977 conveniently summarised the current position (UNCOD, 1977).

The situation as presented above on the current magnitude of the desertification problem has been evaluated in general terms. However, more precise data and methods are required on areas affected, or likely to be affected in the future by desertification processes at national and local scales (FAO/UNEP, 1984). Such analyses are required to obtain more precise figures on desertification and to assist in future action in planning and guiding anti-desertification activities at national and regional levels as a basis for international action to combat desertification, for co-ordination of research, and for the transfer of appropriate technology. For this purpose, the FAO/UNEP project entitled 'Desertification Assessment and Mapping' was initiated (FAO, 1980)

In 1987, the United Nations Environment Programme (UNEP) in collaboration with the Government of Kenya (GOK) launched a project entitled "Desertification Assessment and Mapping Pilot Study in Kenya". The aim of this study was to evaluate FAO/UNEP (1984) methodology for use in the assessment and mapping of desertification and to recommend simplified methodology that could be used elsewhere with appropriate modification.

1.2 THE BACKGROUND OF THE DESERTIFICATION ASSESSMENT AND MAPPING PILOT STUDY IN KENYA

The "Desertification Assessment and Mapping Pilot Study in Kenya" is the follow-up of a joint FAO/UNEP project which culminated in the publication of the "Provisional Methodology for the Assessment and Mapping of Desertification" in 1981 (FAO 1981). The publication describes the processes leading to desertification, details the factors to be considered in assessing each process, considers the combination of processes to quantify four aspects of desertification (status, rate, inherent risk and hazard) and suggests map compilation methods. Although the FAO methodology was revised in 1984 in the light of field-tests in 9 countries, the major criticism remained that the application of the proposed methodology was impractical (FAO/UNEP 1984). The lack of sufficient data, even in developed countries was found to be a major handicap and the cost of acquiring such data could be very high. Consequently, it was recommended at a UNEP meeting on desertification assessment and mapping in Nairobi (11-14 March 1985) that a simpler, refined methodology should be tested in a pilot study project in Kenya.

The project formulation and preparation started in late 1985 and in April 1987, a memorandum of understanding was signed between the Government of Kenya and the United Nations Environment Programme for the implementation of the pilot study project (FP/6201-87-04 (2702)). The pilot study was

to be undertaken in parts of Baringo and Marsabit districts. The criteria for selection of the pilot study areas were:

(a) The areas should be situated in arid or semi-arid zones of Kenya and should represent major ecological features of drylands e.g. vegetation, water etc. as well as being used in typical ways of dry areas through agriculture and range management;

(b) All areas should show typical catenas from higher rainfall to drier parts, thus enabling the establishment of typical transects. The areas should show signs of desertification at various stages, and;

(c) Accessibility by road and air both in the dry and in wet season should be good. The areas should have a good cover of LANDSAT and Systeme Probatoire d'Observation de la Terre (SPOT) images and resource inventories as an added advantage.

The Department of Resource Surveys and Remote Sensing (DRSRS) - formerly known as KREMU, which had earlier shown both interest and willingness to assist in the testing of refined methodology was mandated to implement the project on behalf of the Government of Kenya and in conjunction with UNEP because of its long-term experience in the ecological monitoring of the Kenya rangelands.

The planning for the implementation of the project commenced in September 1987 with the recruitment of required experts/consultants and ordering of project vehicles and SPOT images. The study design was undertaken between September 1987 and February 1988. During the study design, a simplified set of indicators for degradation of vegetation cover, water erosion, wind erosion and human factors were defined and a conceptual outline of the model to give status of desertification developed. The data on selected desertification indicators was collected between February 1988 and March 1989. Data analysis and report writing was carried out between March 1989 and July 1989. The results of the study were presented to a meeting of experts in Nairobi from 24 to 25 July 1989.

1.3 DEFINITIONS

In order to avoid misunderstanding, ambiguity and confusion, the main terms used in this study are defined as accurately as possible. This has become necessary because the literature is full of contradicting definitions on the same subject. Here below is a review of some popular definitions of desertification from the literature, and the working definition used in this study.

1.3.1 Desertification

There are numerous definitions of the word "desertification" in literature. According to the 1977 United Nations Conference on Desertification (UNCOD 1977) desertification was defined as:

"the diminution or destruction of the biological potential of the land, which can lead ultimately to desert-like conditions."

Though, this definition is acceptable for the purposes of a political UN Conference, it is inadequate from the technical point of view, as it is not an operative definition in precise scientific terms (Rozanov and Zonn, 1984). First it is not clear what "desert-like conditions" are. There are wide variations between natural deserts, with some being completely devoid of plant cover and others having fairly well-developed plant cover (UNESCO 1977). Second, any degradation of biological potential is understood as desertification even in arctic and humid environments. Third, there is no clarification of the significance of natural phenomenon to desertification such as period droughts. Finally, there is no clear-cut, measurable, and objective criteria of desertification. Thus this definition does not provide concrete and precise parameters for quantitative assessment, monitoring and control of the process.

Apart from the above definition adopted by the 1977 United Nations Conference on Desertification, other examples of popular definitions of the term desertification are:

(a) Rozanov and Zonn (1984) based on their experiences with desertification in the USSR have defined desertification as:

"A natural or man-induced process of irreversible changes of soil and vegetation of dryland in the direction of aridization and diminution of biological productivity, which in extreme cases, may lead to total destruction of biological potential and conversion of land into desert".

(b) Sabadell et al (1982) in their final report on, "Desertification in the United States" have defined desertification as:

"the sustained decline and/or destruction of the biological productivity of arid and semi-arid lands caused by man-made stresses, sometimes in conjunction with extreme natural events. Such stresses, if continued or unchecked, may lead to ecological degradation and ultimately to desert-like conditions".

(c) Dregne (1983) defined desertification as:

"the impoverishment of terrestrial ecosystems under the impact of man. It is the process of deterioration in these ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy".

(d) Dregne (1977) has also defined desertification as:

"the impoverishment of arid, semi-arid and sub-humid ecosystems by the combined impact of man's activities and drought. It is the process of change in these ecosystems that can be measured by reduced productivity of desirable plants, alteration in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil degradation, and increased hazards of human occupancy".

(e) The Food and Agricultural Organisation (FAO) and the United Nations Environment Programme (UNEP) - FAO/UNEP, 1984) defined desertification as:

"a comprehensive expression of economic and social processes as well as those natural or induced ones which destroy the equilibrium of soil, vegetation, air and water in the areas subject to edaphic and/or climatic aridity".

(f) The World Resources Institute (1989) defines desertification as:

"the deterioration of soil, severely reduced productivity of desirable plants and declining diversity of flora and fauna because of the activities of both people and livestock".

(g) Kharin and Petrov (1977) define desertification as:

"a complex of physiographical (natural) and anthropogenic processes, causing the destruction of arid, semi-arid and sub-humid ecosystems and the degradation of all forms of organic life, which, in turn, results in the diminished natural - economic potential of these territories".

(h) Kassas (1988) defines desertification as:

"a process of ecological degradation by which economically bio-productive land becomes less productive. In extreme instances the final scene is a desert-like landscape incapable of sustaining communities that once depended on it".

In this Study the definition of the term desertification is based on the following criteria:

(i) Desertification has the same meaning as land degradation except the term is specifically used for land degradation processes occurring in arid, semi-arid and sub-humid lands.

(ii) Land degradation is defined here as degeneration or deterioration (loss of qualities that are normal or desirable or proper to its kind); a process which takes place over relatively short periods (less than 100 years); it is not necessarily continuous, can be reversed and can occur in all climates. The main forms of land degradation in arid zones are: Vegetative cover, and soil degradation.;

(iii) Desertification is either caused by a natural phenomenon (i.e. drought), or by human - induced activities or both; and

(iv) Desertification is to a large extent a reversible process (Spooner and Man, 1982, World Resources Institute, 1989).

Based on the above criteria, desertification is defined in this Study as:

<u>a complex of natural and mainly man-induced land degradation processes which lead to the decline of biological productivity of arid, semi-arid and sub-humid lands and in turn, results in the diminished natural and economic potential of these lands</u>.

1.3.2 Aspects of Desertification

For the purposes of assessment and mapping it is necessary to study, describe, quantify and codify the various aspects of desertification. The aspects proposed in the, "Provisional Methodology for Assessment and Mapping of Desertification" (FAO/UNEP 1984) were found to be adequate and have been adopted with slight modifications for use in this Study. The aspects are: risk, status, rate, and hazard of desertification. Here below are definitions of these terms as used in this study:

1.3.2.1 Risk of Desertification

It is the vulnerability of an area to desertification. It should be noted that areas with a high risk are not necessarily areas with a severe status of desertification and vice versa. Risk of desertification is assessed through the analysis of physical and human factors of an area. The factors are: climate, soil and physiography or topography, human population and animal numbers. This aspect of desertification was not directly tackled in this study. It was, however, incorporated in the status aspect.

1.3.2.2 Status of Desertification

Status of desertification is defined here as being the present, former or future situation of desertification indicator(s) for an area in relation to its natural state. Status therefore has to be assessed against an estimate of the natural state of the area.

1.3.2.3 Rate of Desertification

Rate is the measure with which desertification spreads or intensifies in a certain area or region over a defined period of time. It can be positive or negative. Positive meaning increase in desertification and negative meaning decrease. A rate is established through comparison of two different status, divided by the period of time. The first status can be a natural or undisturbed one, but it is often difficult to reconstruct. Thus, ideally status of desertification is compared over a period of time in order to establish rate.

1.3.2.4 Desertification Hazard

Is the summation of various status of desertification indicators for an area. It indicates the actual danger of an area being desertified.

1.3.2.5 Rating for Desertification Assessment and Mapping

The "Provisional Methodology for the Assessment and Mapping of Desertification (FAO/UNEP 1984)" uses a four point rating. The scale ranges from slight to very severe. In the case of this Study it was found necessary to expand this rating to a five point one, so that the rating NONE which is not uncommon in Kenya, and elsewhere can be included (Table 1). However, in all cases except for desertification hazard, it was found practical to use only a three-point rating scale.

Table 1 Rating scale for assessment and mapping of desertification

RATING	5-Point	4-Point	3-Point	2-Point
	None Slight Moderate Severe Very severe	None Slight Moderate Severe Very severe	Slight Moderate Severe	Slight Severe

1.4 SELECTED DESERTIFICATION FACTORS AND INDICATORS

In this study the term "factor" is used to describe particular data collected while "indicator" refers to something that provides information about the condition being investigated. In some cases a factor can be used directly as an indicator, e.g. soil salinity. In other cases factors are combined to provide an indicator, e.g. water erosion potential.

Prior to study implementation, a series of consultative meetings were held by the scientific staff of DRSRS, DC/PAC, GEMS and project consultants to discuss and select desertification assessment methods and indicators to be assessed. The desertification assessment methods and indicators proposed in the FAO/UNEP Provisional Methodology for Assessment methods and Mapping of Desertification were critically evaluated for their practicality, rapidness and cost-effectiveness.

A set of factors were selected for desertification assessment. The factors were categorized into three types: physical, biological and social or socio-economic factors. The details of the factors chosen for each type are given in Table 2. Based on selected desertification assessment factors, a number of indicators were chosen for assessing and mapping desertification at both local and national levels. The details of the chosen indicators are given in Table 3.

In this study human impacts in desertification processes were considered to be very important. Thus a number of socio-economic factors which were not considered in the FAO/UNEP methodology, have been incorporated in this study.

Table 2. Desertification assessment factors

TYPE	Factors	
Physical	Climate	a. Rainfall b. Temperature c. Wind speed, direction and frequency d. Rainfall erosivity (calculated) e. Sunlight duration f. Potential Evapotranspiration - PET (Calculated) g. Sandstorm/dust storm h. Vorticity
	Soils	a. Surface status (rockiness) b. Texture c. Fertility (organic matter) d. Structure e. Permeability f. Erodibility (calculated) g. Alkalinization/Salinization h. Soil unit map
	Topography	a. Slope
Biological	Vegetation	a. Canopy cover of herbaceous and woody plants (%) b. Above ground biomass production (standing crops) of herbaceous/woody cover (kg/ha/yr) c. Plant composition and desirable or key species d. Potential herbaceous production (calculated) e. Vegetation unit map
	Animals	a. Animal population estimates and distribution b. Herd composition c. Herbaceous consumption (calculated)
Socio-Economic	Land and Water use	a. Land use b. Fuel wood consumption c. Water availability and requirements
	Settlement Patterns	a. Settlements b. Infrastructure
	Human Biological Parameters	a. Population structure and growth rate b. Measures of nutritional status c. Feeding habits
	Social Process Parameters	a. Conflicts b. Migration c. Transhumance d. Environmental perception

Table 3. Desertification assessment indicators

	Indicators	Level of Application
Physical	Climate	
	a. Aridity index	L, N
	b. Rainfall variability	L, N
	c. Wind deposition and deflection areas	L
	d. Wind erosion potential (calculated)	L, N
	Soil	
	a. Crusting and compaction	L
	b. Soil salinization/Alkalinization	L
	c. Water erosion areas	L
	d. Water erosion potential (calcuated)	L, N
Biological	Vegetation	
	a. Vegetation degradation (herbaceous and woody) - (calculated)	L, N
	b. Range carrying capacity (calculated)	L, N
	c. Desirable and undesirable plant species	L
Social	Human Factors	
	a. Human settlements	L, N
	b. Land Use	L, N
	c. Fuel wood consumption (calculated)*	L, N
	d. Nutritional status	L, N
	e. Migration	L, N
	f. Environmental perception	L

L = Local
N = National
* = Was not undertaken in this study but data is available at DRSRS

1.5 STUDY APPROACH

The main objective of the Kenya Desertification assessment and mapping Pilot Study was to evaluate the FAO/UNEP (1984) methodology for use in the assessment and mapping of desertification and to recommend a cost-effective, simplified methodology, that could be used elsewhere with appropriate modification. To achieve this objective, a hierarchical study approach was adopted.

In this approach, detailed data was collected at the local level on selected desertification assessment factors using different methods. The detailed data was then evaluated and selected data elements given in Section 3.5 were used in a Geographic Information System (GIS), to develop simple models that could be used in the assessment and mapping of desertification at a national or regional level.

The aim of this approach was to use the detailed data collected in the pilot study to develop simple models that could be used in the assessment and mapping of desertification at local and national levels using available basic data and without or with very limited field work. Also the detailed data was necessary for validating the models. This approach was deemed necessary in order to reduce the cost, time and manpower that would otherwise be required for national desertification assessment and mapping using conventional procedures, yet provide reliable assessment.

2. STUDY AREAS

2.1 BARINGO STUDY AREA

The study area is predominantly a low, or bottomland, and lies between 0° 15' and 1° N and 35° 30' and 36° 30'E (Figure 1). It is located between the Laikipia escarpment to the east and Tugen hills to the west. The altitude ranges from 900m on Njemps flats to 2500m in the Puka and Tangulbei/Pokot highlands in the north. The size of the area is approximately 3600km^2.

2.1.1 Drainage

The Perkerra and Molo rivers are the only permanent rivers which drain into Lake Baringo via the Njemps flats.

2.1.2 Rainfall

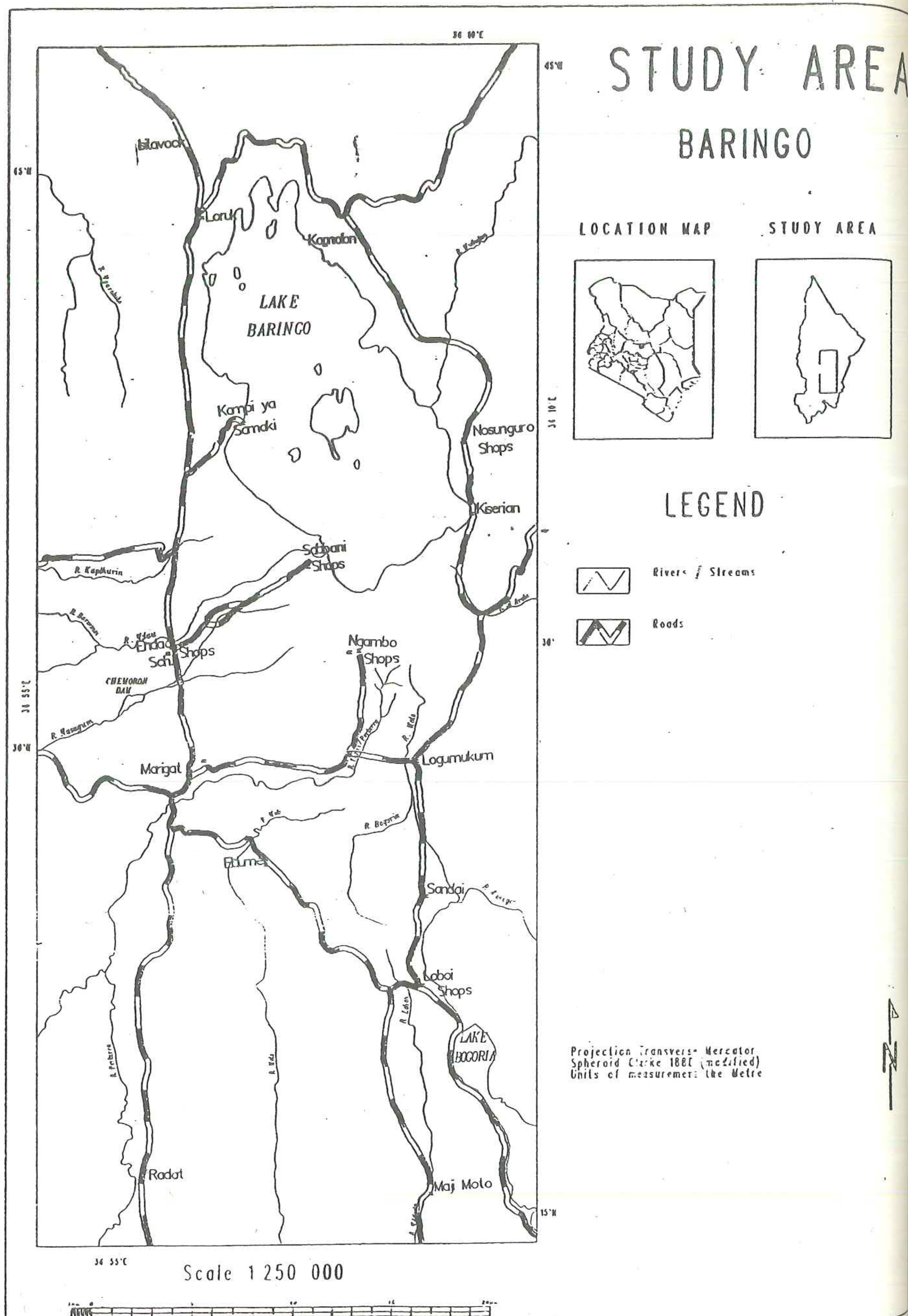
The climate of the region is generally wet. There is one dry season and three wet seasons. The region experiences trimodal type of rainfall occurring in the periods March - May, June - September and October - December. The dry season occurs in the months of January and February. Even during dry periods some significant rainfall amounts have been received mainly on the high ground. The highest rainfall of up to 1900mm is received in areas around the mountains. The rainfall amounts decrease with the decreasing altitude. The mountain ranges in Baringo extend from North to South. The rainfall increases from north to south. The mean annual rainfall in the project area is about 600mm.

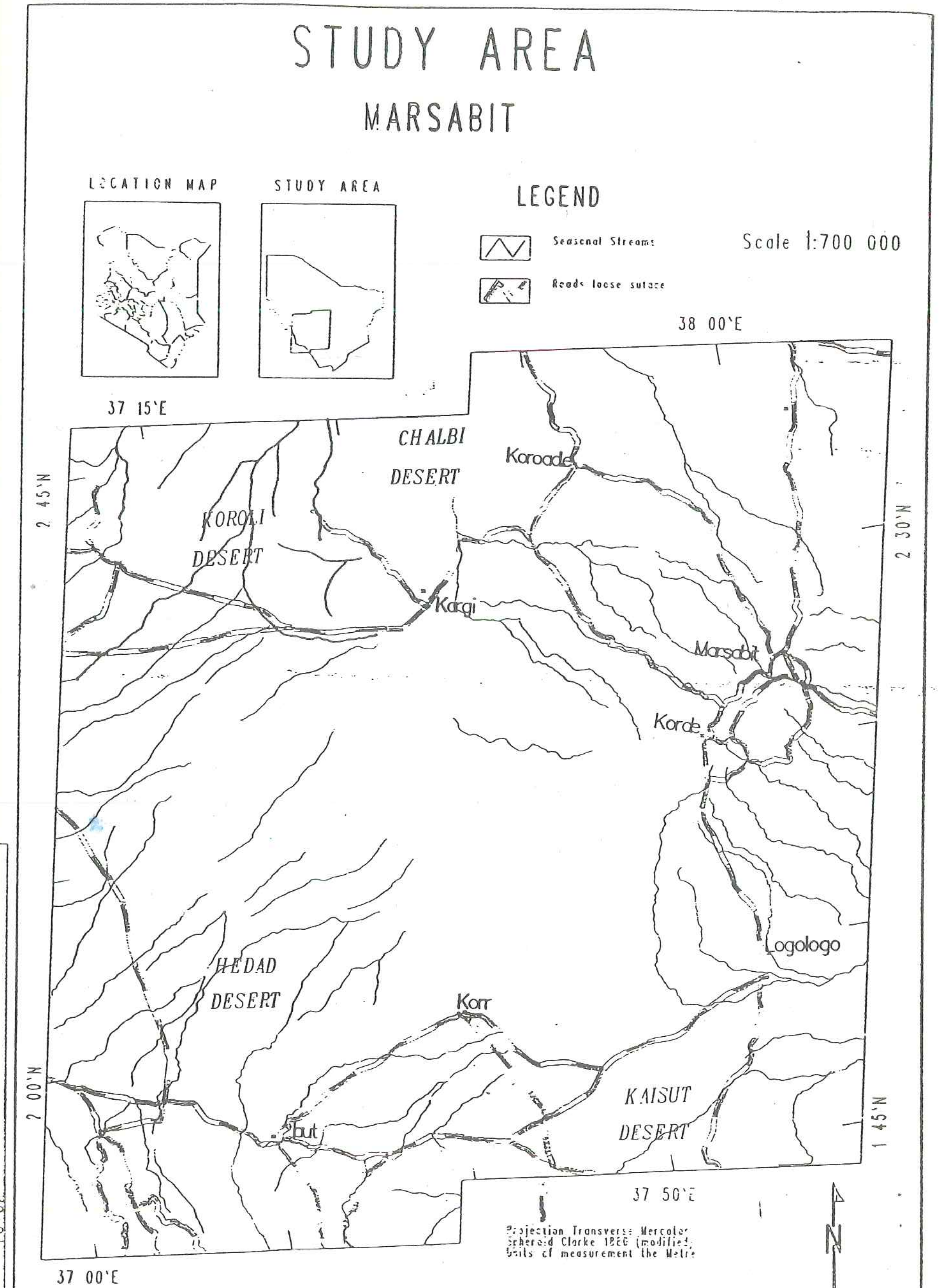
2.1.3 Land Use

The main land use in the study area is livestock keeping. Irrigated agriculture is practised using the Perkerra and Molo rivers. The water from the recently constructed Chemeron Gorge dam is also being used for irrigation in the Endao area. The main crops grown under irrigation are vegetables, fruits and maize.

2.2 MARSABIT STUDY AREA

The study area in Marsabit lies between 2° 00'N and 3° 00'N. and 37° 00'E and 38° 00" E. and covers an area of about 14,000km^2 (see figure 2). The major part of the area lies within the arid lowlands of the Kaisut, Koroli and Hedad Plains. To the south west, it is bounded by the Ndoto Mountains and to the west by Kulal Mountains. Towards the east it rises to 1500m on Mt. Marsabit which is covered by tropical rain forest. The lowest point is the Chalbi desert (salt desert) which is about 400m above sea level. Vast parts mainly the slopes of Mt. Marsabit and Kaisut and Hedad lowlands, are covered with lava. Vegetational characteristics vary from desert halophytes, scattered woodland, dwarf shrub and shrubland, to Rain Forest.


STUDY AREA
BARINGO
LOCATION MAP
STUDY AREA
LEGEND
Rivers / Streams
Roads
LAKE BARINGO
Loruk
Kampi ya Samaki
Nosunguro Shops
Kiserian
Ngambo Shops
Marigat
Logumukum
Sandai
Loboi Shops
LAKE BOGORIA
Radat
Maji Moto
CHEMORON DAM
R. Kapthurin
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
Scale 1 250 000
N


STUDY AREA
MARSABIT
LOCATION MAP
STUDY AREA
LEGEND
Seasonal Streams
Roads loose suface
Scale 1:700 000
38 00'E
37 15'E
2 45'N
2 30'N
2 00'N
1 45'N
37 50'E
37 00'E
CHALBI DESERT
KOROLI DESERT
HEDAD DESERT
KAISUT DESERT
Koroade
Kargi
Marsabit
Korole
Logologo
Korr
Ilaut
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
N

2.2.1 Drainage

Seasonal rivers originate from the hill masses and drain into the Central Plain where their water evaporates or percolates. Water from most of the area drains into old saline lake bed of the Chalbi desert.

2.2.2 Rainfall

The climate of the region of Marsabit is generally dry but marked with two rainy seasons. Some rain may occur during the dry months, although it is quite irregular and unreliable. The region experiences a bimodal type of rainfall which occurs in the periods March - May (long rains) and October - December (short rains).

The remaining months are dry. The region is characterized by a highly variable spatial distribution of annual rainfall. The area around the mountains receive up to 800mm or more annually, while the low lying areas receive an annual average of less than 250mm. Besides this areal variability, there exists large year to year as well as seasonal variations.

2.2.3 Land Use

The lower plateau on Mt. Marsabit on which Marsabit town is situated is used for mixed farming of cattle and small stock, and arable agriculture. Numerous waterholes on the plateau have facilitated the sedentarization of the local pastoralists. The rest of the Marsabit study area is under extensive pastoralism and partly covers the home ranges of the Rendille, Gabbra, Boran and Samburu pastoral tribes.

3. METHODS AND MATERIALS

3.1 INTRODUCTION

A number of methods were used to collect data on the factors and indicators given in Tables 2 and 3. The methods used were those that were believed to be feasible and appropriate for the type of data being collected and period of time allocated for field data collection. Due to the limited period of time allocated for field work, a number of factors which could have required a long period for data collection were not considered in this study. These include soil crusting and compaction, biomass production of woody plants (trees and shrubs), complete cover analysis of recent past photos for determination of rate of desertification, and digital image analysis of SPOT imagery etc.

Below is a brief description of the methods used to collect data for different types of factors. For details the reader is referred to individual consultant reports to the project (see Appendix 1 for list) which are available at the UNEP - Desertification Control Programme Activity Centre (DC/PAC).

3.2 PHYSICAL FACTORS/INDICATORS

Data on physical factors were acquired through field surveys, laboratory analysis, and literature review. Below is a brief description of each of the methods used.

3.2.1 Climate and Physiography

Data on rainfall was obtained from the Kenya Meteorological Department. Further information (analyzed data) on rainfall was obtained from Farm Management Handbook of Kenya (Jaetzold and Schimdt 1982). Different rainfall stations were digitized and their rainfall records used to generate rainfall isohyets.

For the Baringo study area, the isohyets generated by Jaetzold and Schmidt (1982) were used.

The rainfall Erosivity Index or Fournier index (R) was calculated using the following equation:

$$R = \sum_{1}^{12} (p^2/P)$$

Where P = Annual Rainfall
p = Monthly Rainfall

Rainfall stations within the study areas were selected and their monthly and annual rainfalls used to calculate the erosivity index. The erosivity index was then related to the annual rainfall for each of the rainfall stations by regression equations relating erosivity index (R) to annual rainfall (y).

Finally, a map of the erosivity index was generated using a computer by relating the digitized annual rainfall isohyets to their appropriate erosivity value using the regression equation.

Terrain information i.e. slope, was derived from 1:250,000 topographic sheets (Republic of Kenya 1972). The contours at an interval of 60m were digitized and used in generating slope maps using a computer. The slope data was used in the analysis of water erosion status.

3.2.2 Soil Factors/Indicators

A preliminary soil unit map for each study area was produced through visual interpretation of enhanced dry season SPOT imageries which were taken on the 12th September 1986, for Baringo, and on 10th February, 1987 for Marsabit. The visual interpretation was augmented by field checks which were undertaken during both the dry and wet seasons.

During the dry season field visit, the preliminary soil unit maps derived from the visual interpretation of the SPOT images were checked, verified and modified where necessary. Earlier soil unit maps for the areas (Republic of Kenya 1982, Van Kekem 1984) were used to verify the soil units derived from the SPOT images. The final field-checked and corrected soil unit maps were used in collecting information on soil degradation factors. Thus each soil unit (or polygon) formed a basis for collecting detailed data on the chosen factors. The final soil unit maps were digitized and used during the data analysis and modelling phase.

The data on the chosen soil degradation factors was acquired through the analysis of soil samples taken at different depths (0-25 cm, 25-50 cm, 50-75 cm) in each soil unit. The samples were analyzed at the Kenya National Agricultural Laboratories for: soil structure, soil permeability, soil texture class, soil salinization (EC), soil alkalinization (ESP) and soil organic matter.

The analyzed data on organic matter, soil texture, soil structure and permeability was used to calculate soil erodibility for each soil type using the soil erodibility nomograph developed by Wischmeter and Smith (1978). Data on rockiness was collected in the field during the dry season. The rockiness surface cover percent was estimated visually using quadrats each measuring 1m x 1m. Quadrats were randomly laid in each soil unit and percent cover rockiness was estimated visually. Five quadrats were laid in each soil unit and an average percent was calculated.

3.2.3 Water Erosion

Data on water erosion was collected during the wet season. Due to shortage of time and manpower, only qualitative information on various stages of water erosion was collected in each soil unit. The principal assumption followed in collecting the data was that water erosion begins by splash, then as water run-off builds up, it is followed by sheet erosion. As run-off increases, concentration of water in small well defined channels form rills. More removal of soil by higher water flow in the rills leads to gully formation and continued gully development ultimately leads to the formation of badlands. In brief, the process is as follows:

None → Sheet erosion → Rill erosion → Gully erosion → Badland.

Each soil unit in each study area was visited during the wet season and the water erosion status was qualitatively determined through field observations based on the above water erosion definitions.

3.2.4 Wind Erosion

Data on wind erosion was obtained from Kenya Meteorological Dearptment. Data on rainfall, potential evapotranspiration (PET), wind speed, direction and frequency for four years (1982 - 1985) was obtained from the Kenya Meteorological Department records (1984). The wind direction data was used to draw wind roses for each study area; while wind speed and frequency data was used for calculating erosivity wind index.

3.2.4.1 Calculation of wind erosivity

Three formulae were used for the calculation of the erosivity wind index (FAO/UNEP/UNESCO 1979). They are given as follows:

$$C_1 = \frac{V^3}{2.9(P/E)_2} \quad \ldots\ldots\ldots \quad (1)$$

C_1 = Erosivity wind index $(m/s)_n^3$

where	V	=	Mean monthly wind speed at 2m height (m/sec)
	(P/E)	=	Precipitation effectiveness of Thornthwaite
	P	=	Mean monthly rainfall (cm)
	E	=	Mean monthly potential Evapotranspiration (cm)

$$C_2 = \frac{V^3}{2.9\,(P/E)} \quad \ldots\ldots\ldots \quad (2)$$

C_2 = Erosivity wind index $(m/s)^3$

where	V	=	Mean monthly wind speed at 2m height (m/sec)
	P	=	Mean monthly rainfall (cm)
	E	=	Mean potential evapotranspiration

These two indices C1 and C2 were developed from the wind index of Chepil (1962) and were recommended to be used for assessment of wind erosion at detailed level (1:20.000 - 1:100,000)

C_3 = Erosivity wind index $(m/s)^3$

$$C_3 = \frac{V^3}{100}\left(\frac{E-P}{E} \times n\right) \quad \ldots\ldots\ldots \quad (3)$$

Where	V	=	Mean monthly wind speed at 2m height (m/sec)
	E	=	Mean monthly potential evapotranspiration (mm)
	P	=	Mean monthly rainfall (mm)
	(E-P)/E × n	=	number of erosive days per month

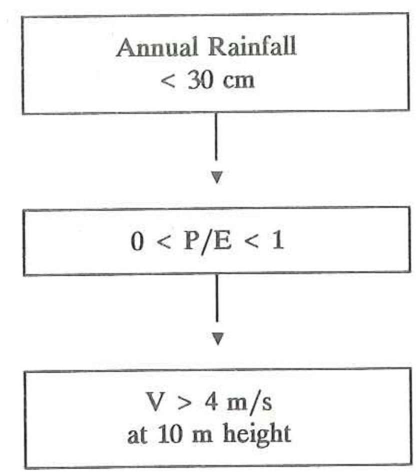
Where the number of days on which erosion occurs is assumed to be proportional to (E-P)/E times the total number of days in a month. This formula was recommended to be used for wind erosion assessment at general level (less than 1.1,000,000). The above formulae were used in computing the erosivity indices for the study areas.

The rainfall (P) and wind speed (V) are easily calculated. The calculation of potential evapotranspiration (E) is tedious and complicated. It can be calculated directly from empirical formula as shown in Appendix 2. Tables developed by Mather (1954) are used in the correction of this formula. Apart from this formula, the procedure given in Appendix 2 can be followed to calculate (E). In Kenya, Penman's equation is used to calculate the potential evapotranspiration (E). Penman's equation needs observations of radiation, temperature, humidity and wind, and whose combination is normally rare.

Although the Penman equation is the one recommended for use in Kenya it cannot be used if one of the parameters mentioned above is missing. Criticisms of Thorntwaites indices are well known, but nevertheless they constitute very useful empirical measures which are most successful in "continental" climates similar to those of the central U.S.A., in which areas they were first developed. Only the observations of temperature are required for the use of this formula.

In the arid areas either the Penman equation or Thornthwaite formula can be used for the calculation of PET as the rate of movement of sand will not vary much. In the sub-humid areas, it is recommended to apply a correction factor of 0.75 on E obtained from the Penman equation before using it in the formula for rate of movement of sand. In the humid areas the Penman equation does not give accurate values of erosivity index particularly in the areas where the wind speed is high.

The following conditions as given in the flow chart below are recommended for determining whether wind degradation is taking place in an area:



NB. The wind speed at 10 meter height is multiplied by a ratio of 0.78 to obtain the wind speed at 2m height (McCulloch, 1965).

3.2.4.2 Calculation of Sand load

The load of sand carried by wind was calculated using Chepil and Woodruff (1957) method. Chepil and Woodruff showed that the relationship between the visibility and dust load (assuming that mass of dust above one mile is negligible) is:

$$C_m = \frac{29.5}{V^{1.25}}$$

Where V = Visibility in miles
C_m = Dust load in tons per cubic mile

Banoub (1970) notes that the relationships between suspended particles and visibility can lead to the definition "that a dust-storm occurs when the horizontal visibility is reduced to less than 1km." The World Meteorological Organisation (WMO) gives the same definition for the dust-storm and sand-storm (WMO, 1988). The visibility codes are given at steps of 100 meters for the first 5 km and then in steps of 1 km, up to 9 km. The actual distance for horizontal visibility beyond 10km is not given. In this study the WMO codes (Table 4) were used in the calculation of the load of sand.

The surface area affected by wind erosion was visually estimated from the dry season SPOT image. The SPOT image, was used to identify and delineate sand deflation and deposition areas. Hummocks/sand dunes were predominantly found in the deposition areas. The percent cover of hummocks and sand dunes in each delineated unit was verified in the field. The field checked units were digitized and the exact area calculated using the GIS technique.

Table 4 WMO codes and corresponding load of sand

Code	Distance(m)	Load of sand tons/mile$_3$
0100	100	944.02
0200	200	396.90
0300	300	239.10
0400	400	166.89
0500	500	126.26
0600	600	100.52
0700	700	82.90
0800	800	70.16
0900	900	60.55
1000	1000	53.09
2000	2000	22.31
3000	3000	13.44
4000	4000	10.62
5000	5000	7.11
6000	6000	5.65
7000	7000	4.66
8000	8000	3.94
9000	9000	3.39

NOTE: The values of the distance are converted from meters to miles before use in the formula.

3.3 BIOLOGICAL FACTORS/INDICATORS

The main biological factors chosen were vegetation and livestock. Data on them was obtained using rapid, and reliable methods, among which were the interpretation of SPOT visual images and field checking, recent past air photo interpretation and field checking, field vegetation sampling, administration of a questionnaire and literature review. Details on these methods are given below:

3.3.1 Vegetation Factors

Data was collected on vegetation factors given in Table 3. Prior to data collection, a vegetation unit map for each study area was drawn through visual interpretation of the enhanced dry season SPOT imageries augmented by field checks. A vegetation classification system suggested by Grunblatt et al (1989) was used.

This was necessary because the map formed a basis for collecting data on the chosen factors for the assessment of degradation of vegetation cover i.e. each vegetation unit formed the primary sampling stand or stratum.

3.3.1.1 Determination of Canopy Cover of Trees and Shrubs

The canopy cover determination of trees and shrubs was done using both the line intercept method (McIntrye 1953, CanField 1941, Heady 1983 and Westmand 1984) and the Ocular or Releve method (Zonneveld et al 1980). The measurements were done during both the dry and wet season.

In each vegetation unit at least two trained vegetation experts made independent visual or ocular estimation of the canopy cover from an elevated point, a Land Rover top, and or by moving around and inside the vegetation cover type.

After ocular estimates, at least three transects were randomly laid within each vegetation type and canopy cover estimates made using the line intercept method. The length of the line transect varied according to plant density, distribution and plant homogeneity in each cover type. For example, cover types of low density had longer transects than those of high plant density or even distribution. However, the minimum, length of the transect was 100m with an average of 300m. Along the transect line, the canopy cover of each shrub or tree intercepted was measured using a measuring tape. The shrubs or trees intercepted were identified and recorded. The bare and herb areas were also measured. Apart from data on canopy cover, the line-intercept method was also used to derive data on plant frequency and composition.

The canopy cover of the woody (trees and shrubs), herb cover and bare area were used in the analysis of vegetation degradation and water erosion status.

3.3.1.2 Primary Biomass Production

Only the primary biomass production (standing crop) of the herbaceous cover was determined. Time available was inadequate to collect data on the biomass production of trees and shrubs. The biomass production was determined using the quadrat method (Grig-Smith 1964, Kershaw 1973, Southwood 1978 and Krebs 1978). The data was collected both in dry and wet season. The data for the wet season was collected immediately after the rains when production was at its peak.

A quadrant of 0.5x0.5m was used and in every vegetation type, a total of 15 quadrants were laid at an interval of 10m along a transect. First, in each quadrat laid, the percent cover of vascular plants, bryophytes, litter, bareground (mineral soil), and rocks or gravel or stones were ocularly estimated and recorded on data sheets. Second, each plant species (less than 0.5m in height) in each quadrat was identified and clipped for drying and weighing. The clipped plant materials were oven-dried for three days at a temperature of 70°C before weighing. The oven dry weight for each vegetation type was calculated in (kg/ha/yr) to obtain the primary biomass production.

The data was used to produce general primary production maps and in estimating carrying capacities for the two study areas.

3.3.1.3 Desirable Species

A detailed plant checklist for each vegetation cover type was made by an experienced taxonomist. In each vegetation type, the taxonomist randomly recorded as many plant species as he came across through the tallying system. The plant species were recorded on the basis of either being rated rare, frequent, common or abundant. The checklist was enriched by new hits made during sampling using both the quadrat and line intercept sampling methods.

The plant checklist was used in the mapping of desirable plant species. Desirable plant species in this context are those plants that provide the bulky forage material for both livestock and wildlife. The desirable species listing was compiled from literature especially from previous studies by Integrated Project for Arid Lands (IPAL) (Lusigi et al 1986,) and also from field interviews with the local people.

A ratio of desirable species to the total species was calculated for each vegetation type and used in the derivation of vegetation degradation status.

3.3.1.4 Recent Past Photo Interpretation

To determine the rate of vegetation degradation, recent past aerial photos dating as far back as 1950, were acquired for certain selected areas in the study areas. The areas selected were those where it was apparent that vegetation degradation had occurred and are currently heavily settled, as well as control areas. The photos were interpreted using both a stereoscope and dot grid. The analysis aimed at demonstrating changes in the woody vegetation in terms of area and percent cover, agricultural activities and human settlements. The vegetation maps emanating from this exercise were digitized and using the overlay capabilities of the GIS, vegetation changes over the years under consideration were discerned.

3.3.2 Animal Factors

Animal (livestock) numbers and their distribution in the study areas were derived from two main sources. From the Department of Resource Surveys and Remote Sensing and from a questionnaire administered at the study areas. The department has been collecting information on livestock and wildlife numbers and distribution in the Kenya rangelands since 1977 using systematic reconnaissance flights (SRF) (Norton-Griffiths 1978) and the data is kept in the department's data bank.

The questionnaire was designed to provide among other things information on animal numbers, and herd composition at a household level. Information was also collected on the general grazing systems and on local views about historical conditions of the range and the number of animals that used it as compared to the present.

Information on both economic and social values attached to each livestock species was also collected. Information on the perceived impact of livestock on the environment was also solicited. Livestock numbers were used to calculate the present stocking rate of the study areas, and to determine population trends. Using the data collected, it was possible to comment on the economic and social values of livestock as perceived by pastoralists, including the part they play in environmental degradation.

3.4 SOCIAL FACTORS

Data on social factors (see Table 3) was predominantly collected through the administration of a questionnaire except for the information on agriculture, settlement expansions, and human population trends, and measures of the nutrition status of the inhabitants.

The data on agriculture, settlements and sedentarization was obtained after analysing recent past aerial photos and SPOT imagery. Data on human population trends was extracted from the district administration files and from the 1969 and 1979 population census records (Central Bureau of Statistics (CBS), 1969, 1979). Information on population structure at the household level was collected through the administration of a questionnaire. Nutritional status was determined from measurements of the circumference of the mid-upper arm on children between ages 1-5 years. A circumference of less than 13.5cm meant the child and indeed the household was suffering from some form of nutritional stress (Caldwell 1975).

3.5 DATA ANALYSIS (MODELLING)

Preliminary analysis focused on a review of the FAO/UNEP methodology to select data elements appropriate for a national level desertification assessment. As already indicated data was gathered through field studies and by review of the available literature. As already indicated, the data was entered in the GIS by digitizing maps and entry of tabular datasets. A preliminary desertification assessment using the FAO/UNEP methodology was performed in Marsabit and was evaluated using the field data. On the basis of this evaluation a revised methodology was selected for application in Baringo and later in Marsabit. The results for Marsabit are given in a different report (see Appendix 1 - Report No. 5).

The revised methodology focused on the development of models that could be used in desertification assessment and mapping at national and regional levels. Five models of assessment of desertification status were developed:

The titles are:
1. Water erosion status
2. Wind erosion status
3. Vegetation degradation status
4. Range carrying capacity status
5. Human population density status

These models were developed using the detailed data collected in the study areas. Thus field data on the status of water and wind erosion and vegetation degradation were used to cross-check and validate the simulated status of these aspects. Information on desirable/undesirable species was used to validate vegetation degradation models. The range carrying capacity status was based on the present stocking rates and available forage, while the human population status was based on the density of human settlements. Using the field data, the simulated status, was fined-tuned to reflect a true picture of the field condition. Due to time constraint the models were not tested in other areas.

The development of these models was only possible through the use of the overlay capabilities of the Geographic Information System (GIS). The details on how the models were developed and the algorithms used are given in a separate report (see Appendix 1). Below is a brief discussion on each model and data elements used.

3.5.1 Water Erosion Status

The simulated water erosion status was generated using the Universal Soil Loss Equation (USLE) (Wishchmeir and Smith 1965) which was modified to suit the local conditions. Thus the land management and conservation factors in the U.S.L.E. were substituted with vegetation and rockiness factors. This was necessary because the study areas were predominantly used for extensive grazing and are located in semi-arid and arid areas where very little cultivation is practised. Rockiness factor is based on coarse fragments values used by Olderman (1988). The water erosion status was therefore analyzed using the following equation:

Status = Slope * Erosivity * Erodibility factors * Vegetation cover (%) * Rockiness factor (%).

Based on this analysis and field data, it was found feasible to rate water erosion status into a three-point scale: slight, moderate and severe. The rating was based on soil deformation features caused by water. Thus water erosion status was rated slight if the area had only rills and was rated as being moderate if it was experiencing sheet erosion and had moderate gullies. It was rated severe if the area was extremely gullied and had developed into badland.

The details on the data elements used in the analysis of water erosion status are given under sub-section 3.2.2 and 3.3.1.

3.5.2 Wind Erosion Status

The data required for the analysis of wind erosion status were: vegetation cover (%), rockiness cover (%) and potential wind erosion in the study areas. The rockiness and vegetation cover (%) data was collected in the field (see sub-sections 3.2.2 and 3.3.1.1).

The potential wind erosion in the study areas was calculated as explained in subsection 3.2.4.1 of this report.

As for the water erosion status, it was found feasible to rate wind erosion into a three-point scale: slight, moderate, and severe, based on vegetation and rockiness cover. The following equation was used in wind erosion status analysis.

Status = Vegetation cover (%) * Rockiness factor (%) * Wind erosivity index

3.5.3 Vegetation Degradation status

The vegetation degradation status for herbaceous biomass was derived by subtracting actual vegetation production from potential vegetation production of the study areas.

The potential herbaceous vegetation production was calculated using Rainfall Use Efficiency (RUE) values given by Pratt and Gwynne (1977) as detailed in Le Houeroux (1984). The RUE factor is the quotient of annual primary production by annual rainfall, i.e. the number of kilograms of aerial dry matter biomass produced over 1 ha in one year per millimetre of total rainfall. A rockiness factor was included to reflect varying site productivity. The actual vegetation production was determined from field data (see sub-section 3.3.1.2). The vegetation degradation status was therefore determined using the following equation:

Status = Actual Herb Production - Potential Herb Production
Potential Herb Production = Annual Rainfall * RUE * Rockiness factor

The vegetation degradation status was further analysed by calculating the ratio of desirable species to the undesirable species in each vegetation type (sub-section 3.3.1.3). Both the vegetation degradation status and the ratio of desirable species to the undesirable species were rated using a 3-point scale: slight, moderate, and severe.

3.5.4 Range carrying capacity status

The range carrying capacity status was derived by subtracting the predicted livestock herbaceous consumption from the actual herbaceous biomass available in each study area.

The actual herbaceous biomass (standing crop) was determined as explained in sub-section 3.3.1.2. This biomass was reduced by about 25 per cent to provide for the usual errors associated with vegetation sampling using small plots or quadrants (Pratt and Gwynne 1977).

The data on livestock numbers and their distributions for each study area was obtained from the Department of Resource Surveys and Remote Sensing (DRSRS). The body weights used in the calculation

of annual consumption requirements for each livestock species were: camel 301 kg, cattle 180 kg, donkeys 150 kg, and shoats (sheep and goats) 24 kg.

These body weights were obtained from Lusigi (1984). In calculating consumption for each animal species the following assumptions were made:

1. Each animal consumes forage material equivalent to about 2.5% of its body weight daily (Pratt & Gwynne 1977); and

2. That animals consume only about 66% of the available forage material without damaging range condition. This is a proper use factor which has been adopted for use in range science.

In addition the percent of diet of herbaceous material for each livestock type was considered. Based on Lusigi (1984), the diet of cattle, shoats, donkeys and camels consist of 99%, 80%, 99% and 71% of herbaceous material respectively.

Using the above data and assumptions the range carrying capacity status for each study area was determined. The status was rated into a 3-point scale: slight, moderate, and severe.

The slight rating represents areas where the stocking rates fails to exceed the range carrying capacity, while moderate represents areas where stocking rates almost exceed the range carrying capacity. Finally severe rating represents areas where the range carrying capacity is exceeded and range deterioration is apparent. The range carrying capacity was determined using the following equation:

Status = Available Herb Biomass - Predicted Livestock Consumption
where Available Herb Biomass = Field Data

3.5.5 Human Settlement Density Status

The human settlement density status was generated using SRF data collected by the Department of Resource Surveys and Remote Sensing on permanent human settlements (or dwellings). The dwellings were classified into three categories and then rated as follows:

Category	Rating
0 to 10 dwellings/km^2	Slight
10 to 20 dwellings/km^2	Moderate
20 dwellings/km^2	Severe

3.5.6 Desertification Hazard Map

A final desertification hazard map was generated by overlaying the results of the above analyses and adding up the individual status scores. The desertification hazard map which represents the actual danger of an area or region being desertified was rated into a 4-point scale rating: none, slight, moderate and severe.

4. RESULTS

4.1 INTRODUCTION

Detailed results for the soils, vegetation, wind erosion and human components of this study are given in separate individual reports (Appendix 1). In this report only a summary of the results of each individual report are given. The results are given in both tabular and map form. The maps were generated using the Geographic Information System technology. Most of the maps have not been printed on hard copies but are available in the GIS at DRSRS and can be produced when needed. For the purpose of this report, it was found necessary to produce only the status and hazard maps.

4.2 THE SOILS COMPONENT

The following maps and tabular data for both Baringo and Marsabit study areas were produced:

Maps

a. Soil unit maps
b. Rockiness cover maps
c. Water erosion maps
d. Soil erodibility maps
e. Soil salinization and alkalinization maps

Tabular

a. Revised criteria for assessing water erosion
b. Revised criteria for assessing salinization and alkalinization
c. Results of soil analysis for Baringo study area
d. Results of soil analysis for Marsabit study area.

The above generated maps (b to e) were transformed into 5 qualitative ratings of desertification (none, slight, moderate, severe and very severe) and the output are status maps for each factor indicator. The revised criteria for the assessment of water erosion and salinization and alkalinization are based on the detailed data collected in the study areas. The criteria may be applicable elsewhere where such detailed assessment may be undertaken.

4.3 THE VEGETATION COMPONENT

The following maps and tabular data for both Baringo and Marsabit study areas were produced:

Maps

a. Vegetatio 1/land use maps cover
b. Vegetatio.. canopy cover (including ground bareness, herb layer cover, shrubs/trees)
c. Biomass production (standing crop)
d. Distribution of desirable plant species.

Tabular

a. Seasonal Biomass production in different vegetation types
b. Plant frequency and density
c. Plant community associations
d. Data for correlation analysis (releve method versus line intercept method).

Table 5. Changes in vegetation cover and agriculture for six sites in Baringo 1950 - 1981

Site	Period	Areas that improved to a better cover class		Areas that degraded to a worse cover class		Areas slightly degraded or improved but remained in same cover class		% Area that changed into agriculture
		% Area	% Change in cover	% Area	%Change in cover	% Area	% Change in cover	
Marigat	1950-1981	3.9	+30	5.0	15	73.0	-2	18.1
Kampiya Samaki	1950-1981	2.0	+8	4.5	-15	91.5	-4	2.0
Sandai	1950-1981	6.5	+10	14.9	-32	72.8	-9	5.8
Komolion	1950-1981	0	0	0	0	100	0	0
Ngambo	1950-1981	43.2	+60	27.7	-10	25.0	-6	4.1
Salabani	**1950-1981**	**11.0**	**+20**	**31.6**	**-13**	**55.9**	**+3**	**1.5**
Average		11.1		14.0		69.7		5.3

Table 6. Changes in vegetation cover and agriculture for six sites in Marsabit 1950 - 1981

Site	Period	Areas that improved to a better cover class		Areas that degraded to a worse cover class		Areas slightly degraded or improved but remained in same cover class		% Area that changed into agriculture
		% Area	% Change in cover	% Area	% Change in cover	% Area	% Change in cover	
Illaut	1956-1972	0	0	18.0	-15	82	0	0
Balesaa	1957-1972	0	0	5.0	-25	95	04	Negligible
Logologo	1956-1972	0	0	100	-20	0	09	0
Kargi	1957-1972	0	0	0	0	100	0	0
Korr	1956-1972	0	0	0	0	100	0	0
Karale	1957-1972	0	0	0	0	100	0	Negligible
Average		0		20.5		79.5		Negligible

Table 7. Changes in settlements in the 12 sites of Baringo and Marsabit

Site	Year	No. of settlements	Year	No. of settlements	% change in settlements
BARINGO					
Marigat	1950	36	1981	668	1756
K. Samaki	1950	2	1981	463	23000
Sandai	1950	5	1981	100	1900
Ngambo	1950	20	1981	136	580
Salabani	1950	13	1981	132	915
Komolion	1950	6	1981	12	50
MARSABIT					
Ilaut	1956	97	1972	147	52
Balesa	1957	30	1972	43	43
Kargi	1957	19	1972	36	89
Logologo	1956	15	1972	67	347
Koir	1957	7	1972	58	729
Karalle	1957	15	1972	21	40

The above generated maps (b and d) were transformed into 5 qualitative rating of desertification and the output are status maps. Vegetation communities in the same ecological zones were considered together and the cover classes suggested by Grunblatt et al (1989) of closed, dense, open, sparse and barren (or bare) were employed in the severity rating.

The results on rate, analysed from recent past photographs are summarised in Tables 5, 6 and 7. The dot grid methodology proved useful in the case of Baringo where photographs available were at scales of 1:20,000 and 1:40,000. It was possible to delineate vegetation community boundaries, cultivated areas, and to count settlements. However, for Marsabit the photographs available were at scales of 1:50,000 and 1:80,000. At these scales the smaller trees and shrubs which are common in these areas are hardly discernable. It was, however, possible to draw broad areas of different canopy covers by visual estimation and therefore changes in boundaries were possible but not their actual canopy covers. At these scales of Marsabit it was also possible to delineate cultivated areas and settlements could be identified and counted. The time span considered was 32 years (1950 - 1981) for Baringo and 16 years (1956 - 1972) for Marsabit.

In Baringo, it was found that some vegetation communities expanded in area as well as improved in canopy cover, while others also expanded in area and degraded in canopy cover (see Table 5). The causes of improvement were mainly due to irrigation in Perkerra at Marigat. The area downstream the irrigation scheme changed from sparse vegetation to closed forest due to water percolating downstream and providing enough soil moisture. Other areas are frequently flooded and changed into grasslands. In some other sites the course of rivers changed and created new and better vegetation cover at their deltas on Lake Baringo.

It is, therefore, difficult to give one single rate of change on vegetation cover. However, on average the area which improved was 11%, the area which degraded was 14% and that which remained the same was 70%. The area under cultivation increased from a negligible area to occupy an average of 5% of the study sites.

The settlements (and therefore population) increased tremendously in all the study sites (Table 7). The large increase in Kampi Samaki was due to tourism activities and fishing and fish processing industry at the centre; while in Marigat it was due to irrigation scheme activities at Perkerra.

The general picture for Marsabit is that no significant degradation occurred during the 16 years except for Logologo and a little for Illaut. Agriculture except for around Marsabit mountain was negligible and settlements, increased but not as much as in Baringo. Because the degradation was apparent only at Illaut and Logologo, it would not be fair to derive a rate and generalise it to the whole study area.

4.4 WIND EROSION

The following maps and tabular data for both Baringo and Marsabit study areas were produced:

<u>Maps</u>

a. Wind deflation and deposition areas
b. Wind roses

<u>Tabular</u>

a. Wind erosion assessment using mean wind speed at 2m height (m/sec)
b. Wind erosion assessment using the frequency of active wind (V>6m/sec) expressed as % of total number of wind observations for 1982 - 1985
c. Annual ratings of movements of sand
d. Load of sand carried by wind in tons per cubic mile.

The major finding on wind erosion in Marsabit were:

1. The rate of soil/sand flow is negligible at the windward site of Mt. Marsabit but increases with distance at the leeward side until it reaches a maximum that a given wind can carry.

2. The deflation areas are found to exist in the north and south of Mt. Marsabit. These are the areas where cyclonic and anticylonic vortices have been found to exist.

3. Severe wind erosion occurs during dry seasons due to high frequency of severe sand-storms/dust-storms and also due to the wind deflation areas having little or no vegetation cover.

In the Baringo study area the main findings were:

1. No wind action was observed during the time of field study (wet season). The ground was bare in many places.

2. In the dry season, (December, January, February and March), it was reported that wind speeds are very high and during this period severe dust-storms occur. This is the period when the ground is dry and bare.

4.5 HUMAN ECOLOGY

Social-cultural and socio-economic data were collected in the two study areas in both map and tabular form:

<u>Maps</u>

a. Livestock grazing system

<u>Tabular</u>

a. Human feeding habits
b. Livestock herd composition, numbers and ranking of species importance.
c. Water availability
d. Human population
e. Measures of nutrition
f. Main constraints to livestock sales
g. Settlement types
h. Reasons for migrating
i. The socio-economic status
j. Factors for socio-economic development
k. Whether there is pressure on land resources and reasons for land degradation
l. Traditional methods of environmental conservation and the status of the environment as it is now compared to what it was 20 years ago.

The details of the data are presented in a separate report (see Appendix 1). The major findings of the human ecology aspect of this study were:

1. The human population has drastically increased in the two study areas since 1962 (Tables 8 and 9). The average inter-censal population growth rate between 1969 and 1979 in Marsabit has been estimated at 6.4% per year. Between 1969 and 1979 the Boran population grew by 6.8%, the Gabbra 6.2% and the Rendille 1.5% per annum. Based on the 1979 population census, the Njemps location population in Baringo was 8642. Out of this, 6800 were Ilchamus (Njemps) and the rest were Tugen who came in from the hills in search of arable land. The Ilchamus population increased more than 300% between 1929 and 1979 (Little 1981); this gave an annual increase of about 2%.

2. There is increasing pressure on land resources in both areas. About 80% of the respondents were of the opinion that pressure on land resources was increasing. The main factors responsible for this pressure were said to be increase in both human and livestock population and decrease in rainfall. This situation has been compounded by sedentarization in certain centres where there is water, shops, dispensaries, schools, famine relief posts e.g. at Korr, Maikonna, Kargi, Marsabit town, Logologo and Illaut in Marsabit and Kampi Samaki, Marigat, Loboi, Sandai in Baringo.

3. Cattle were singled out by the pastoralists (80% of those interviewed) as being the main agents of environmental degradation - mainly through overgrazing and trampling. Sheep and goats are also seen as playing an important role in environmental degradation. The camel was singled out as the least destructive animal in both respects. Most respondents were willing to sell excess livestock, but due to low prices offered and the long distances to markets, they cannot sell their livestock.

4. About 70% of the respondents said that their immediate environment is more degraded now than it was in the past. This is because settlements have been set up which encourage families to settle permanently in selected areas, leading to a breakdown in the pastoral grazing system. The cutting of vegetation for construction of *manyattas* (temporary houses), and for firewood, has greatly reduced vegetation cover around the settlements.

5. The environmental degradation due to overgrazing is likely to continue because this study confirmed that among the Pokot, Rendille, Gabbra and Samburu, their diet is still largely meat, milk and blood from livestock, with minimal diversification of dietary tendencies.

Table 8. Human population Baringo lowlands (Njemps location)

Sub-Location	1979 Population	% Increase since 1962	1979 Population (per km^2.)
Ngambo	3116	101	66
Loiminange	1519	62	8
Eldume	810	57	19
Mukutani	1708	46	8
Salabani	1789	31	50
Marigat Trading Centre	987	-	160

Source: LBS 1962 and 1979 Population census, and Little (1981)

Table 9. Total population of the Gabra, Rendille and Boran in 1962, 1969, and 1979 in Marsabit District

	1962	1969	1979
Gabra	10,734	15,890	23,410
Boran	3,283	13,432	30,444
Rendille	13,638	17,686	19,856

Source: CBS population census 1962, 1969, and 1979

4.6 RESULTS OF DATA ANALYSIS

Using the Geographic Information System Technology, a set of selected data sets from the above results plus other ancillary data were integrated and used in developing five models for desertification assessment and mapping. Figures 3 to 8 give the modelling results for the Baringo study area. These models have been validated through field checks.

The details about models are given in a separate report (Appendix 1) but a general discussion is given in section 3.5 of this report. The developed models can be used to assess and map desertification at a national level. However, it should be noted that the models can still be refined further or modified if need be for a national study. For example, during the review meeting it was recommended that for national or global assessment, the following integrated models should be considered:

1. Soil degradation: including water and wind erosion;
2. Vegetation degradation;
3. Land-use: Livestock stocking rates, crops, and agricultural marginalization;
4. Societal/Population impact:socio-economic data and land tenure;
5. Climate: Index of aridity and rainfall variability.

5. DISCUSSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

The main objectives of this study were:

1. To evaluate the applicability of the FAO/UNEP Provisional Methodology for Assessment and Mapping of Desertification.

2. Develop a simplified methodology that could be used for the assessment and mapping of desertification at local, national and regional levels;

Based on the results and experience gained in this study, the following conclusions and recommendations are made:

5.2 APPLICABILITY OF THE FAO/UNEP METHODOLOGY

A detailed evaluation of the methodology indicated that it was extremely expensive to collect the detailed data on the proposed desertification indicators.

It was also noted that most of the data required was not available even in developed countries (Sabadell, et al 1982, Babaev et al 1984). It was therefore concluded that the proposed methodology is only applicable at a local or pilot study level, and cannot be used in assessing and mapping desertification at a national and regional level. However, it should be noted that quite a number of indicators could be used to assess and map desertification at a national or regional level if only generalized data on them was used.

Details on which indicator can be used at the local or national levels are given in Table 3.

Concerning the methods proposed in collecting data, it was felt that for the collection of the detailed data, it is inevitable that the methods have to be mainly field - based and consequently expensive. The proposed use of remote sensing in collecting more generalized data was considered more appropriate and of wider application.

5.3 HIERARCHICAL STUDY APPROACH FOR ASSESSING AND MAPPING DESERTIFICATION

In this study an hierarchical study approach was adopted in an attempt to develop a simplified methodology for assessing and mapping desertification at local, national and regional level. The principle behind this approach was to collect detailed data at local level and then select from it generalized data elements which could then be analyzed and used in developing desertification assessment and mapping models. The models could then be used to assess and map desertification at the national level using basic data which may readily be available, or can be collected quickly.

This approach entailed collection of detailed data on the chosen factors and indicators (Table 2) using mainly ground based methods. Thus this approach initially quite expensive, but once the models have been developed it becomes less expensive. Based on the models developed in this study, it is apparent that detailed data on a number of parameters considered in this study can only be used at the local level.

5.4 DESERTIFICATION INDICATORS

There are many types of indicators that can be used in desertification assessment and mapping. The choice of indicators to be used will depend on the objectives of the assessment and level of detail required. For example if the assessment is undertaken at a pilot study level, detailed data on a variety of indicators may be required. However, if the study is undertaken at a regional level, only generalised data on selected indicators may be required.

In this study, data was collected on varied types of factors/indicators. During the data analysis it became apparent that some of the indicators could suitably be used for desertification assessment at a pilot or local level only.

However, some of the indicators were found to have wider application and could successfully be used in developing models that could be used in national assessments (See Table 3). The data elements used in the development of desertification assessment and mapping models for this study are given in section 3.5.

The developed models are considered as being suitable for desertification assessment - particularly at a national level for they can be easily verified through field observation.

5.5 METHODS USED IN DATA COLLECTION

A variety of methods were used in collecting data in this study. The methods included the use of remote sensing, field surveys, administration of questionnaires and literature review. The SPOT satellite imagery was used to produce preliminary vegetation and soil unit maps. This was in turn used to map areas of intensive water erosion.

The field surveys were used to collect detailed data on both soil and vegetation parameters. The questionnaire technique was used to collect socio-economic data.

All the above methods have their advantages and disadvantages. The remote sensing techniques give generalized data but at a lesser cost, while the field surveys give detailed data but at a very high cost. The choice of what method to use in collecting data will depend mainly on the objective of the study. However, if the objective is to provide generalized data at a smaller scale, then remote sensing techniques are recommended as being rapid and relatively cost-effective. For example in this study, about two days of satellite image analysis were required to produce preliminary soil-vegetation unit maps for the two study areas. However, it took about 10 days in each study area to collect detailed vegetation and soil data using field survey methods described in section 3.0. The time needed to collect detailed data was actually double because the data was collected during both the dry and wet seasons. Based on the financial expenditure of this study (see Appendix 4) it can be said that this study became expensive mainly because of the field surveys which included the administration of questionnaires.

To reduce the cost of collecting data at the national level, it is proposed that remote sensing be used in collecting more generalized data and simpler methods be used in collecting the more detailed data. It is recommended that ocular or visual estimation should be used in collecting data on vegetation and human settlements rather than the use of ecological methods as long as the person making the visual estimates is experienced in making of consistent estimates. In this study, ocular estimation of vegetation canopy cover was found to be as good as the data derived from line-intercept measurements.

Equally visual estimation of rockiness was found to be as good as that determined using quadrats.

It should be noted that reliable visual estimation depends on the experience of the estimator and consistence of estimators depends on training, experience and calibration. It is further recommended that SRF methods be used in collecting data on livestock, human settlements and other environmental attributes i.e., vegetation.

5.6 THE USE OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN THE ASSESSMENT AND MAPPING OF DESERTIFICATION

The GIS is an important tool in the assessment and mapping of desertification because of its capabilities in supporting modelling. The GIS allows for the integration of a number of data elements and has a wider scope of data manipulation. Its convenient use to produce and update maps and tabular data makes it a very important tool for desertification assessment. In this study the GIS was used in the digitization and analysis of data and in the development of desertification models, and final products.

5.7 APPROACH TO NATIONAL ASSESSMENT AND MAPPING OF DESERTIFICATION

The models developed in this study can be used to assess and map desertification at national level. The models require only generalized data. A number of institutions in Kenya collect the data that is required for the developed models. Though most of the data for the use in the models may be available, the need for further collection of data in the field to augment the existing one cannot be over-emphasized. Also there is a need to validate assessments generated using the models.

5.8 DESERTIFICATION ASSESSMENT OF THE STUDY AREAS

5.8.1 Introduction

The results of this study show that desertification which is land degradation in arid, semi-arid and sub-humid areas is a major problem in the study areas. The main forms of desertification identified were soil and vegetation degradation. The soils are being degraded through water and wind erosion, while vegetation degradation is through tree and shrub cutting and overgrazing.

Both soil and vegetation degradation are very severe around settlement areas. Apart from experiencing common land degradation problems, the study areas differ in a number of aspects i.e., climate, land use, socio-economic, degree of land degradation and potential for land rehabilitation.

5.8.2 Climate

The details on climate for the two study areas are given in chapter 2. In general the Marsabit study area is located in an arid environment (with exception of areas around Mt. Marsabit) where the average annual rainfall is less than 250mm. The area has seasonal rivers which originate from hill masses and drain into the central plain where their water evaporates or sinks.

In contrast, the Baringo study area is located in a semi-arid/sub-humid environment where the average annual rainfall is about 600mm. The area is drained by two permanent rivers which drain into Lake Baringo via the Njemps flats.

5.8.3 Land Use

As a result of difference in climate, the land use patterns in the two areas differ in a number of ways.

In Marsabit, the land is predominantly used for extensive grazing, with only areas around Mt. Marsabit being used for both arable agriculture and grazing. The area is inhabited by three nomadic tribes: the Rendille, Gabbra and Boran. The Gabbra occupy the northern and north west, the Rendille south and south-west and Boran occupy the eastern and south-eastern parts of the study area. The grazing system in the district is governed by rainfall regime. Thus during wet season (March to May) most of the grazing is confined in the lowlands. During the dry season, the animals are moved to the mountain areas i.e, the Gabbra move to the Huri Hills and Mt. Kulal, the Rendille move further southwards into Ndoto Mts. in Samburu district, and the Boran more or less confine grazing around Mt. Marsabit throughout the year. The availability of water is the most crucial factor in this grazing system. Thus a number of areas are not grazed at all due to lack of water. There is a tendency for animals to graze around areas where there are boreholes or wells. These areas are being over utilized and consequently are heavily degraded. Due to the harsh climate, the camel is the most important livestock species in this area, followed by goats.

Unlike Marsabit, the land use practice in Baringo is different and diversified. First, the grazing system is not as extensive as in Marsabit, though seasonal grazing is practised. There are three ethnic groups in the area. These are the Njemps, Tugen and Pokot. The Njemps inhabit the central lowlands or what is commonly known as Njemps flats (area between L. Bogoria and L. Baringo).

The Tugen inhabit the Tugen hills and the Pokot occupy the northern parts of the district - Muktany/Nginyang/Tanguilbei areas. The Njemps practice arable agriculture using irrigation. They are also fishermen and predominantly lead a sedentary life. They also keep livestock which is mainly grazed in the lowlands in the wet season and moved into Laikipia escarpment during the dry season.

The Tugen are basically agriculturists, though some of the families have livestock in the lowlands. The Pokot are solely pastoralists and their grazing system is well-coordinated and controlled by elders. Since the Pokot inhabit the drier parts of the study area, the camel is increasingly becoming a very important animal in their community.

Unlike Marsabit, where land is predominantly owned by tribal communities, in Baringo the land tenure system is different. In the highland areas (Tugen Hills) the land has been adjudicated and is individually owned. The lowland areas (Njemps flats) are currently being adjudicated. It is only the Pokot territory which is still being owned communally.

5.8.4 Socio-Economic

The economic activity of Baringo is more diversified than that of Marsabit. In Baringo both pastoralism and arable agriculture are very important while in Marsabit pastoralism is the most important. Apart from pastoralism and arable agriculture, the people in Baringo are also involved in other economic activities i.e., fishing, business and tourism activities. This is possible because Baringo has a good communication network and is near to major towns, hence the marketing of both livestock-mainly goats and agriculture produce is not a major problem.

As a result of its strategic position and diversity in economic activities, the population in the Baringo Study area is increasing very fast. Based on the 1979 population census, the Njemps location population was 8642 out of this 6800 were Ilchamus (Njemps) and the rest were Tugen who came from the hills in search of arable land.

In contrast, the economic activities in Marsabit are very limited due to a number of factors, the main ones being its location far away from major towns and its poor communication network. Also its harsh climatic conditions does not allow diversification in land use. As a result the major economic activity in the area is pastoralism. Thus livestock products form the major diet of the people who inhabit this area. Due to its location and poor communication, marketing of livestock is a major problem. In spite of the previously mentioned factors, the population is increasing rapidly, particularly around market centres and towns. The average inter-censal population growth rate between 1969 and 1979 has been estimated at 6.4% per year. Most of the population is found in market centres i.e., Marsabit town, Kargi, Maikonna, Korr, Illaut and Logologo where there are shops, schools, missions, dispensaries and other social amenities.

5.8.5 Degree of Land Degradation

Land in Baringo is more prone to degradation than in Marsabit. This is mainly due to the type of soil, and the amount of rainfall received - mainly rain water from the Tugen hills. The soil in the lowlands or flats is friable and therefore liable to both water and wind erosion. Thus during the rainy season, soil is eroded and the consequence is the formation of gullies and badlands.

The areas in the study area where water erosion is very severe are Loboi, Eldume, Marigat and Endao. Water erosion is being accelerated in these areas due to increasing human and livestock population. Due to overgrazing, trampling and the cutting of trees, especially around settlement areas, the soils are bare and loosened and this increases their vulnerability to both wind and water erosion. Also due to increasing use of fertilizers in the irrigation schemes, the problem of salinization is increasingly becoming important. Wind erosion in Baringo, occurs only during the dry season (January - March) when most of the areas are bare. During this period, heavy dust-storms occur and a lot of soil is blown away.

Lastly as a result of overgrazing especially around settlement areas, most of the desirable plant species have disappeared and have been replaced by undesirable ones e.g., Heliotropium Spp, Portulaca Spp etc.

Due to the practice of extensive grazing in Marsabit, the land degradation is not a problem in many areas except around the settlements and trading centres. Marsabit being located in an arid environment, water erosion is not very important except on the slopes of Mt. Marsabit and the southern areas bordering the Ndoto Mountains. However, wind erosion in this area is more important than for Baringo. Wind erosion is severe in the flat areas where the channel separating the Ethiopian Highlands and Ndoto and Marsabit Mountains is narrow. The winds occur in this channel throughout the year but they are very severe during the dry season. Due to vegetation cover on Mt. Marsabit and other hills and lava and rock cover in the lowlands, the wind erosion effect is minimized, otherwise the area is prone to very serious wind erosion.

5.8.6 Potential for Land Rehabilitation

Although land degradation is more severe in Baringo than Marsabit, the land in Baringo has a higher potential for rehabilitation than Marsabit. This is mainly because the area receives ample rainfall, the soils are fertile (alluvial sediments) and there are permanent rivers. The current land rehabilitation programmes in the area have shown that degraded land can be rehabilitated through revegetation and the potential for plant regeneration is high. As a result of the on going adjudication programme, it is expected that land rehabilitation will be speeded once land is owned individually. The people in the area are already aware of the need for soil conservation. The potential for rehabilitation of degraded areas in Marsabit is there but not as high as in Baringo. This is mainly because the area is located in an arid environment and already some areas i.e., Chalbi Desert, have attained desert conditions. However, rehabilitation programmes particularly around settlement areas have shown that vegetation can recover and thrive in some of the areas.

In both the Baringo and Marsabit study areas, land degradation has been aggravated mainly by an ever-increasing human population (see Tables 8 and 9).

5.9 RECOMMENDATIONS

Based on the findings of this study the following recommendations are made:

1. Remote sensing techniques (Satellite Data and Systematic Reconnaissance Flights (SRF) should largely be used in the gathering of data for assessment and mapping of desertification at national level. The techniques are simple, rapid and relatively cost-effective. It is recommended that the use of visual interpretation of satellite imagies should be adopted with minimum digital image analysis.

2. The development and use of models in desertification assessment and mapping at regional or national level should be encouraged and strengthened. Further improvement and validation of the developed models is essential.

3. Visual or ocular estimation methods should largely be used in collecting data from the field particularly for the data to be used at a national or regional level. This will allow for rapid gathering of detailed data from the field and reduce costs.

4. The socio-economic data in desertification assessment is very important and should not be ignored. However, most of it is applicable at local or management level.

5. The desertification indicators given in Table 3 are recommended for desertification assessment and mapping at local, and national levels.

6. Because of the large amounts of data required for the modelling process and for generating tabular and cartographic products the use of GIS is recommended. The use of GIS will allow establishment of data base for further or long-term evaluation. Development of standard methods of data analysis will enhance the usefulness of the GIS.

6. REFERENCES

1. Banoub, E. F. (1970). Sand-storms and dust-storms in U.A.R. Tech. note No. 1; Meteorology Department, Cairo, 35pp.

2. Babaev, A. G. I. S. Zonn and N. S. Orlovsky (1984). The USSR experience in desert reclamation and desertification control. Moscow 1984.

3. Chepil, W. S. (1965). Transport of soil and snow by wind. Met. Monographs, Vol. 6. No. 28.Am. Soc. Boston, pp 123-137.

4. Chepil, W. S. and N. P. Woodruff (1975) Sedimentary characteristics of dust storms 11: Visibility and dust concentration. Am. J. Soc.,New Haven, Conn., 225, pp 104-114.

5. Caldwell, J. (1975). The Sahelian Drought and its Demographic Implications. Overseas Liaison Committee Paper No. 8., American Council on Education.

6. Kenya (1971). Kenya Population Census, 1969 Ministry of Economic Planning and Development. CBS.

7. Kenya (1981) Kenya Population Census, 1979. Ministry of Planning and Development, Nairobi. CBS.

8. Dregne, H. E. (1977). Desertification of Arid Lands. Advances in Desert and Arid Land Technology and Development Volume 3. Hardwood Academic Publishers.

9. Dregne, H. E. (1977). Desertification of Arid Lands. Economic Geography 53 (4): 322-331.

10. FAO/UNEP/UNESCO (1979). A provisional methodology for soil degradation assessment, Rome.

11. FAO/UNEP (1984). Provisional Methodology for Assessment and Mapping of Desertification, Rome.

12. FAO (1980) Report on the first FAO/UNEP Expert Consultation on Desertification Assessment and Mapping. Rome.

13. FAO (1981) Provisional Methodology for Desertification Assessment and Mapping. Rome.

14. Grunblatt J., W. K. Ottichilo and R. K. Sinange (1989). A Hierarchical Approach to vegetation classification in Kenya. Afr. J. Eco. Vol.27, 45-51.

15. Grig - Smith, P (1964). Quantitative and Plant Ecology, 2nd ed., London Butterworth.

16. Heady, H. F. (1983). Suggestions to KREMU for vegetation monitoring procedures. (Unpublished manuscript), University of California. Berkeley.

17. Houerou, H. N. (1984). Rain Use Efficiency. A unifying concept in Arid-Land Ecology. Journal of Arid Environments 7:213-247.

18. Jaetzold, R. and H. Schmidt (1982), Farm Management Handbook of Kenya Vol.III, Nairobi: Ministry of Agriculture and German Technical Team.

19. Kharin, N. G. M. P. Petrov (1977), Glossary of terms on natural conditions and desert development, Materials for the UN Conference on Desertification. Nairobi, Kenya.

20. Kassas, M. (1988). Ecology and Management of Desertification Earth '88' Changing Geographic Perspectives.

21. Kenya Meteorological Department (1984). Climatological Statistics for Kenya.

22. Kershaw K. A., (1973). Quantitative and Dynamic Ecology (2nd Edition).

23. Krebs, J. (1978). The experimental Analysis of Distribution and Abundance. 2nd edition , New York. Harper and Row Publishers.

24. Little, P. D. (1981). Combating Desertification and Rehabilitating Degraded production systems in Northern Kenya. IPAL Technical, A-4, UNESCO, Nairobi.

25. Lusigi, W. (1984). Integrated Resource Assessment and Management Plan for Western District, Marsabit, Kenya. UNESCO - FRG-MAB Integrated Project in Arid Lands.

26. Lusigi W. J. , E. R. Nkurunziza, K. Awere - Gyekye, S. Masheti (1986) Range Resource Assessment and Management Strategies for South - Western Marsabit, Northern Kenya. UNESCO, Nairobi.

27. Mabbutt J. A. (1984). A new Global Assessment of the Status and Trend of Desertification Environmental Conservation Vol.II No. 1 Switzerland.

28. Mather, J. R. (1954). The measurement of potential evapotranspiration Climatology. Vol.III No.1.

29. McIntyre, G. A. (1953). Estimation of Plant density using line transects. J. Ecol. 41:319-330.

30. McCulloch, J. S. G. (1965). Tables for the rapid computation of the Penman estimates of evaporation E.A.A.F.R.O., Nairobi.

31. Olderman R. (1988). Guidelines for general assessment of the status of human induced soil degradation. International Soil and Information Center (ISRIC). Wageningen, The Netherlands Working Paper No. 88/3.

32. Norton-Griffiths. M. (1978). Counting Animals. Second Edition. African Wildlife Leadership Foundation. Nairobi.

33. Pratt. D. J. and M. D. Gwynne (1977). Rangeland Management and Ecology in East Africa. Hodder and Storughton, London.

34. Rozanov B. G. I. S. Zonn (1983). The Definition, diagnosis and Assessment of desertification in relation to experience in the USSR. Desertification Control Bulletin Number 7. UNEP, Nairobi.

35. Kenya (1972). Topo Sheets for Baringo and Marsabit (1:250,000) Survey of Kenya, Nairobi.

36. Kenya (1980). Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, Nairobi.

37. Sabadell, J. E. E. P. Risley, H. T. Jorgenson and B. S. Thornton (1982). Desertification in the United States Bureau of Land Management Department of the Interior.

38. Spooner, E. and H. S. Mann (1982). Desertification and Development Dryland Ecology in Social Perspective. Academic Press, N.Y.

39. Southwood, T. R. E. (1978). Ecological Methods, with Particular Reference to the Study of Insect Populations. New York: John Wiley and Sons.

40. UNCOD (1977). United Nations Conference on Desertification, New York.

41. UNESCO (1977) Map of the World Distribution of Arid Regions MAB Technical Notes 7.

42. Van Kekem (1984). Soils of the Mt. Kulal - Marsabit Area. Ministry of Livestock Development, Nairobi.

43. Westman, W. E. (1970). Mathematical models of catina and their relation density and area sampling techniques. In G.P Patil, E.C. Pielon and W. E. Water (Eds). Statistical Distributions. Pennsylvania State University, University Park, pp 515-536.

44. Wischemeier, W. H. J. and D. D. Smith (1965). Evaluation of Factors in the soil loss equation. Jnl. of Agriculture Eng.39.

45. WMO (1988). Manual on Codes, Vol. 1. International Code WMO No. 36, 1988 edition.

46. World Resource Institute 1989. The World Resources 1988-89. Basic Books Inc., New York.

47. Zonneveld, I. S., H. van Gils and D.C. P. Thalen (1979). Aspects of the ITC approach to Vegetation Survey. Doc Phytosociologiques N.S. Vol IV, Lille

Appendix 1

LIST OF INDIVIDUAL CONSULTANT REPORTS

1. Report on Soils in the UNEP/DRSRS Desertification Assessment and Mapping Project by M. J. Kamar.

2. Vegetation Assessment and Mapping in Baringo and Marsabit Areas by W. K. Ottichilo and R. K. Sinange.

3. Human Ecology as a Factor in the Desertification Process in Baringo and Marsabit Districts Pilot Study Areas by H. A. Mwendwa.

4. Assessment of Applicability of FAO/UNEP Methodology on Wind Erosion in Selected Areas in Marsabit and Baringo and Recommended Wind Degradation. Indicators by J. H. Kinuthia.

5. Desertification Assessment Modelling: Kenya Pilot Study by Jess Grunblatt.

Appendix 2

CALCULATION OF PET BY THORNTHWAITE EQUATION (1948):

$E = 1.6\,(10t/I)^{a}$ .... (i)

where

E = potential evapotranspiration (cm/month)

t = mean monthly temperature (°C)

I = heat index for the year which is the summation of 12 monthly indices ...... (i)

$i = (t/5)^{1.514}$.................................. (ii)

$a = 6.75 \times 10\text{-}7I^{3} - 7.71 \times 10^{-5}I^{2} + 1.79 \times 10^{-2}I + 0.49$...... (iii)

The formula gives unadjusted rates of PET.

Appendix 3

PROCEDURE FOLLOWED TO CALCULATE ADJUSTED POTENTIAL EVAPOTRANSPIRATION (E) BY USE OF TABLES:

The unadjusted E is adjusted for day and month length, taking a month of 30 days of 12 hours each as standard. The relationship between temperature and evapotranspiration in several areas tend to converge where potential evapotranspiration is 13.5 cm and temperature is 26.5°C. At lower temperatures there is increasing divergence in potential evapotranspiration.

The procedure followed is outlined below:

1. Obtain mean monthly temperatures for the whole year in °C from the meteorological publications where available.
2. Obtain the values of i from Table A corresponding to monthly mean temperatures.
3. Obtain I (annual heat index) by summing i in Appendix 1 for 12 months.
4. Use I to get unadjusted monthly PET from Table B (a) and multiply the value obtained from table by 30. The values obtained are in mm and are converted to cm before use.
5. For mean monthly temperatures above 26.50°C obtain the unadjusted monthly PET from Table Bb. Multiply the value obtained by 30. The values obtained are in mm and are converted to cm before use.
6. Use the latitude of the station and from Table C obtain the correction factor.
7. Multiply the unadjusted monthly PET by correction factor to get the corrected value of PET.

Note: Tables A, B and C were reproduced from the measurement of Potential Evapotranspiration, Publication in Climatology Volume VII No.1 edited by Mather (1954).

Appendix 4

FINANCIAL ANALYSIS FOR APPLICATION OF THE METHODOLOGY

1. INTRODUCTION

This financial analysis covers the costs incurred in implementing the methodology used to assess and map desertification in the study areas. The analysis only considers the costs of collecting and analysing detailed data at local level. It does not consider the costs for the purchase of vehicles and administration of the project. This financial analysis approach was deemed appropriate in order to evaluate the actual cost per Km^2 of applying the methodology at the local level. It is hoped that the actual cost would act as a guide when budgeting for similar projects elsewhere.

1.1 LOCAL ASSESSMENT

The study components considered were vegetation, soils, wind erosion and human ecology. Also included in the study components is the data analysis and modelling. The details on personnel, time, field allowances, cost of maintaining and running vehicles are given in individual reports of each study component. In this analysis, the aggregated cost for each component is given as well as the cost of collecting and analysing the same data in one square kilometre (km^2). This information is given in Table 1. The aggregated cost covers the two study areas with a total area of 17,600 km^2.

The aggregated cost for each component includes consultant's fees, field allowances, cost of running and maintaining vehicles. Included also are costs for the purchase of SPOT images for vegetation, soil and wind erosion mapping, the purchase of aerial photos for the vegetation mapping, the cost of analysing soil samples and the payment to field enumerators for the human ecology component. For data analysis, the cost includes computer time, computer paper and pens and cost of hiring a systems analyst and data analyst.

Table 1 The aggregated cost of each study component

Study Component	Total cost (US Dollars)	Cost per km^2 (US Dollars)
Vegetation	33,848	1.92
Soils	28,418	1.62
Wind Erosion	11,085	0.63
Human Ecology	13,310	0.76
Data Analysis	34,500	1.96
Total	121,161	6.89

From the information given in Table 1, it is apparent that the costs of collecting data are different for each study component. The cost of collecting vegetation data was the highest and was followed by the soils data. However, it should be noted that the cost of collecting human ecology data would have been equally higher had the data been collected during both dry and wet season.

Based on this analysis, it can be concluded that the cost of collecting and analysing data on all the study components was about US\$7/km^2 at local level. This is expensive particularly if the assessment was to be undertaken at national level. However, at local level, this cost is considered to be modest given that detailed data necessary for management are collected and analysed.

1.2 NATIONAL ASSESSMENT

For national desertification assessment and mapping, less detailed data is required. As proposed in this study, only generalized data is required for the development of assessment and mapping models. In the case of Kenya, most of the data required for national assessment is available. The climatic data is readily available at the Kenya Meteorological Department. The exploratory soil map and agro-climatic zone map of Kenya (1:1,000,000) has been produced by Kenya Soil Survey and has already been digitized by GEMS-GRID (UNEP). The data on vegetation, livestock and wildlife numbers and on human settlements for the Kenya rangelands are available at DRSRS. And data on human ecology for a number of areas in Kenya can be found at the Central Bureau of Statistics, Institute of Development studies (University of Nairobi), Ministry of Planning and National Development (ASAL Project) and in existing literature.

Therefore a national desertification assessment project in Kenya will require very limited field data collection. The main task would be to collate and analyze all the required data from different government departments and institutions and integrate it in the proposed models. However, limited field work will have to be undertaken to gather missing data and to validate the desertification maps that would be produced through modelling exercise.

Given that most of the required data for desertification assessment and mapping in Kenya is available, it envisaged that the overall cost of collecting and analysing data per km^2 will be much less than at the pilot or local level. It is estimated that the cost per km^2 will be about an eighth of the cost per component in this study. (Table 2).

Based on this estimate, it would cost about US\$ 0.90 per Km^2 in Kenya. Given that the total land area of Kenya is about 567,000 km^2, the total cost would be about US\$ 510,300.

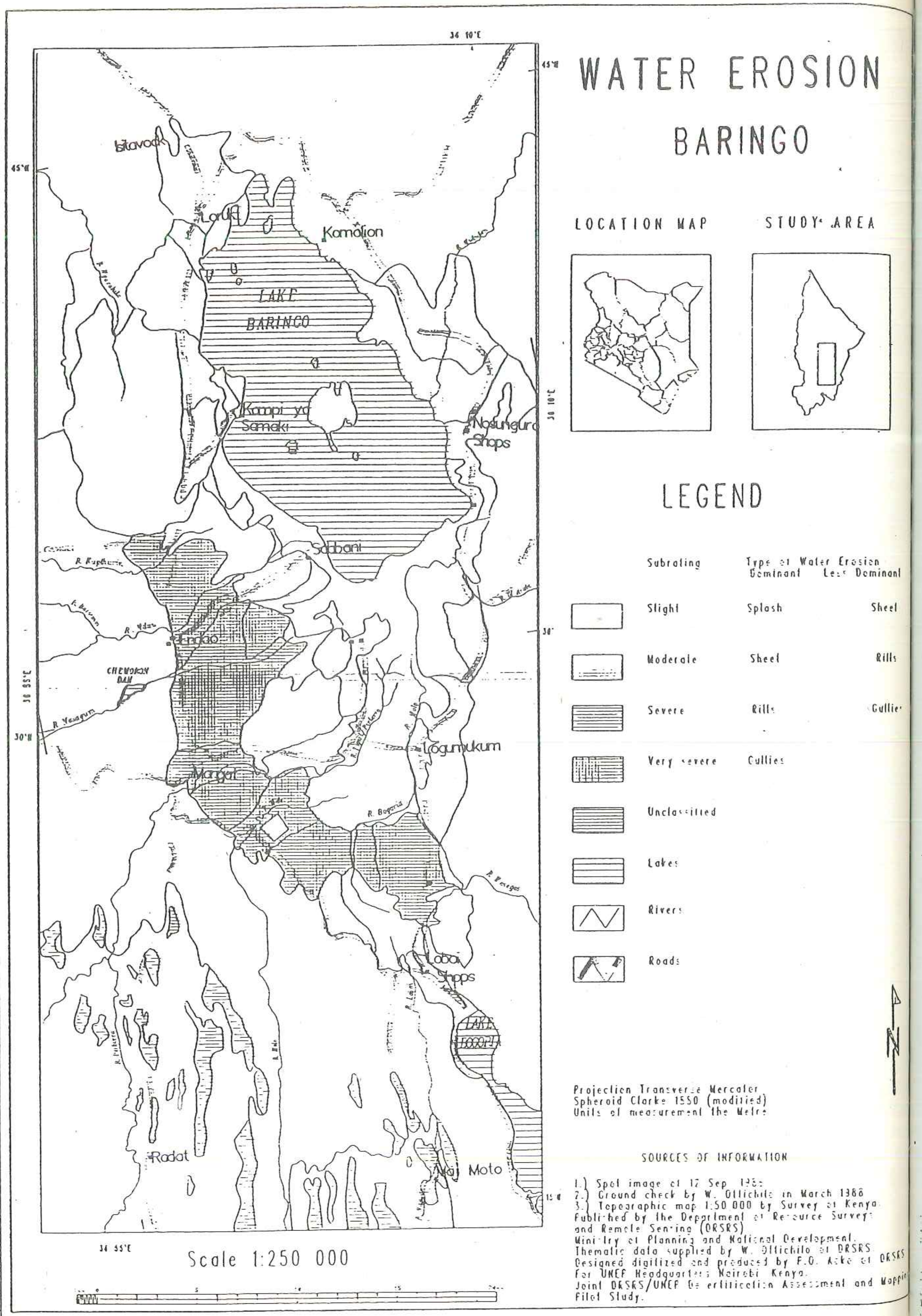
Table 2 Estimated cost for national desertification assessment and mapping

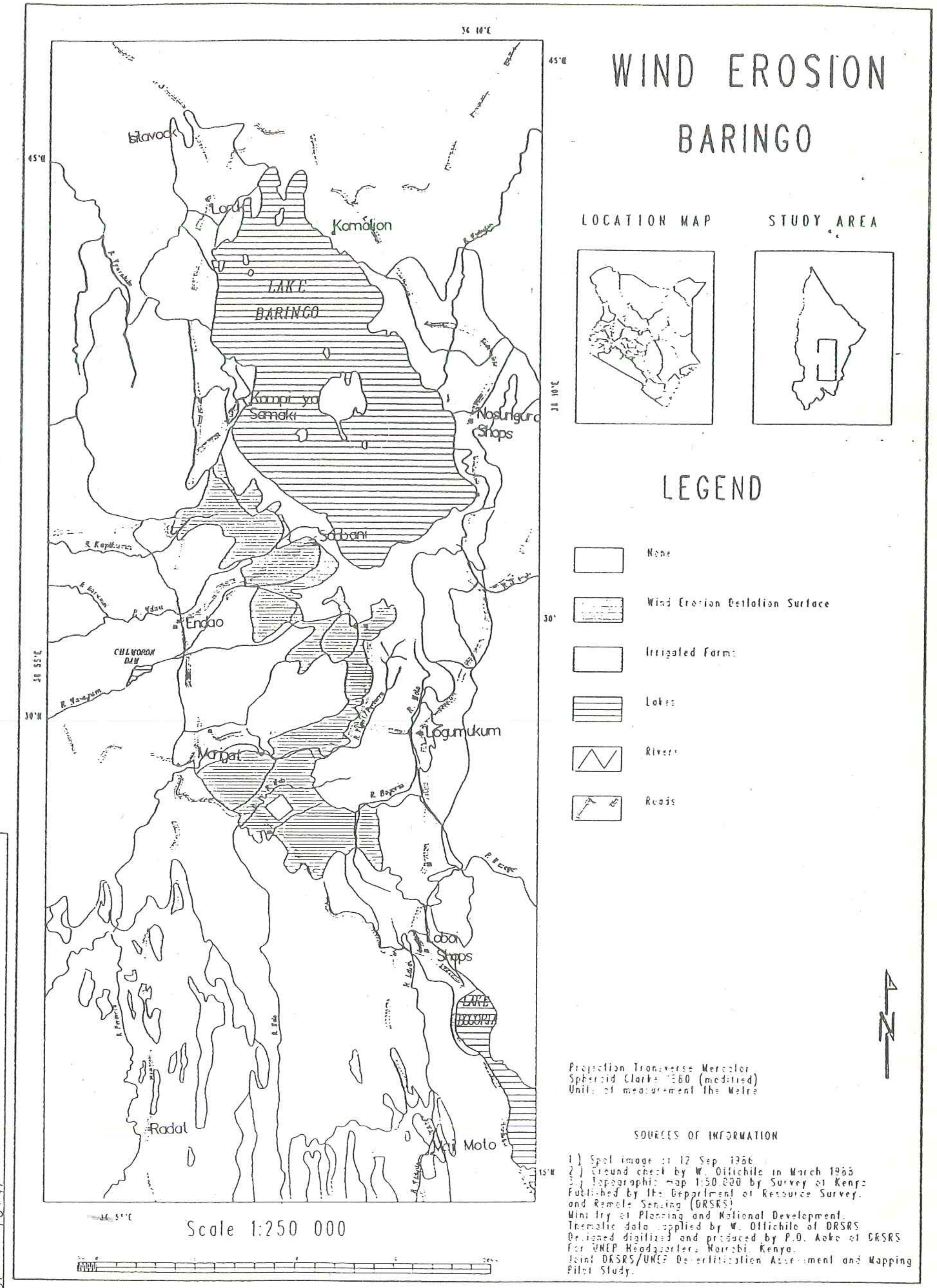
Study Component (US\$)	Total Cost (US\$)	Per km^2
Vegetation	136,080	0.24
Soils	113,400	0.20
Wind	45,360	0.08
Human Ecology	56,700	0.10
Data Analysis	141,750	0.25
Total	493,290	0.87

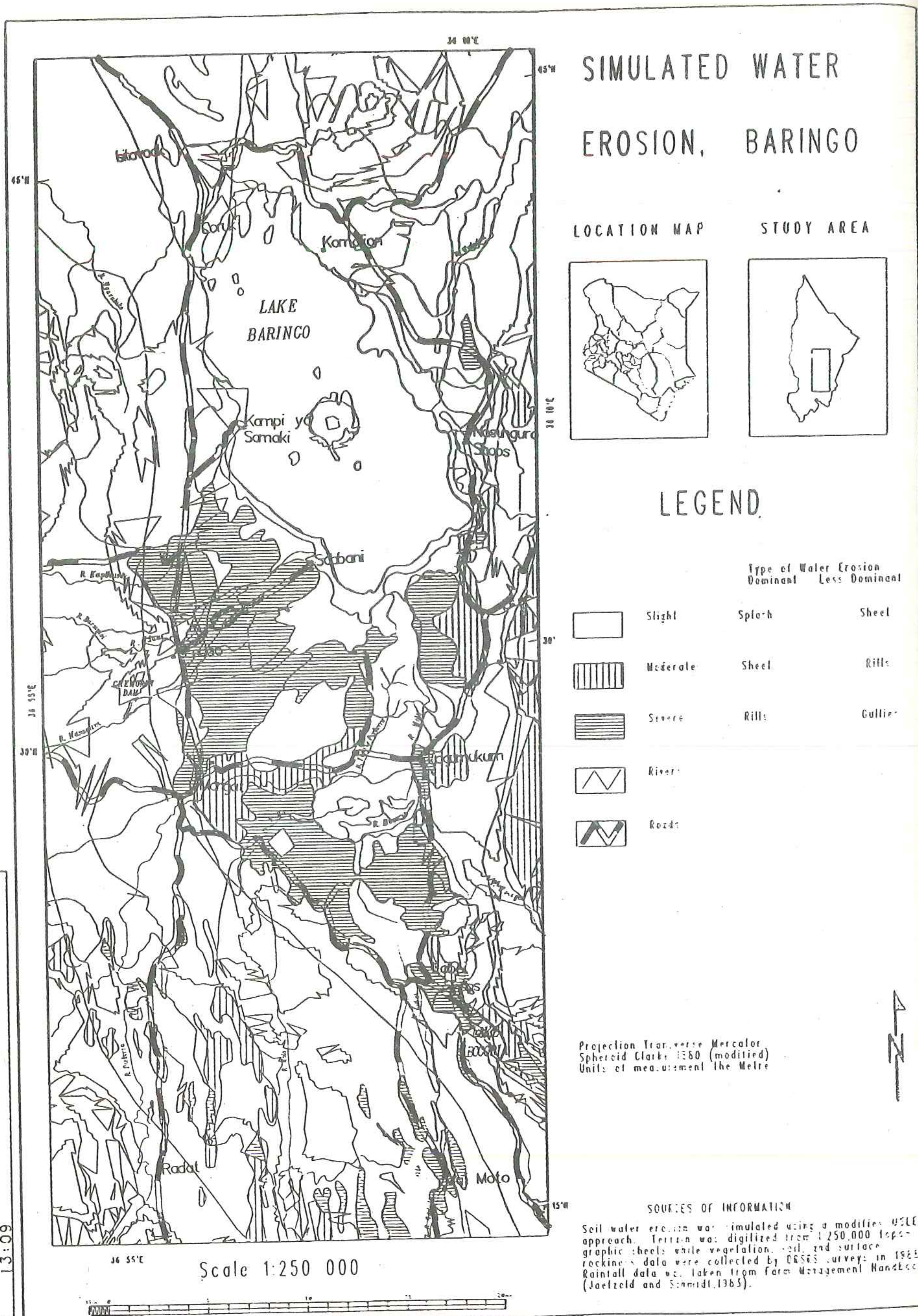
Appendix 5

EXPERIMENTAL MAPS FOR BARINGO STUDY AREA

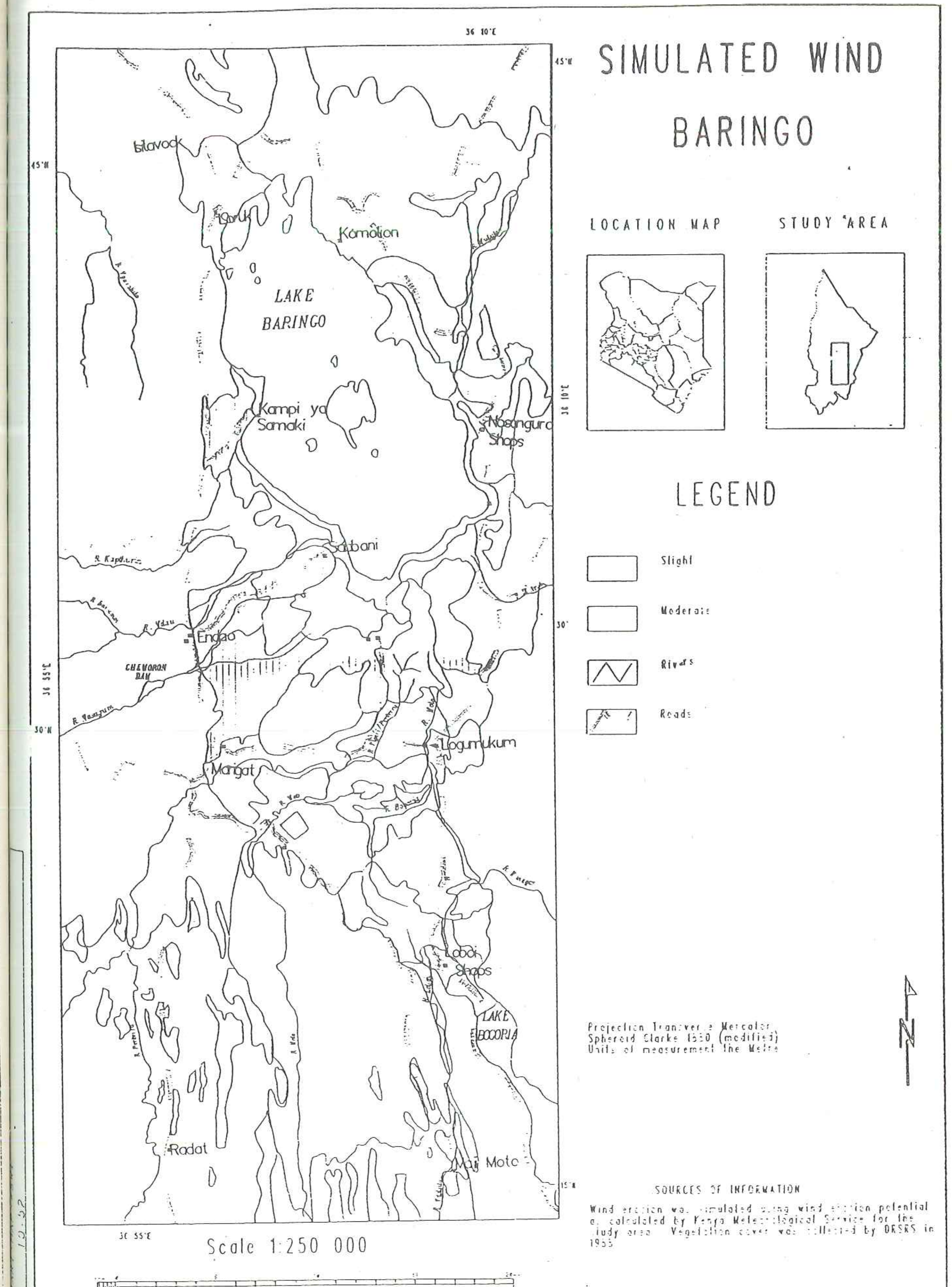
1. Water Erosion
2. Simulated water erosion
3. Wind erosion
4. Simulated wind erosion
5. Vegetation degradation
6. Range carrying Capacity
7. Desirable and undesirable species
8. Human settlement
9. Desertification hazard


WATER EROSION
BARINGO
LOCATION MAP
STUDY AREA
LEGEND
Subrating
Type of Water Erosion Dominant Less Dominant
Slight Splash Sheet
Moderate Sheet Rills
Severe Rills Gullies
Very severe Gullies
Unclassified
Lakes
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Loruk
Sabani
Endao
Marigat
Logumukum
Loboi Shops
LAKE BOGORIA
Radat
Maji Moto
CHEMOROK DAM
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
SOURCES OF INFORMATION
1.) Spot image of 17 Sep 1986
2.) Ground check by W. Ottichilo in March 1988
3.) Topographic map 1:50 000 by Survey of Kenya
Published by the Department of Resource Surveys and Remote Sensing (DRSRS)
Ministry of Planning and National Development.
Thematic data supplied by W. Ottichilo of DRSRS
Designed digitized and produced by F.O. Aoko of DRSRS
For UNEP Headquarters Nairobi Kenya.
Joint DRSRS/UNEP Desertification Assessment and Mapping Pilot Study.
Scale 1:250 000


WIND EROSION
BARINGO
LOCATION MAP
STUDY AREA
LEGEND
None
Wind Erosion Deflation Surface
Irrigated Farms
Lakes
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Loruk
Sabani
Endao
Marigat
Logumukum
Loboi Shops
LAKE BOGORIA
Radat
Maji Moto
CHEMOROK DAM
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
SOURCES OF INFORMATION
1.) Spot image of 17 Sep 1986
2.) Ground check by W. Ottichilo in March 1988
3.) Topographic map 1:50 000 by Survey of Kenya
Published by the Department of Resource Surveys and Remote Sensing (DRSRS)
Ministry of Planning and National Development.
Thematic data supplied by W. Ottichilo of DRSRS
Designed digitized and produced by F.O. Aoko of DRSRS
For UNEP Headquarters Nairobi Kenya.
Joint DRSRS/UNEP Desertification Assessment and Mapping Pilot Study.
Scale 1:250 000

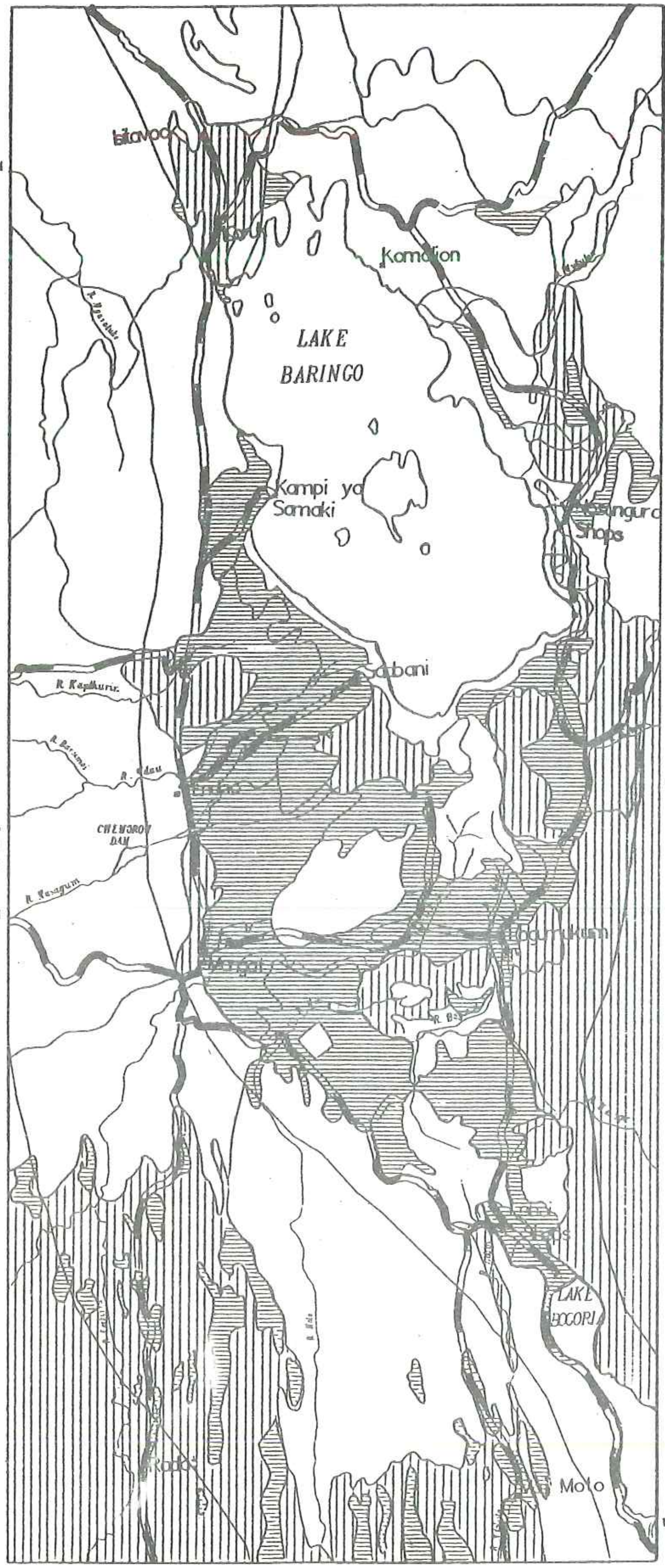


SIMULATED WATER
EROSION, BARINGO
LOCATION MAP
STUDY AREA
LEGEND
Type of Water Erosion
Dominant
Less Dominant
Slight
Splash
Sheet
Moderate
Sheet
Rills
Severe
Rills
Gullies
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Loruk
Bilavock
Nosanguro Shops
Salabani
Endao
CHEMORON DAM
Logumukum
Marigat
LAKE BOGORIA
Radat
Moto
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
SOURCES OF INFORMATION
Soil water erosion was simulated using a modified USLE approach. Terrain was digitized from 1:250,000 topographic sheets while vegetation, soil, and surface rockiness data were collected by DRSRS surveys in 1985. Rainfall data was taken from Farm Management Handbook (Jaetzold and Schmidt, 1983).
Scale 1:250 000
36 10'E
36 55'E



SIMULATED WIND
BARINGO
LOCATION MAP
STUDY AREA
LEGEND
Slight
Moderate
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Loruk
Bilavock
Nosanguro Shops
Salabani
Endao
CHEMORON DAM
Logumukum
Marigat
Loboi Shops
LAKE BOGORIA
Radat
Moto
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
SOURCES OF INFORMATION
Wind erosion was simulated using wind erosion potential as calculated by Kenya Meteorological Service for the study area. Vegetation cover was collected by DRSRS in 1985
Scale 1:250 000
36 10'E
36 55'E

VEGETATION DEGRADATION BARINGO



LOCATION MAP | STUDY AREA

LEGEND

- Slight
- Moderate
- Severe
- Rivers
- Roads

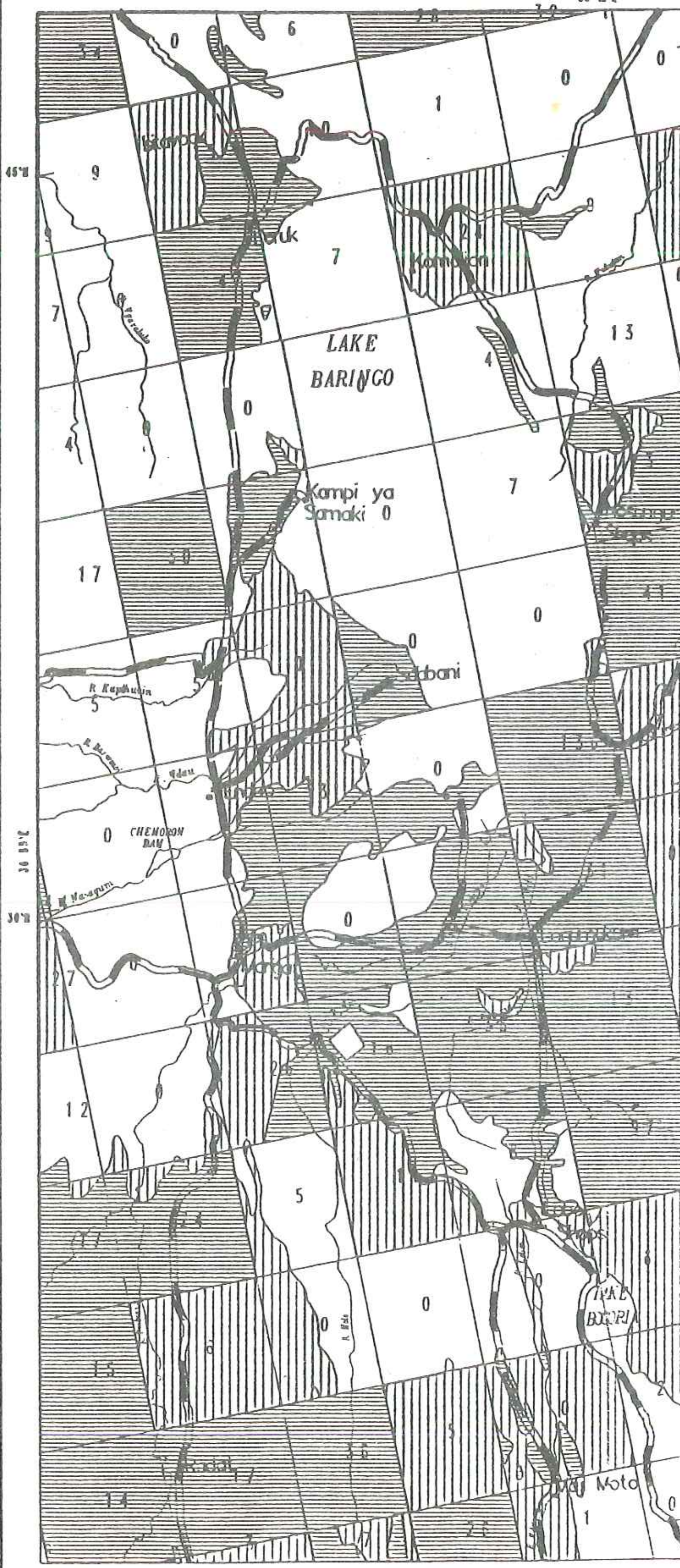
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre

Scale 1:250 000

SOURCES OF INFORMATION

Vegetation degradation was calculated from wet season herbaceous biomass data collected for the study area by DRSRS in 1986. Potential vegetation was calculated according to Honerou, 1984 using rainfall data from Farm Management Handbook (Jaetzold and Smith, 1983).

RANGE CARRYING CAPACITY, BARINGO



LOCATION MAP | STUDY AREA

LEGEND

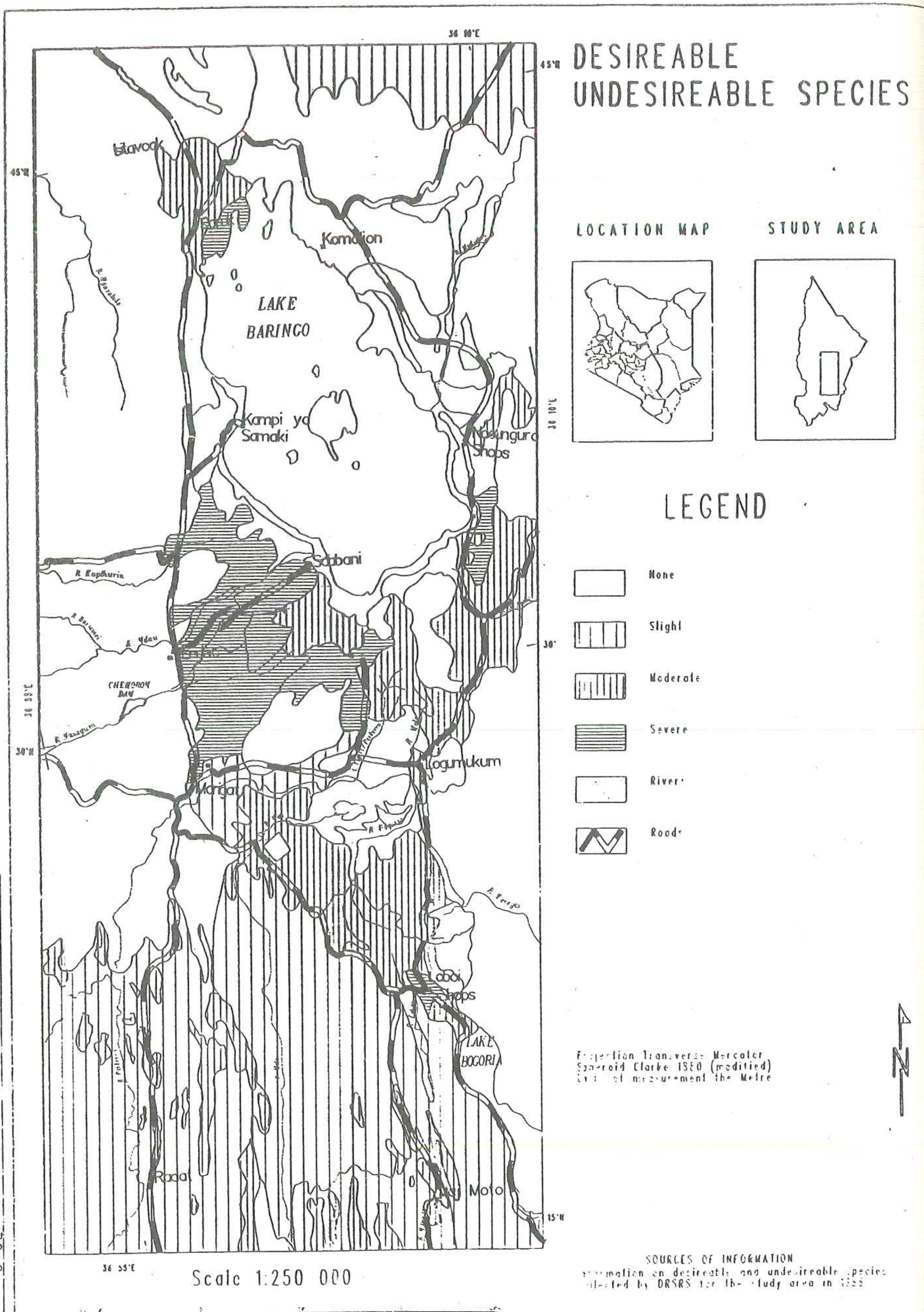
- Slight (0-10)
- Moderate (11-20)
- Severe (>20)
- Tropical Livestock Unit
- Rivers
- Roads

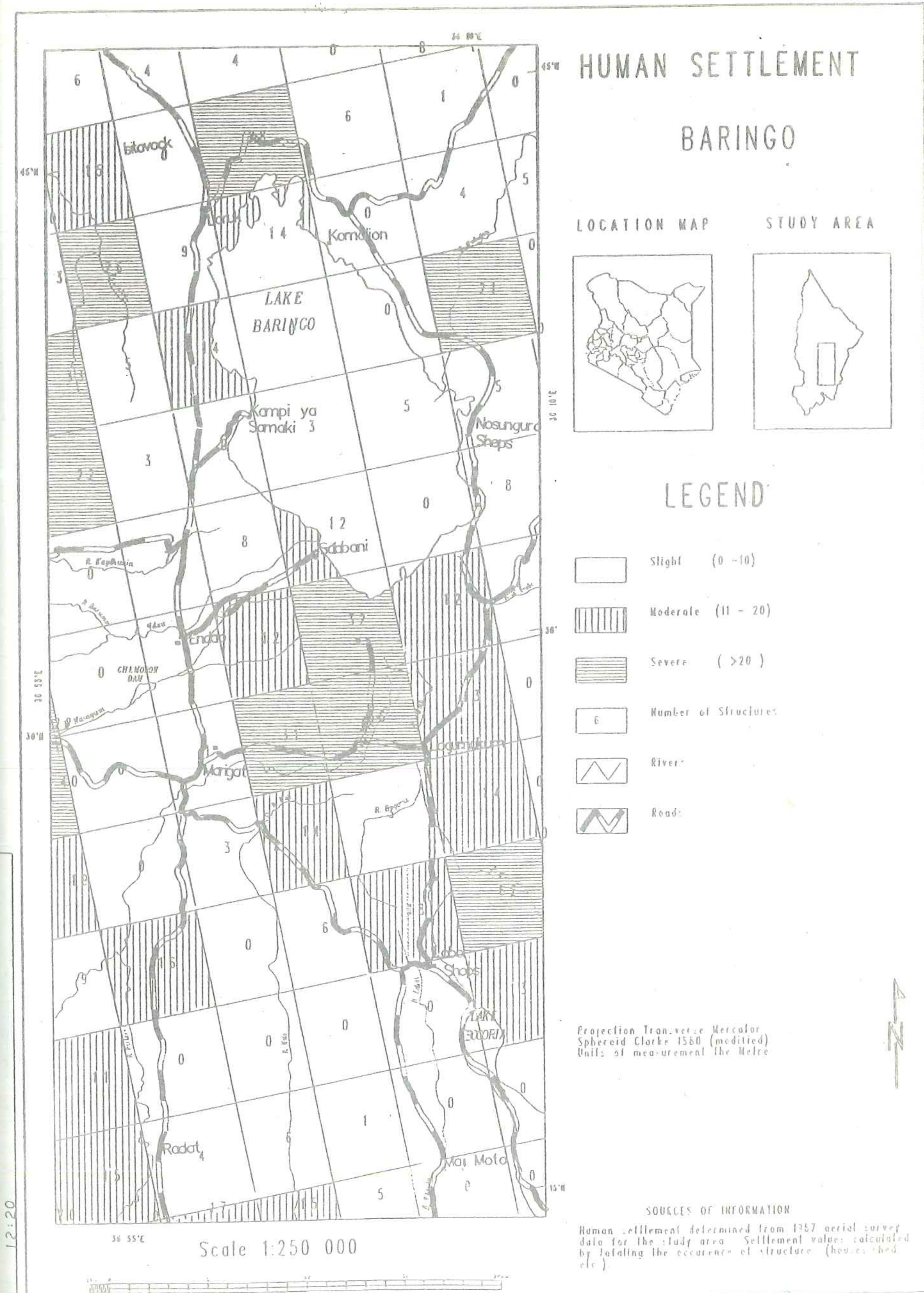
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Unit of measurement the Metre

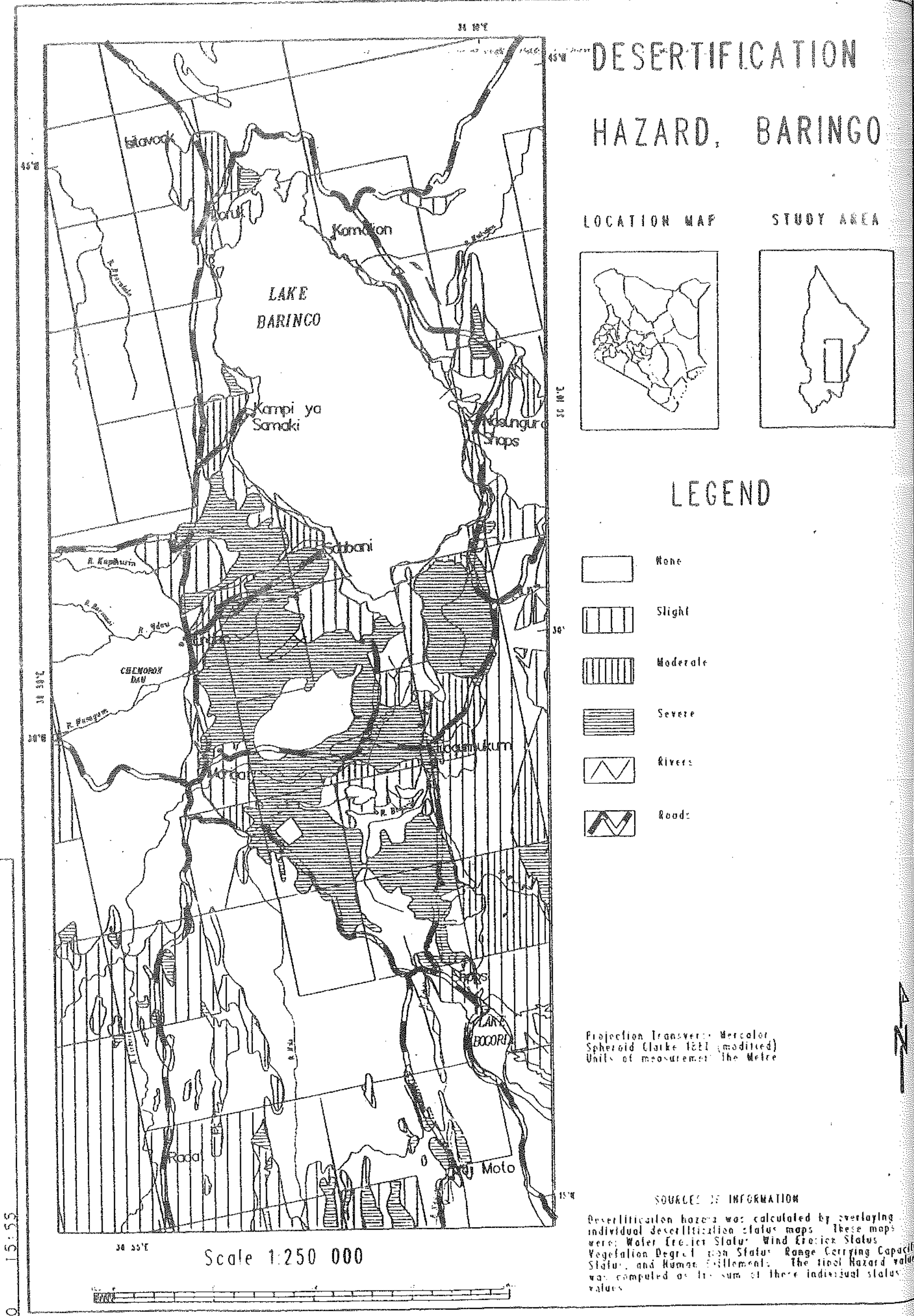
Scale 1:250 000

SOURCES OF INFORMATION

Range carrying capacity was calculated using wet season herbaceous biomass data as collected by DRSRS in March 1986 and DRSRS livestock numbers as collected in September 1987. Cattle, sheep and goat, donkeys and camels were considered in this analysis.


DESIREABLE
UNDESIREABLE SPECIES
LOCATION MAP
STUDY AREA
LEGEND
None
Slight
Moderate
Severe
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Salabani
Nosunguro Shops
Logumukum
Marigat
Loboi Shops
LAKE BOGORIA
Maji Moto
Radat
CHEMORON DAM
R. Kapthurin
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Unit of measurement the Metre
SOURCES OF INFORMATION
Scale 1:250 000


HUMAN SETTLEMENT
BARINGO
LOCATION MAP
STUDY AREA
LEGEND
Slight (0 -10)
Moderate (11 - 20)
Severe (>20)
Number of Structures
Rivers
Roads
LAKE BARINGO
Kampi ya Samaki
Komolion
Salabani
Nosunguro Shops
Logumukum
Marigat
Endao
Loboi Shops
LAKE BOGORIA
Maji Moto
Radat
CHEMORON DAM
R. Kapthurin
Projection Transverse Mercator
Spheroid Clarke 1880 (modified)
Units of measurement the Metre
SOURCES OF INFORMATION
Scale 1:250 000



RECOMMENDATIONS ON APPLICATION IN THE SAHELIAN ZONE OF THE FAO/UNEP PROVISIONAL METHODOLOGY FOR DESERTIFICATION ASSESSMENT AND MAPPING

N.G. Kharin
Institute of Deserts
Turkmen SSR Academy of Sciences
for
CENTRE FOR INTERNATIONAL PROJECTS (CIP)

Prepared under UNEP/USSR/Mali Project (FP/6201-87-05)
"Support to West African Countries in Strengthening National Desertification Control Activities Through Research and Training"

February 1990

CONTENTS

INTRODUCTION

The present recommendations were prepared by Dr. N. Kharin based on the final scientific report of the USSR/UNEP Project FP/6201-87-05 implemented by the Institute of Deserts, Turkmen SSR Academy of Sciences in 1987/1989. The following scientists participated in the project activities: from the USSR - Dr. N. G. Kharin, Dr. N. S. Orlovsky, Dr. G. A. Alferov, Dr. M. G. Dmitriev, Dr. T. A. Babayeva, Dr. P. Essenov, Dr. A. A. Kiril'tseva; from Mali - Dr. J. Berte, Dr. U. Dumbia, Dr. A. Maiga.

The methods used were based on the FAO/UNEP Provisional Methodology, guidelines prepared by the Institute of Deserts, Turkmen SSR Academy of Sciences, and results of field tests carried out in Mali in 1987-1990.

1. CRITERIA OF DESERTIFICATION

During the field tests use was made of the FAO criteria (Provisional Methodology, 1981, 1983, 1984) together with the newly-proposed criteria taking into account the local conditions. As a result the following three major types of desertification were found in the test area: (i) degradation of vegetation cover, (ii) wind erosion, (iii) water erosion, (iv) soil compaction.

Degradation of vegetation cover is the most widely spread type of desertification in the tested area. It is caused by overgrazing, deforestation of trees and shrubs for fuel and construction, and also ploughing of virgin and fallow lands. The FAO criteria on degradation of vegetation cover are shown in Table 1. They cannot be exactly applied to the tested area due to the following reasons:

1) Protective cover of the woody/shrub vegetation is very insignificant (not exceeding 7-10%), hence the scale needs to be specified;

2) Number of grazed species in the savannah is not a desertification criterion. Many species, particularly shrubs, survive in the overgrazed condition but their abundance decreases;

3) During many centuries of economic activities, determination of potential productivity is of theoretical value only. Besides there are no reliable data on the present productivity. Therefore we introduced a new criterion of desertification - change in the protective cover of the woody-shrub belt. It approximately corresponds to changes in productivity which is a function of the protective cover of vegetation.

Table 1 FAO/UNEP criteria to assess degradation of vegetation cover (present state)

CRITERIA	Desertification classes			
	Slight	Moderate	Severe	Very Severe
1. Protective cover of perennial vegetation, per cent	>50	50-20	20-5	<5
2. Rangeland characteristic, per cent of the grazed species	>75	75-50	50-25	<25
3. Present productivity, per cent of potential productivity	>90	90-60	60-30	<30

Table 2 Specified criteria to assess degradation of vegetation cover in Western Mali

Aspects	Criteria	Desertification classes			
		Slight	Moderate	Severe	Very Severe
Present state	1. State of the vegetation cover				
	a) wood-shrub	Thicket with protective cover above 5%, minor damage by man.	Vegetation cover damaged by man. Protective cover 2-5%.	Vegetation cover heavily damaged by man. Thorn and weed trees are predominant. Protective cover of 1-2%.	Trees and shrubs are almost totally absent.
	b) Grass layer	The grass cover is grazed by cattle to a large extent		Grass cover is totally grazed by cattle. Sporadic water and wind erosion.	
	2. Fire-damaged vegetation cover				
	a) Wood-shrub layer	Less than 25% trees and shrubs damaged by fire	25-50% trees and shrubs damaged by fire	Over 50% trees and shrubs damaged by fire	Trees and shrubs totally damaged by fire
	b) Grass layer	Grass cover sunburnt at less than 50% of the area		Grass cover sunburnt at over 50% of the area.	
Desertification rates	1. Decreased protective cover of wood-shrub layer	<25%	25 - 50%	50 - 75%	> 75%
Inherent risk of desertification	1. Ecosystems stability	Stable ecosystems of clay plains (PA1, PA2, PA3) and plains with heavy loamy sand (PL4, PL5, PL8, PL11, PL12)	Relatively stable ecosystems with laterite crust (TC1, TC3, TC4 TC5, TC6)	Unstable mountaineous ecosystems (TR2, TR3, TR4, TR7, TR9), ecosystems of depressions with seasonal excessive humidity (TH8), ecosystems of alluvial plains and depressions, temporarily filled with water	Very unstable ecosystems of grass-covered and damaged sands (D5, DA4, DA5)

Specific criteria for degradation of vegetation cover are shown in Table 2. The ecosystem stability is considered as a criterion of the inherent risk of desertification (IRD). It includes such parameters as soil mechanical composition, slopeness, stoniness, graveliness, flooding, etc. In view of the existing classification of soil-vegetation complexes represented in the Atlas of Mali (Les Ressources........., 1983) they were further classified according to the accepted stability.

The FAO criteria for wind erosion are shown in Table 3. Wind erosion is widely spread in the northern and north-eastern parts of the Jelimane district. Field tests showed that these criteria did not completely reflect the state of eroded area on the tested territory.

The present state of deflation depends on overgrazing, cutting of woody-shrub vegetation, and collection of grass vegetation for fuel and domestic purposes, and also on the spreading rainfed agriculture in the semi-sufficient and sufficient rainfed areas. Farmers here obtain some harvests in the anomalous humid years, while in medium and below medium humid years the harvest is poor or zero. In such years the ploughed lands are subject to strong wind erosion. Therefore the soil and vegetation cover and climate conditions favour desertification process, particularly deflation and wind erosion, while economic activities contribute to them.

Table 3 FAO/UNEP criteria to assess wind erosion (present state)

CRITERIA	Desertification classes			
	Slight	Moderate	Severe	Very Severe
1. Percentage of area under sandy hillock	<5	5-15	15-30	>30
2. Soil losses above the root layer expressed in per cent:				
a) at soil depth above 1 m	<25	25-50	50-75	>75
b) at soil depth below 1 m	<30	30-60	60-90	>90
3. Present productivity in percentage to potential productivity	100-80	80-65	65-25	<25
4. Soil thickness, (cm)	>90	90-50	50-10	<10
5. Percentage of area covered by gravel	<15	15-30	30-50	>50

Table 4 shows new criteria to evaluate the present wind erosion, inherent risk of desertification and rates of desertification.

The inherent risk of desertification (IRD) is characterized by a group of soils according to their mechanical composition with due account for the vegetation cover, i.e. by the soil-vegetation complexes. Soils with heavy mechanical composition, clays and heavy clays have low risk of desertification, medium-textured and clay loam soils have moderate IRD, loamy sand soil have high IRD, and sandy soils - very high IRD.

Water erosion is one of the most wide spread types of land degradation. It was tested using the FAO/UNEP methodology, and also guidelines worked out by the Institute of Deserts, Turkmen SSR Academy of Sciences.

Table 5 shows the criteria for assessing water erosion by the FAO/UNEP methodology. Under field test they proved to be of little or no use for compiling the desertification map of Mali. Therefore we proposed using the following additional criteria to evaluate the inherent risk of desertification: density of erosion network, slope steepness, mechanical composition of soil, soil profile thickness, and protective cover of vegetation (Table 6). The soil profile thickness is listed among the FAO/UNEP criteria. Hence we propose using specific parameters to assess a profile thickness to suit the local conditions. Classification of soil-vegetation complexes by the IRD was carried out on the basis of mechanical composition of soil, profile thickness, and protective vegetation cover.

Therefore, the PA1 and PA2 soil-vegetation complexes on the flat weak clay plains have a low risk of desertification. Moderate risk of desertification is observed at PL5, PL11, PL12, TC4, TC5, and TC6 soil-vegetation complexes, and also at laterite with stony soils found on the stony terrain with steep slopes or loamy mechanical composition (including very gristly) with heavy and very heavy drainage (TR3, TR9).

Soil compaction is a unique feature of desertification. Compaction and soil crusting occur on virgin and fallow lands flooded in rainy season, and also on lands cultivated for various crops. Soil structure of the arable lands is affected by crusting, flooding, compaction of sub-ploughed layers, and formation of the so-called "plough bed".

While assessing the desertification processes in Mali, soil compaction and crusting were considered as major soil criteria. They are typical of all soil types and arable lands (virgin, fallow, flooded and irrigated).

The FAO/UNEP methods contain criteria to assess this type of desertification (Table 7).

The most reliable criteria for the Kayes and Jelimane districts are ferrous accumulation and compactness. Other criteria are either unrecorded at the studied area or found in limited plots (e.g. carbonate concretions or gypsum accumulation).

Therefore, to assess this type of desertification we proposed other indicators describing the inherent risk of desertification (Table 8).

However they do not adequately describe all desertification classes. The mechanical composition of soil alone is typical of all desertification classes. Other criteria (e.g. flooding by rain and flood water, land-use pattern) have relative values.

It is clear from Table 8 that the data on desertification rates for compact soil are missing. The FAO methods do not provide for such criteria. Soil compaction and crusting are slow moving processes. It requires special studies to determine their dynamics within a short interval (from 1980 to 1989). These studies lie beyond the present paper. Yet it can be stated that the processes are ongoing. The soil and climatic conditions favour these processes. Therefore we assumed that desertification rate was slow which was reflected in the map of desertification.

Table 4 Specified criteria to assess wind erosion in Western Mali

Aspects	CRITERIA	Desertification classes: Slight	Moderate	Severe	Very Severe
Present State	1. Percentage of area with wind erosion	<5	5-15	15-30	>30
	2. Thickness of eroded surface layer, cm	<5	5-10	10-20	>20
	3. Alluvial soil thickness, cm	<5	5-10	10-20	>20
	4. Volume of discharged soil, t/ha per year	<0.5	0.5-1.0	1.0-3.0	>3.0
Desertification rate	1. Percentage of increased eroded lands	<10	10-25	25-50	>50
Inherent risk of desertification	1. Mechanical composition of soils and ground	silt, heavy loam	Medium and light loam	Sandy loam	Sand
	Distribution of soil and vegetation complexes according to inherent risk of desertification	PA2, PA3, PL8, T15 TR9, X5	PA1, P11, P12, TC1, TC4, TC5, TC6, TH8, TR3, TR4, TR5	PL4, PL5, TC3, TR2, TR6, TR7	DA4,DA5, D4

Table 5 FAO/UNEP criteria to assess water erosion (present state)

No. CRITERIA	Desertification classes: Slight	Moderate	Severe	Very Severe
1. Surface state	Gravel and small-size stones occupy 10%	Stones and Boulders occupy 10-25%	Boulders and rocks occupy 25-50%	Boulders and rock discharges occupy over 50%
2. Erosion type	Sheet washing and flow erosion from slight to moderate	Sheet washing and flow erosion from moderate to severe	Sheet washing and gully erosion, severe	Sheet washing and deep gully erosion,very severe
3. Topsoil washing, per cent	< 10	10-25	25-50	> 50
4. Gullies area, per cent	< 10	10-25	25-50	> 50
5. Soil thickness, cm	> 90	90-50	50-10	< 10
6. Soil losses above root layer, per cent	< 25	25-50	50-75	> 75
a) undamaged soil thickness below 1 m	< 30	30-60	60-90	> 90
b) undamaged soil thickness above 1 m	< 30	30-60	60-90	> 90
7. Present productivity in per cent to potential productivity	100-85	85-65	65-25	< 25

Table 6 Specified criteria to assess water erosion in Western Mali

Aspects	CRITERIA	DESERTIFICATION CLASSES			
		Slight	Moderate	Severe	Very Severe
Present state	1. Surface state	Gravel and stones occupy less than 10%	Stones and boulders occupy 10-20%	Boulders and rocks occupy 25-50%	Boulders and discharge occupy over 50%
	2. Erosion type	Sheet washing and flow erosion from slight to moderate	Sheet washing and flow erosion from moderate to severe	Sheet washing, flow and gully erosion, severe	Sheet washing and deep gully erosion, very severe
	3. Topsoil runoff, % of the area	< 10	10-25	25-50	> 50
	4. Percentage of area under gullies.	< 10	10-25	25-50	> 50
	5. Erosion network density, per 10 sq. km	< 2	2-5	5-10	> 10
Desertification rate	1. Increased area of eroded land (%)	< 10	10-25	25-50	> 50
	2. Increased area under gullies	< 10	10-25	25-50	> 50
Inherent risk of desertification	1. Slope steepness (%)	Flat and almost flat, 2	Low steep slopes, 2-6	Medium steep slopes, 6-13	Steep slopes, 13
	2. Mechanical composition of soil	Sandy	Sandy loam	Loamy soil	Clay soils
	3. Soil profile thickness (cm)	> 100	100-50	50-25	< 25
	4. Protective cover of vegetation (%)		5-2		< 2
	5. Soil and vegetation complex distribution in classes	PA1,PA2,	DA4,DA5, PA3, PL4,PL5,PL11,PL12, TC4,TC5,TC6.	D5, PL8, TC1,TC3, TH8, T15, TR4,TR5,TR6,TR7.	TR3, TR9

Table 7 FAO/UNEP criteria to assess soil compactness and crusting

CRITERIA	Desertification classes			
	Slight	Moderate	Severe	Very Severe
Calcification, depth, cm	Sporadic inclusion and/or tumors 30-50	Crusts at 30-50 depth or sporadic inclusions and tumors, < 30	Heavy at a 10-30 depth or crusting < 30	Crusts at a depth < 10
Gypsum accumulation, depth, cm	Inclusions at a depth 50-100	Gypsum sand or powder 30-50	Gypsum powder < 30	Crust < 10
Ferrum accumulation and tumors, depth, cm	Tumors and concretions 30-50	Crusting and tumors and concretions < 30	Ferrous powder < 30	Ferrous powder < 10
Silicon oxide accumulation, depth, cm	Crusting > 50	Crusting 30-50	Crusting 10-30	Crusting < 10

Table 8 Specified criteria to assess soil crusting in Western Mali

Aspects	CRITERIA	DESERTIFICATION CLASSES			
		Slight	Moderate	Severe	Very Severe
Present State	1. Ferrum accumulation and tumors at a depth, cm	Tumors and concretions, 30-50	Crusting and tumors and concretions, <30	Ferrous ore (10-30) and crusting	Ferrous ore <10
Inherent risk of desertification	1. Flooding by rain and flood water	Not flooded or flooded for a short period of time (in rainy season)		Long-term flooding by rain and flood water (over six months)	
	2. Landuse pattern	Lands and fallow lands unused in agriculture		Rainfed and irrigated lands	
	3. Mechanical composition of soils	Sandy and loamy (with gravel) sand	Sandy loam (silty and gristly)	Clay loam (silty and gravel)	Clayey (silty and gristly)
	Distribution of soil and vegetation complexes according to inherent risk of desertification	D5, DA4, DA5	TR2, TR3, TR4, TR6, TR7, TR9, TH8	TC1, TC3, TC4, TC5, TC6	PA3, PA1, PA2, PL4, PL5, PL8, PL11, PL12, PL15, T15

To determine the total risk of desertification (TRD) it is necessary to find the following: present state (PS), desertification rate (DR), inherent risk of desertification (IRD), animal impact on environment (AIE), and the degree of anthropogenic impact (DAI). Using the FAO methods the total risk of desertification is determined as follows:

$$TRD = PS + DR + IRD + AIE + DAI$$

The animal impact on environment (AIE) at the tested area was found empirically due to the absence of reliable data on the rangeland productivity. The FAO recommended formula was used:

$$CE = 1.0\,P + 42.2$$

where: p is precipitation, mm/y;
CE is estimated consumption, kg/ha.

The livestock in Mali was estimated in UBT. According to the Atlas of Mali the fodder rate per UBT is 6.5 kg/day and the total amount is 2281.25 kg.

In the Jelimane district and northern Kayes district with the mean annual precipitation of 550 mm/year this amount is as follows:

$$CE = 1.03 \times 550 + 42.2 = 608.7\ kg/ha$$

According to our expert assessment carried out in the field the bio-productivity (and hence the CE) decreases by 75% during desertification. Therefore the CE in the driest season in the northern Kayes district and in the Jelimane district amounts to 25% (152.17 kg/ha) of the estimated value.

Having divided it by 2281.25 we will obtain a potential load per 1 ha equal to 0.067 UBT. In real life the total amount of 85333 UBT are grazing at 570000 ha in the Jelimane district which equals to 0.150 UBT per 1 ha. Hence the real load is 2.24 times the estimated value. It is slightly less in the southern Kayes district. The average overgrazing at the tested area is not less than -200% and higher at some plots.

Using the FAO methods the animal impact on environment (AIE) is estimated as follows:

The actual livestock in per cent to the estimated figure (potentially possible)	AIE
>200	very severe
100-200	severe
66-100	moderate
20-60	slight

Therefore the animal impact on environment (AIE) is very severe at the tested area.

The FAO methods recommend that the degree of anthropogenic impact (DAI) should be determined per the amount of food produced at the specific area. Other sources of food should also be taken into consideration. Having found the per capita food ratio expressed in calories per day it is possible to calculate the amount of population that could be fed at the specific area. Due to the absence of reliable data on the size and potential productivity of the arable land it was impossible to make these calculations at the tested area.

Table 9 Land classes identified during automated processing of space imagery

No.	CLASS	JR	R	NDVJ
1.	Areas without vegetation cover and heavily damaged by water and wind erosion	95	74	0.12
2.	Very heavily degraded savannah on soils with light mechanical composition	92	73	0.12
3.	Heavily degraded savannah on soils with different mechanical composition	88	69	0.12
4.	Water logged areas with thick vegetation	88	65	0.15
5.	Flooded areas	83	68	0.10
6.	Steep eroded slopes	80	65	0.13
7.	Medium-steep eroded slopes	81	62	0.13
8.	Accumulation slopes of gentle slopeness	76	63	0.10
9.	Lands with heavy water erosion without vegetation	77	59	0.13
10.	Heavily degraded tree savannah on crusty soil	73	60	0.05
11.	Heavily degraded savannah on crusty soil damaged by fires	72	57	0.04
12.	Tree savannah on crusty soil, weakly and moderately damaged by fires	67	59	0.09
13.	Tree savannah on crusty soil, medium degraded	62	54	0.07
14.	Tree savannah on crusty soil and stony slopes, weakly damaged	65	51	0.07
15.	a) Savannah damaged by fires b) Water surfaces	59	51	0.07

The Institute of Deserts, Turkmen SSR Academy of Sciences proposed a method to assess the degree of anthropogenic impact (DAI) by the population density which was used at the tested area. The population density scale at the tested area is as follows:

Degree of anthropogenic impact (DAI)	Population density, per 1 sq. km
slight	<5
moderate	5-10
severe	10-15
very severe	>15

2. METHODS FOR DESERTIFICATION MAPPING BASED ON REMOTE SENSING

To compile the desertification map use was made of the following space photographs:

1) **LANDSAT** (1980);

2) Soviet space photographs made on 8 May, 1989 using the MSU-SK scanning system on board the **"KOSMOS-1939"** satellite (Selivanov, Touchin, 1988).

The **LANDSAT** photographs were used during the 1988 field tests to compile a preliminary desertification map of the tested area. The map and desertification criteria were specified during the 1989 field studies.

The final map of the present state of desertification was compiled upon the digital processing of the Soviet space photographs. The **MSU-SK** scanner had the following parameters:

- resolution m	243 (per shot) 175 (per line) 590 (per heat channel)
- spectral channels, mkm	1. 0.5-0.6 2. 0.6-0.7 3. 0.7-0.8 4. 0.8-1.1 5. 10.4-12.6

The initial data comprised the magnetic tape recorded multi-zonal heat image along channels 1-4. The image size was 1490 by 1398 units, the total volume was 1490 by 1398 by 4 bytes.

The radiometric correction was performed at the first stage of processing. Then the spectral classification of multi-zonal images was carried out. The aim of processing was to code each unit by a separate class number according to its brightness within the given range of spectrum. There exist two methods for classification: with and without education. In the first case the plots belonging to the known land category are selected and further processed. It was done because the field tests had been carried out prior to space photography.

For these reasons the second method was used. At the beginning the spectral classes are isolated and further interpreted according to the subject. The automated classification of multi-zonal images is based on the modified single-band algorithm (Mandel, 1988). The class centres were found according to the following procedures:

1) the first unit of the X_1 image is selected as the centre of the Z_1 class;

2) another unit of the X_i image is selected and the distance between the centres is measured. The X_i should be added to Z_k at the following condition:

$$|Z_k - X_i| \leq T$$

Otherwise 3 spacing is used. Once the unit is added the central point should be adjusted.

3) a new unit is created with the help of X_i unit;

4) the procedure is finished upon all units having been studied, otherwise spacing 3 is used.

The number of classes depends both on the image type and porosity distance (T) adjusted prior to processing. The optimum T is assessed empirically depending on the required number of classes.

The processing of data was carried out at T=4. Channels 2 and 4 were the only channels used. The T channel was not used because of the low contrast, and channel 3 was not used due to a strong correlation with channel 4. During processing 15 representative classes were formed including 97.2% of the image units. The remaining 6 classes were related to noise interference, and coupled with the representative classes.

The established classes were further identified with the land types described during the field tests. The 15 land classes are shown in Table 9.

Additional data on the vegetation cover were obtained using the normalized difference vegetation index (NDVJ) calculated according to the formula (Townshed, Justice, 1986):

$$NDVJ = \frac{NIR - R}{NIR + R}$$

where: NIR is the unit brightness in channel 4;
R is the unit brightness in channel 2.

The vegetation index was calculated as follows. During the first observation the NDVJ was calculated for each unit and the minimum and maximum was found for the completed image. During the second observation the map units were generated according to the formula:

$$R = \frac{L(NDVJ - MIN)}{MAX - MIN}$$

where: R is the current unit of the map;
L is the output number supplied by the user.

Satisfactory results were obtained during the following procedure:

- smoothing the channels 2 and 4 of the adjusted image by the two-dimensional recurrent median filter;

- visual analysis of the map and closeness of the non-representative levels with the closest representative one;

- smoothing the revised map by the local majority method with the 3 x 3 window.

As a result of the above-described procedure the NDVJ distribution map was compiled at 9 representative levels. The NDVJ intervals corresponding each level are shown in Table 10.

Table 10 NDVJ ranges for digital map levels

Level No.	Range
1.	0.000 - 0.069
2.	0.069 - 0.083
3.	0.083 - 0.096
4.	0.096 - 0.110
5.	0.110 - 0.124
6.	0.124 - 0.137
7.	0.137 - 0.151
8.	0.151 - 0.165
9.	0.165 - 0.220

At the final stage of compiling the desertification map the digital image was interpreted in accordance with the elaborated legend.

The LANDSAT 1980 space imageries were treated in a similar manner.

Comparing the 1980 and 1989 space "photographs" it was possible to establish the desertification rate in accordance with the existing criteria. The data were used in compiling the map of inherent risk of desertification.

Table 11 Legend scheme of the map for total risk of desertification

Class of desertification	ASPECTS					Points	Colour
	Present state	DR	IRD	IAE	DAI		
Weak	1	a	1	1	L	< 30	Yellow
	3	3	3	4	2		
Medium	2	b	m	11	M	30-45	Orange
	6	6	6	8	4		
Heavy	3	c	f	III	F	45-60	Brown
	12	12	12	15	8		
Very Heavy	4	d	h	IV	H	>60	Red
	18	18	18	25	12		

The map of total risk of desertification covers all aspects of the FAO methods. Table 11 describes the scheme of the map legend. Each map colour corresponds to a formula, e.g.

2 c m IV F

The degree of each component's impact on the total risk of desertification is shown in Table 11. For example:

2	-	present stage (moderate)	6
c	-	desertification rate (heavy)	12
m	-	inherent risk of desertification (moderate)	6
IV	-	animal impact on environment (very heavy)	26
F	-	degree of anthropogenic impact (heavy)	8
Total:			52

The total risk of desertification at the studied map contour is strong. It should be coloured red on the map.

3. DESERTIFICATION MAPS AND THEIR ANALYSIS

The following three desertification maps were compiled:

- map of the present state of desertification;
- map of desertification rates and inherent risk of desertification;
- map of the total risk of desertification.

The map of the present state of desertification shows different desert classes (weak, moderate, heavy and very heavy) marked by different colours. The desertification types are indicated by the non-scale symbols. The map comprises 70 contours. The average contour size is 370.6 sq. km, the minimum size is 14 sq. km., maximum - 1753 sq. km. The analysis of digital data shows a great diversity due to an intricate structure of the natural and territorial complexes, and also due to the anthropogenic impacts.

For these reasons many contours are complex. Their parameters are shown in Table 12. On the map they are distinguished by the prevailing desertification type.

The total data on desertification area is shown in Table 13. It is clear that desertification processes are not prominent in the northern part of the tested area. Precipitation here is low and the anthropogenic impact is very high since practically 10% of the Jelimane district is subject to heavy and very heavy desertification.

The map of rates and inherent risk of desertification shows the following features: coloured space - desertification rate, slashed line - inherent risks of desertification. The total data on these aspects is shown in Tables 14 and 15.

It is clear from the map that desertification processes develop at a higher rate in the northern part of the tested area. The inherent risk of desertification is a factor of ecosystems stability. Most stable are the ecosystems in the central part of the tested area. Ecosystems of sandy soils are unstable and subject to desertification.

The map of total risk of desertification shows the trends for its development. The data on total risk of desertification is shown in Table 16. It is clear that desertification is most prominent in the Jelimane district. It should be noted that degradation of arid ecosystems in the Kayes district is heterogenous. Severe desertification plots are found in the southern part of the district (70 contour).

Analysis of the 1980 and 1989 space photographs and also field observations enable us to arrive at a conclusion that degradation of arid ecosystems is a successive process. Very heavy degradation of the vegetation cover is accompanied by intensified water and wind erosion which consequently results in total degradation of arid ecosystems. At this stage the bio-productivity is close to zero, vegetation cover is completely destroyed and water and wind erosion are intensified.

Table 12 Desertification parameters within separate contours (per cent)

No.	Types of desertification	Desertification classes: Slight	Medium	Severe	Very severe
1	2	3	4	5	6
1.	Water erosion				60
	Wind erosion				40
2.	Wind erosion				80
	Water erosion			20	
3.	Wind erosion				70
	Soil compaction		20		
	Vegetation degradation			10	
4.	Soil compaction		60		
	Water erosion			20	
	Vegetation degradation			20	
5.	Vegetation degradation				100
6.	Vegetation degradation				100
7.	Vegetation degradation				100
8.	Unsuitable land				
	Vegetation degradation				70
9.	Soil compaction			20	
	Wind erosion			10	
10.	Unsuitable land			10	
11.	Vegetation degradation				60
	Soil compaction			30	
	Water erosion			10	
12.	Vegetation degradation				100
13.	Vegetation degradation				80
	Water erosion			20	
14.	Vegetation degradation			100	
	Soil compaction			70	
15.	Water erosion			30	

Table 12 Desertification parameters within separate contours (%) continued

1	2	3	4	5	6
16.	Vegetation degradation				100
17.	Vegetation degradation			100	
18.	Vegetation degradation				100
	Soil compaction			30	
19.	Water erosion			30	
20.	Soil compaction				100
21.	Soil compaction			70	
	Vegetation degradation				30
22.	Vegetation degradation			70	
	Soil compaction			30	
23.	Soil compaction			100	
	Vegetation degradation			70	
24.	Soil compaction			30	
25.	Soil compaction				100
26.	Vegetation degradation			100	
27.	Vegetation degradation				100
28.	Vegetation degradation		100		
29.	Unsuitable land				
30.	Vegetation degradation			100	
31.	Soil compaction			100	
	Vegetation degradation			90	
32.	Soil compaction			10	
33.	Soil compaction			100	
	Water erosion		30		
	Soil compaction			70	
34.	Water erosion		30		
35.	Soil compaction			100	
	Soil compaction			80	

Table 12 Desertification parameters within separate contours (%) continued

No.	Types of desertification	Desertification classes			
		Slight	Medium	Severe	Very severe
1	2	3	4	5	6
36.	Water erosion			20	
37.	Soil compaction			100	
	Vegetation degradation		70		
38.	Soil compaction		30		
	Vegetation degradation			70	
39.	Water erosion		30		
40.	Soil compaction			100	
41.	Soil compaction		60		
	Vegetation degradation			30	
	Water erosion			10	
42.	Soil compaction			70	
	Vegetation degradation		30		
43.	Soil compaction			70	
	Water erosion		30		
44.	Soil compaction			70	
	Vegetation degradation			30	
45.	Vegetation degradation			60	
	Soil compaction			20	
	Water erosion			20	
46.	Vegetation degradation				100
47.	Soil compaction				70
	Water erosion			20	
	Vegetation degradation				10
48.	Vegetation degradation				100
49.	Vegetation degradation			100	
50.	Water erosion				100
51.	Vegetation degradation		100		

Table 12 Desertification parameters within separate contours (%) continued

1	2	3	4	5	6
52.	Vegetation degradation		100		
53.	Vegetation degradation		70		
	Water erosion	30			
54.	Water erosion			100	
55.	Vegetation degradation		100		
56.	Water erosion			100	
57.	Vegetation degradation		70		
	Soil compaction		20		
	Water erosion		10		
58.	Vegetation degradation		70		
	Water erosion		30		
59.	Vegetation degradation			100	
60.	Water erosion			100	
61.	Water erosion			100	
62.	Vegetation degradation	100			
63.	Vegetation degradation		100		
64.	Vegetation degradation		100		
65.	Vegetation degradation			80	
	Water erosion			20	
66.	Vegetation degradation			70	
	Water erosion		30		
67.	Vegetation degradation		100		
68.	Vegetation degradation			100	
69.	Soil compaction			100	
70.	Water erosion	60			
	Vegetation degradation		40		

Table 13 Summed-up data on desertification areas, in sq. km and per cent

Desertification Types	Desertification classes				Total	%
	Slight	Medium	Severe	Very severe		
JELIMANE DISTRICT						
Vegetation degradation		89	1626	1204	2919	76
Wind erosion	-	-	149		149	4
Water erosion	-	-	-	-	-	-
Soil compaction	-	-	764	13	777	20
Unsuitable land	-		-	-	1945	-
TOTAL	-	**89**	**2539**	**1217**	**3790**	**100**
KAYES DISTRICT						
Vegetation degradation	499	3322	8619	1718	141158	64
Wind erosion			20	780	800	4
Water erosion		1627	810	51	2488	11
Soil compaction		520	3614	520	4654	21
TOTAL	**499**	**5469**	**13063**	**3069**	**22100**	**100**
TOTAL TESTED AREA						
Vegetation degradation	499	3411	10245	2922	17077	67
Wind erosion	-	-	169	780	949	3
Water erosion	-	1627	810	51	2488	10
Soil compaction	-	510	4378	533	5431	20
Unsuitable land					1945	
TOTAL	**499**	**5558**	**15602**	**4286**	**27890**	**100**

Table 14 Desertification rates

District	Desertification classes								Total	
	Slight		Moderate		Severe		Very Severe			
	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Jelimane	311	8	-	-	3196	83	338	9	3845	100
Unsuitable land	-	-	-	-	-	-	-	-	1945	
Total: Jelimane	311				3196		338		5790	
Kayes	5318	24	4278	20	9952	46	2552	10	22100	100
Total of the tested land	5629	22	4278	16	13148	52	2890	10	25945	100
Unsuitable land									1945	
TOTAL	**5629**		**4278**		**13148**		**2890**		**27890**	

Table 15 Inherent risk of Desertification

District	Desertification classes								Total	
	Slight		Moderate		Severe		Very Severe			
	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Jelimane	1215	32	508	13	191	5	1931	50	3845	100
Unsuitable land	-	-	-	-	-	-	-	-	1945	
Total:	1215		508		191		1931		5790	
Kayes	6635	30	5064	23	8332	38	2069	9	22100	
Total on tested area	7850	31	5572	21	8523	33	4000	15	25945	
Unsuitable land									1945	
TOTAL	**7850**		**5572**		**8523**		**4000**		**27890**	

Table 16 Total risk of Desertification

District	Desertification classes								Total	
	Slight		Moderate		Severe		Very Severe			
	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Jelimane	-	-	-	-	226	6	3619	94	3845	100
Unsuitable land									1945	
Total:	-	-	-	-	206		3619		5790	
Kayes	688	3	816	4	10295	46	10301	47	22100	100
Total on tested area	688	2.5	816	3.5	10507	41	13920	53	25945	100
Unsuitable land									1945	
TOTAL	**688**		**816**		**10507**		**13920**		**27890**	

CONCLUSIONS

1. Field tests of the FAO/UNEP provisional criteria to assess and map desertification were carried out in two districts of Mali (Kayes and Jelimane). It was found that the methods proposed by FAO/UNEP and Institute of Deserts, Turkmen SSR Academy of Sciences could be applied to study desertification in the Sahelian zone. The methods include: classification of desertification processes, isolating the classes and aspects of desertification, and integrated cartographic description of desertification by a series of thematic maps.

2. It was found that criteria of desertification should be regional. In this context new specified criteria were worked out to reflect the natural features of the region, anthropogenic impacts and availability of statistical data.

3. We propose that a new criterion of inherent risk of desertification should be used - ecosystems stability. Criteria for inherent risk of desertification were elaborated for the following desertification types widely spread in the Sahelian zone: degradation of the vegetation cover, water and wind erosion, soil compactness and crusting.

4. Desertification mapping should be carried out on the basis of automated space systems for data collection and processing (LANDSAT, RESOURCE, etc.). The tested area was studied using the Soviet space photographs with the automated processing of the imagery.

5. The elaborated criteria for assessing and mapping desertification could be used to study desertification in the Sahelian zone. The criteria could be extrapolated within similar landscapes in the longitudinal direction and on a limited scale northward and southward of the tested area.

REFERENCES

1. I.D. Mandel. Cluster analysis. Moscow, 1988 (in Russian)

2. A.S. Selivanov and Yu M. Touchin. "RESOURCE-1" operational system of Earth watch. Remote sensing of Earth, 1988, No. 3 (in Russian).

3. N.G. Kharin et al. Methodological basis for studying and mapping desertification processes (at the example of Turkmenistan arid lands). Ashkhabad, 1988, pp 97 (in Russian).

4. Les resources terrestres au Mali (Atlas). Vol. I, II, III, New York, 1983.

5. Kharin, N.G., Orlovsky, N.S., Babayeva, T.A., Kiril'tseva, A.A., Redzhepbaev, K. Explanatory note to the map of man-made desertification of the USSR arid lands, scale 1:250 000. Ashkhabad, 1988.

6. Provisional methodology for desertification assessment and mapping, FAO/UNEP, Rome, 1981, 65.

7. Provisional methodology for assessment and mapping of desertification, FAO/UNEP, Rome, 1983, 103p.

8. Provisional methodology for assessment and mapping of desertification, FAO/UNEP, Rome, 1984, 83p.

Annex I

DESERTIFICATION CONTROL: CONCEPTUAL DATABASE MODEL ON DESERTIFICATION

Desertification is a complex physiographic process caused and accelerated either by natural and by man-induced factors. Desertification accounts for the reduction of the quantity and deterioration of the quality of renewable natural resources. This in its turn causes reduction in the economic potential of arid territories and worsening of living conditions of people. Thus, desertification can also be regarded as a socio-economic process, the process of destruction of social, economic and sometimes political stability in the regions prone to desertification.

Once having appeared, desertification has the tendency to expand in space and time. Feedback mechanism comes into action, and causes and effects change their places. Alteration of albedo in desertified areas, leading to heat exchange disturbance, is of great importance, because in the long run there may appear disturbances of atmospheric circulation processes and climate may change globally.

So, desertification is characterized by a number of quantitative and qualitative indicators, that form information base on desertification. The information base in its turn is being supported by the data bank service.

A data bank (DBk) can be defined as a man-machine system consisting of:

1) data bases (DB) - named structured sets of interrelated data on specific subject area, that are under centralized programmed control (Date, 1980);
2) database control system (DCS) - language and programmed nucleus of DB the use of which automates the process of design of systems of data computer processing;
3) applied programmes' system;
4) computer systems of a certain configuration;
5) personnel, servicing data bank - administrator service of DBk.

All these components, except for applied programmes, are obligatory constituent parts of DBk. Although the system of applied programmes is not an obligatory component of DBk, we introduce it into the DBk, because the latter will perform certain scientific calculations.

An approximate DBk structure is given below. DB on desertification is the central one, its structure being shown below (Fig. 2).

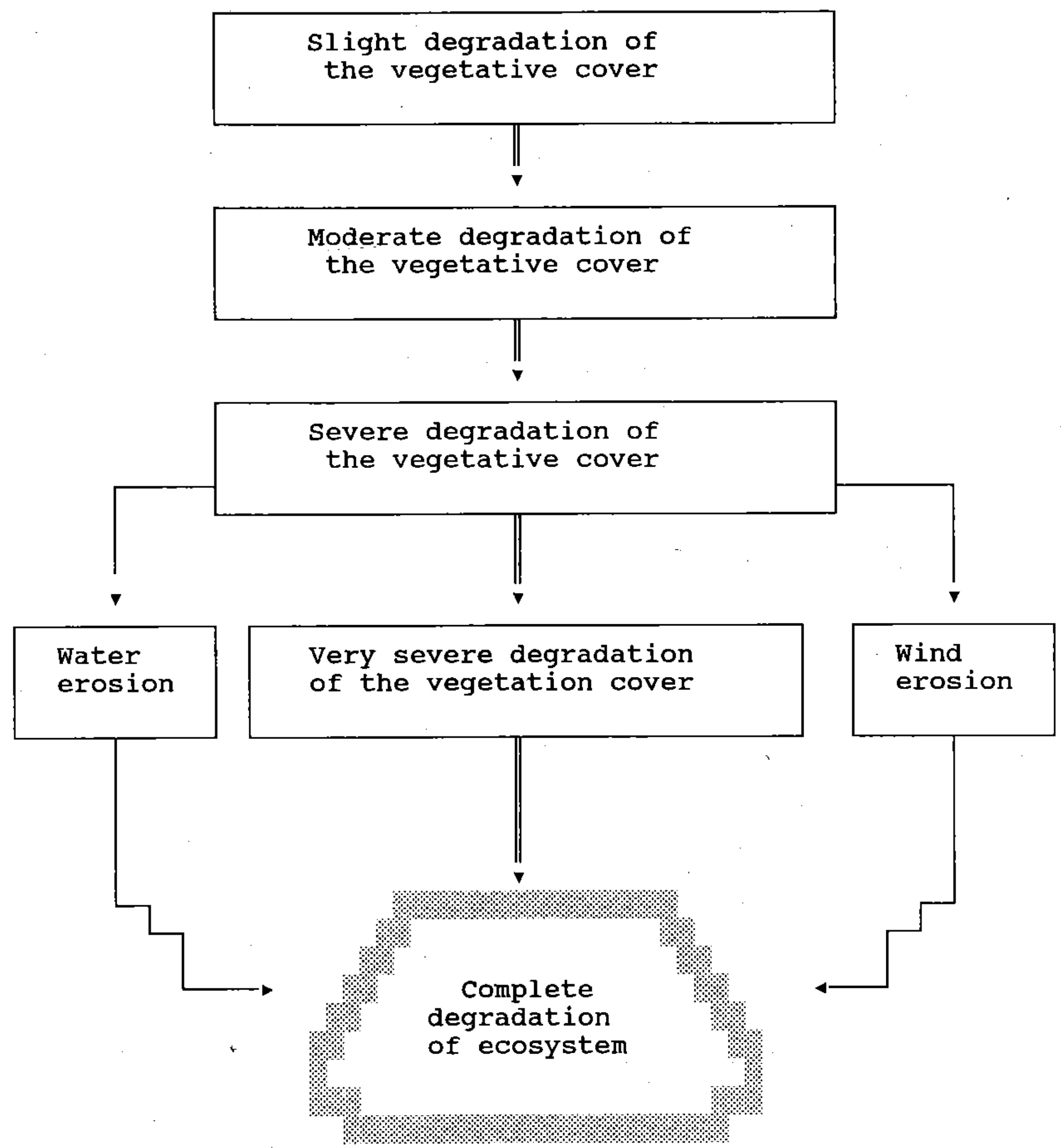


Fig. 1 Process of the arid ecosystem degradation.

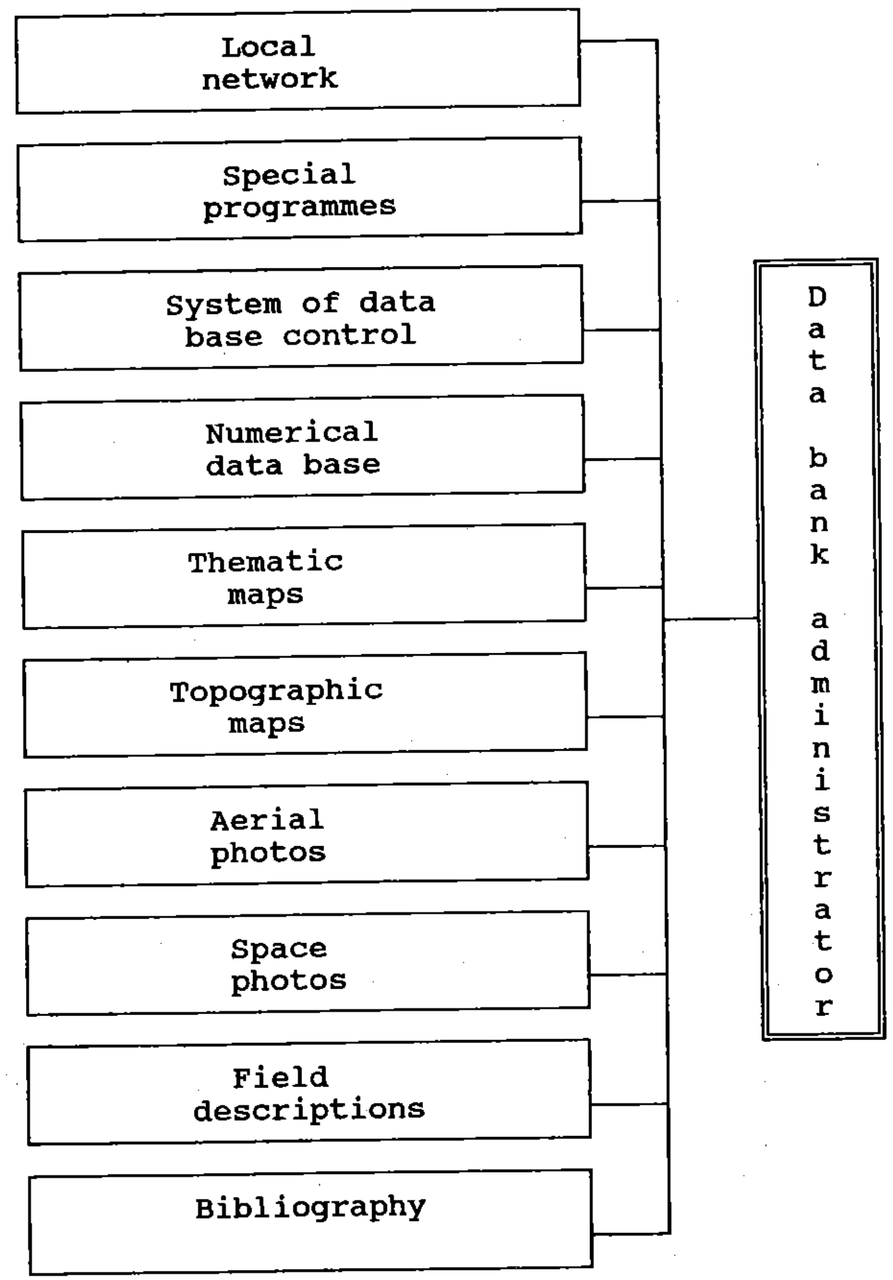


Fig. 2 Data bank on desertification

This database will also be referred to as a subject or digital one. The following databases should be in the DBk (they are enumerated together with the possible search attributes):

Topographic maps database

- international sheet division trapezium
- scale
- year of compiling

Subject maps database

- international sheet division trapezium
- scale
- year of compiling
- map types

Aerial photographs database

- international sheet division trapezium
- scale
- year of photography
- type of photography
- spectrum zone
- type of photographic material

Space photographs database

- international sheet division trapezium
- scale
- year of photography
- type of images
- spectrum zone
- type of photographic material
- resolution on the ground

Field observation database

- region (international sheet division trapezium)
- year
- natural conditions in the region

1. REFERENCES DATABASE

All these databases can be digitally stored on magnetic mediums but it is better to have them as a supplement to the subject database, and this supplement will be a reference-information system for searching the information in need on certain specific "mediums" (in the storage of books, maps, photographs etc.).

We regard a conceptual data model (CDM) as a model of the information content of a subject area (here desertification) at the level of determining a set of files or file groups and logic links between them. Fig. 3 represents stages of database structure design. This diagram is a modification of the diagram suggested by Digo (1988).

On the diagram presented CDM forms a unit consisting of two subunits, namely, conceptual model at the level of metadata (that is data on data) and infologic model. The infologic model by Digo S. M. (1988) is a description of a subject area without orientation to software and hardware to be used further. The infologic model is an initial one for the datalogic model of a database. The latter is a model of a logic data level, being supported with DCS means, that is this model is constructed with regard for the integral specific DCS. Physical data model is used to adjust datalogic model to the storage medium. Physical design takes into account the type of storage, place, data recording regulations etc.

Designing a database one may proceed either from an "object" and from "requests". One of the possibilities is to proceed from an "object" trying to "remember" as many requests as possible and to meet them further with the help of various data processing programmes.

Thus, constructing a CDM we are practically resolving the problem of designing an approximate data structure, because the design itself consists of the following stages: - a logical database model, file models design, models of relationships between files design (The system of management....., 1987).

Having constructed CDM it is necessary to fully develop the schemes of all types of files (schemes of series of files are presented in the paper) so that to finalize the database structure design.

Before describing the database structure it is needed to work out the principal plan of defining desertification - the conceptual model of desertification at the metadata level.

This plan is given below (Fig. 4 a - e). Desertification (Fig. 4) is considered by us as a natural man-made process caused by the interrelation of numerous natural and man-induced factors. The definition of this process will be incomplete if causes of desertification, after effects of desertification and measures to combat desertification are not mentioned.

Despite the diversity and complex interaction of the factors determining the given components of the plan, it turned out to be possible to choose and classify the main groups of factors.

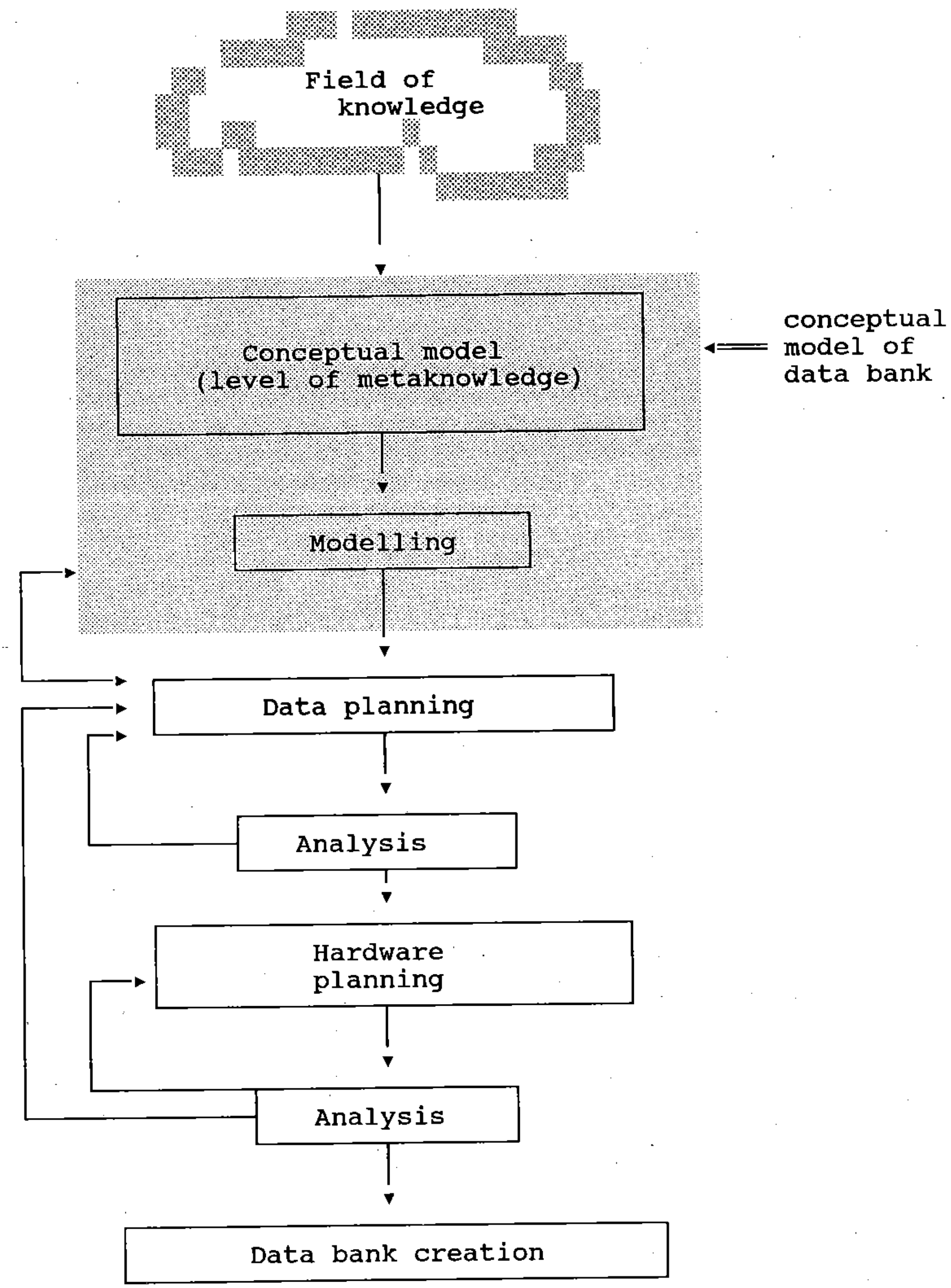


Fig. 3 Stages of the data bank planning

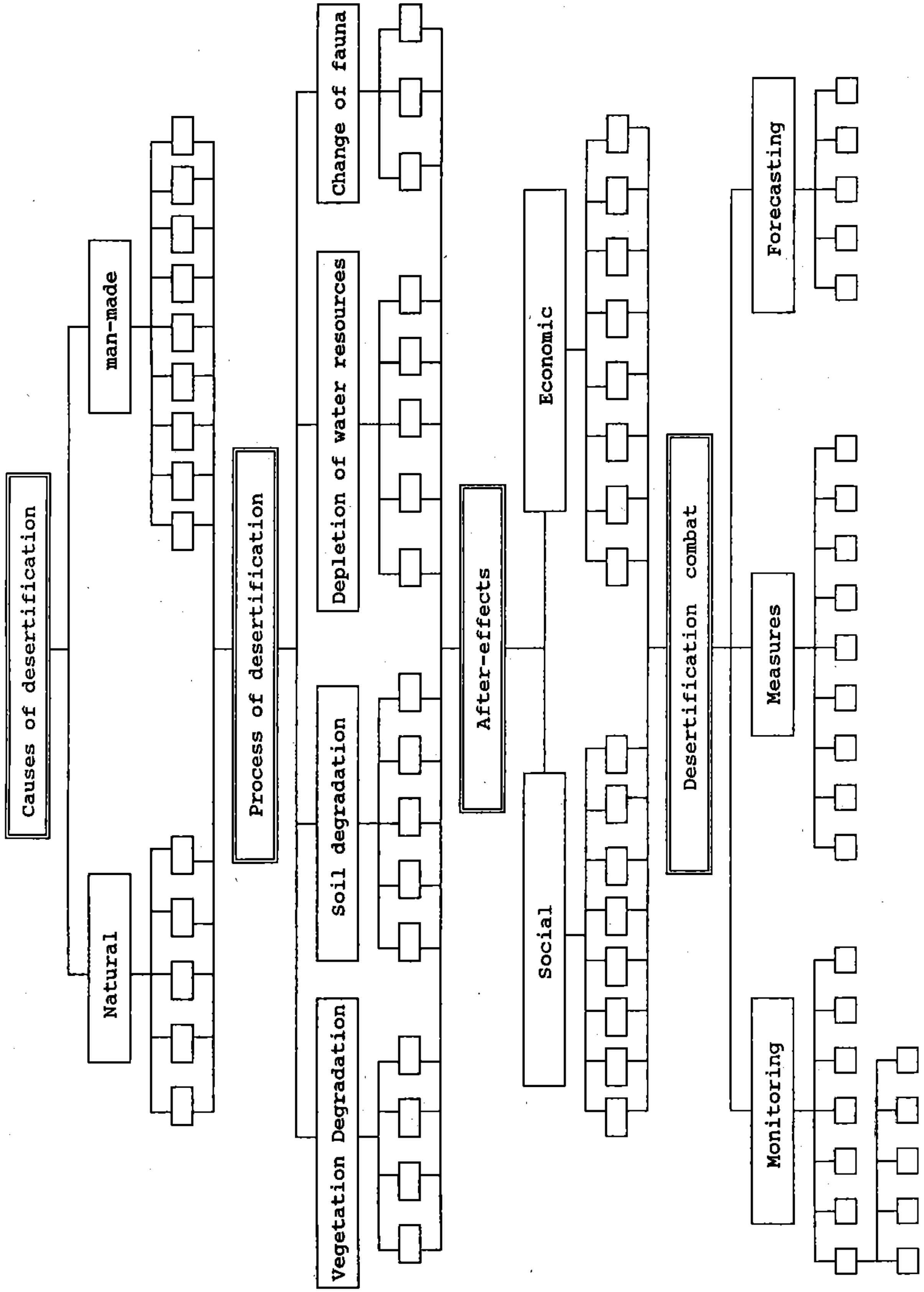


Fig. 4 Conceptual model of desertification

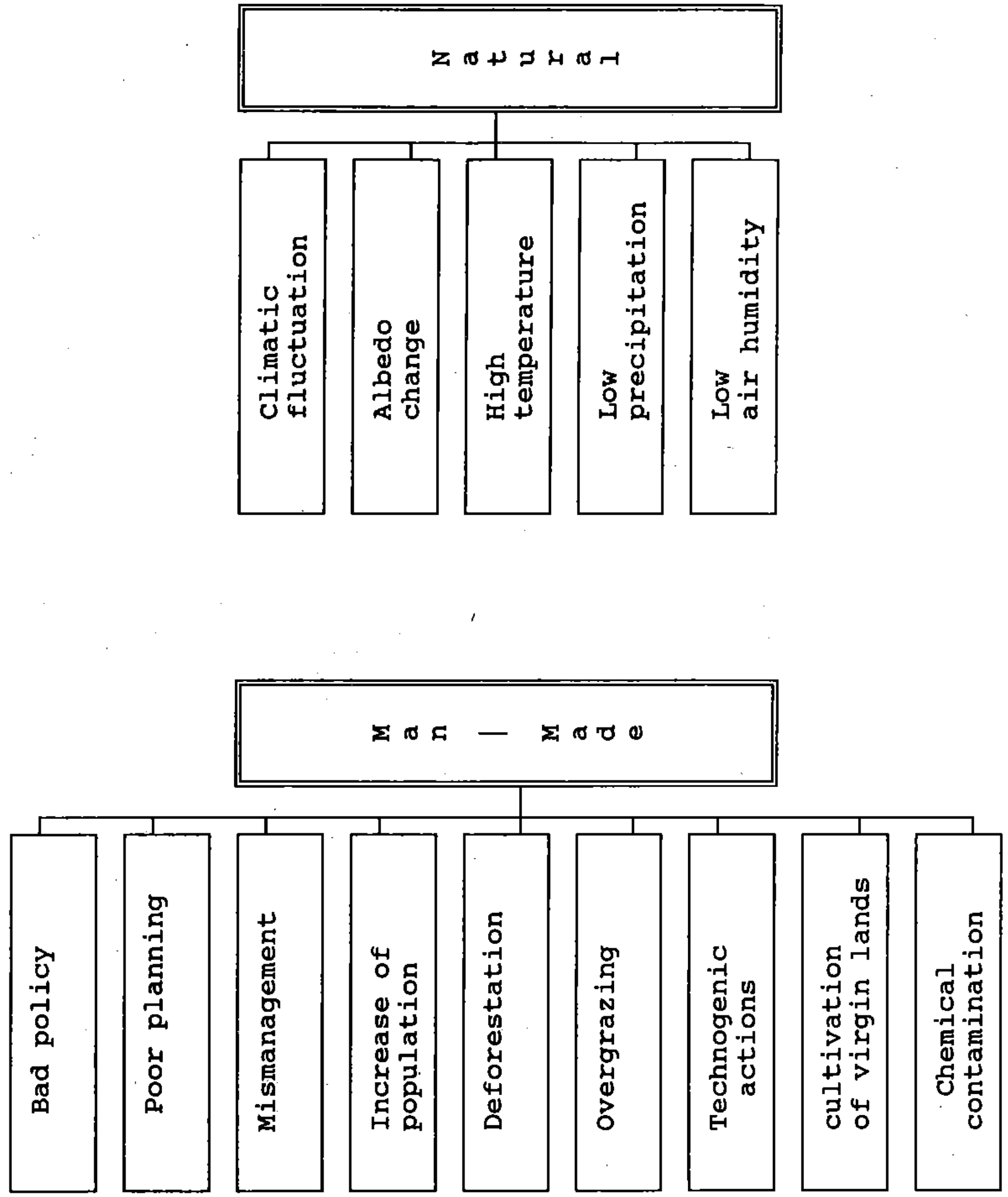


Fig. 4a

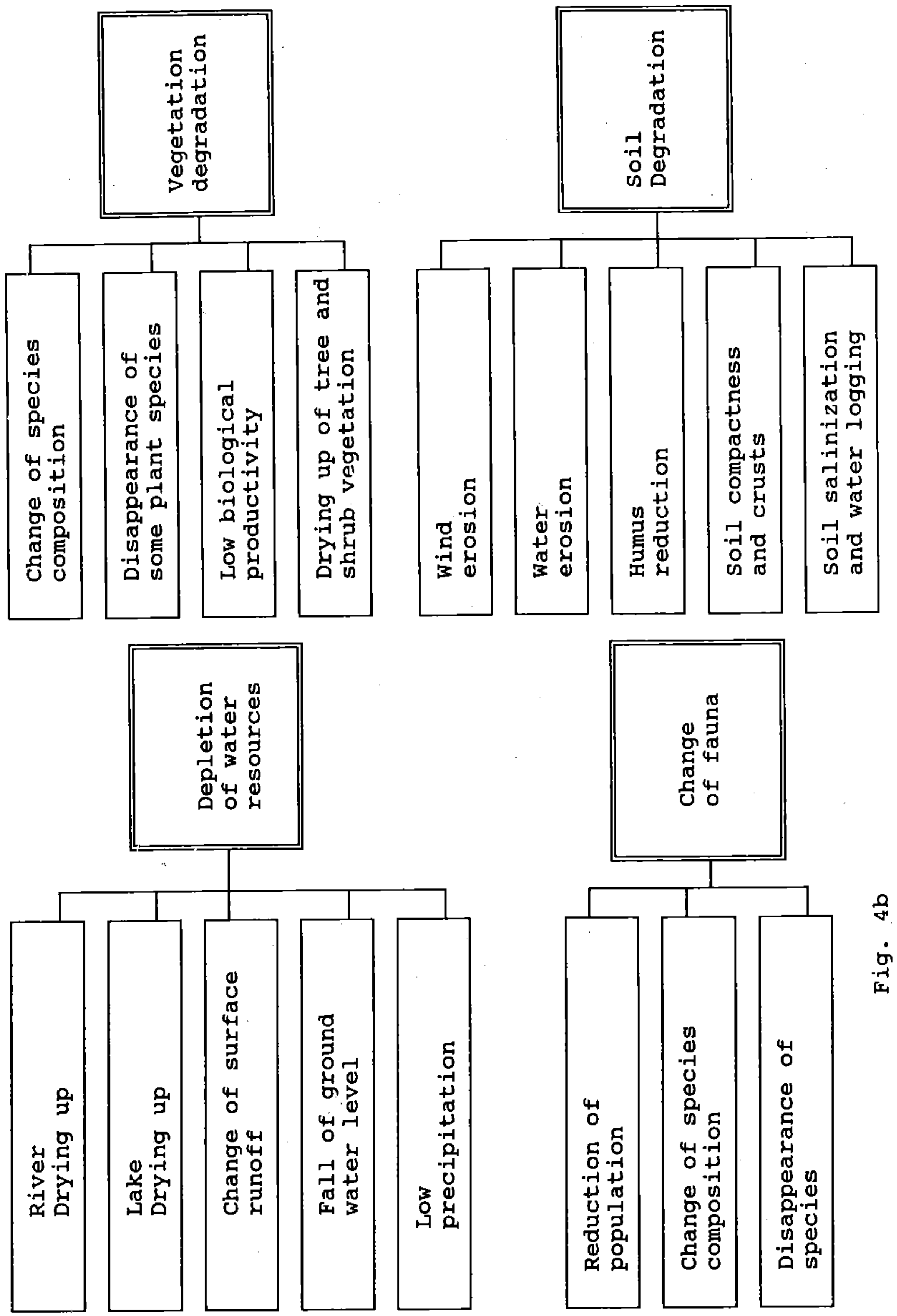


Fig. 4b

Causes of desertification can be described with the two groups of data sets: natural causes and man-induced causes (Fig. 4a).

Natural causes of desertification are mainly related to climatic peculiarities and conditions, such as extreme aridity, uneven distribution of precipitation throughout a year and its variability from year to year, frequent recurrence of droughts, low air humidity, high values of temperature and albedo.

High dryness of the air, mobility of soil substrate and scarce natural vegetation favour, even with small increase in wind velocity, cropping up of deflation processes - sand storms, leading to dustiness of atmosphere.

Dust is an integral part of the atmosphere above deserts, and due to this radiation and microphysical properties of air masses change. The impact of these factors on desertification process is consecutively revealed in the plan.

The unity of natural and man-induced factors can be explained by underlying surface albedo variability. Either with durable droughts and with overgrazing vegetation cover degradation occurs and albedo increases. It has been proved that the increase in underlying surface albedo reduces the amount of precipitation, giving rise to climatic desertification that leads to self-development of deserts.

Irrational activity of man often plays a decisive role in the development of desertification processes, while natural factors serve as a prerequisite to the origination of such processes.

Nine groups of man-induced factors leading to the development of desertification processes have been defined. "Chemical pollution of the environment" group is of special importance. Negative experience accumulated in the arid regions of the USSR testified that environmental pollution may occur as a result of the use of mineral fertilizers, pesticides, herbicides and other chemical substances. Being of a certain use to the society, application of chemical substances often distorts natural matter balance, intensifies difficult-to-remove environmental pollution, poses a certain threat to every living thing, causing deterioration of social conditions and population health. Proceeding from this it is quite correct to consider pollution of the environment part of desertification process.

So, natural and man-induced factors interact and cause the origination of desertification process (Fig. 4b), which is characterized by the following file sets.

The group of vegetation degradation has files describing species composition of vegetation, forests and pastures area, data on disappearing of certain vegetation species.

Soil degradation is described with the help of files with data on wind and water erosion areas, salinization and water-logging of soils.

Water resources depletion is characterized by the data on water discharge in rivers, surface runoff values and ground water level.

Fauna changes are reflected with the data on population, species composition and certain species dynamics.

Naturally, desertification process has after-effects, either social and economic.

Social block has 7 files (Fig. 4c). Nomadism is not found in the arid zone of the USSR, but it is typical for the countries of Africa and Asia.

In some regions of desertification, that became the zones of ecological disaster, social changes are especially pronounced. For example, in the regions adjacent to the Aral Sea sanitary situation worsened because of the drying up of the Aral Sea, salinization and contamination of soils and water (Kotliakov, 1988).

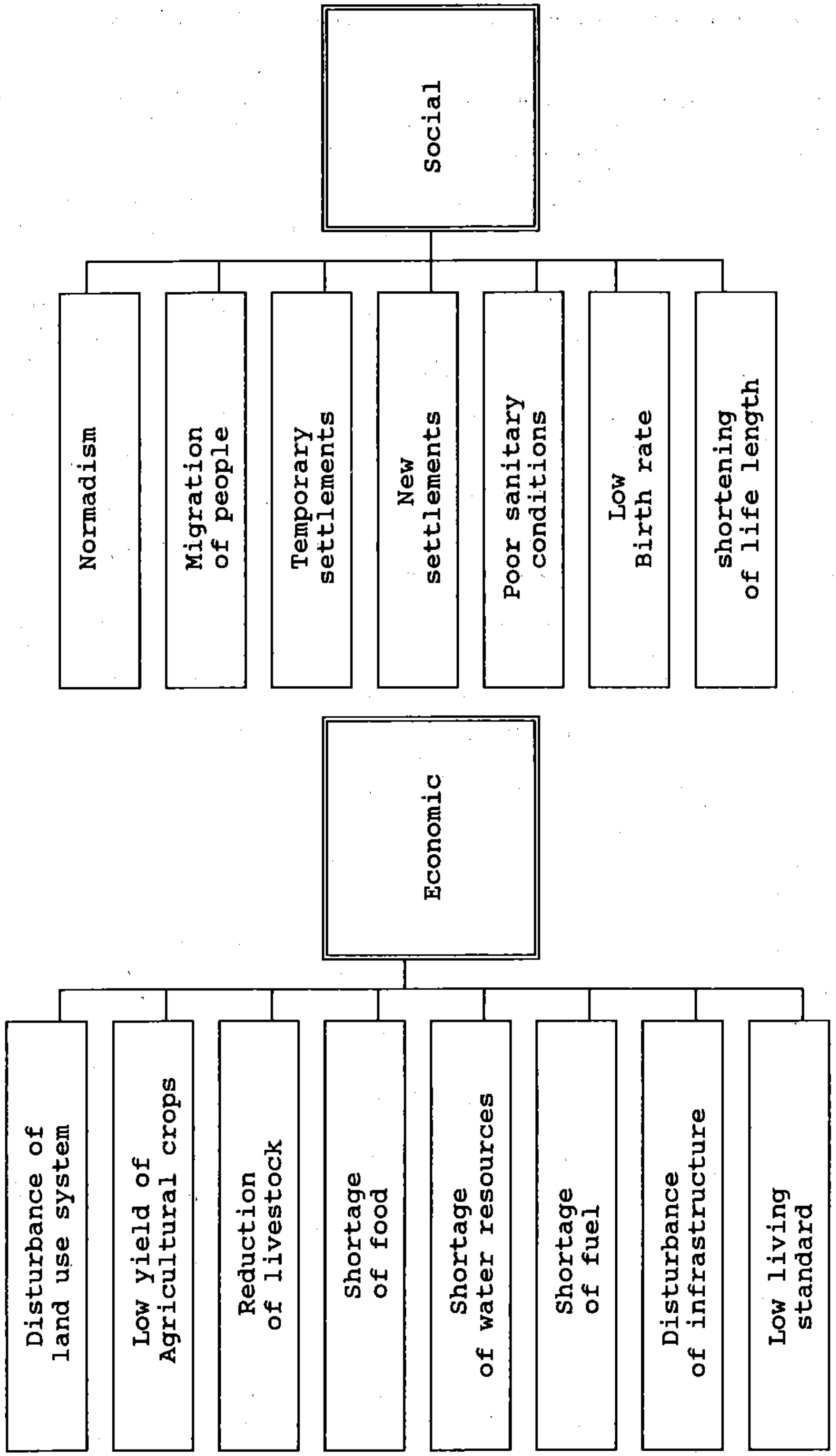

Social
Normadism
Migration of people
Temporary settlements
New settlements
Poor sanitary conditions
Low Birth rate
shortening of life length
Economic
Disturbance of land use system
Low yield of Agricultural crops
Reduction of livestock
Shortage of food
Shortage of water resources
Shortage of fuel
Disturbance of infrastructure
Low living standard

Fig. 4c

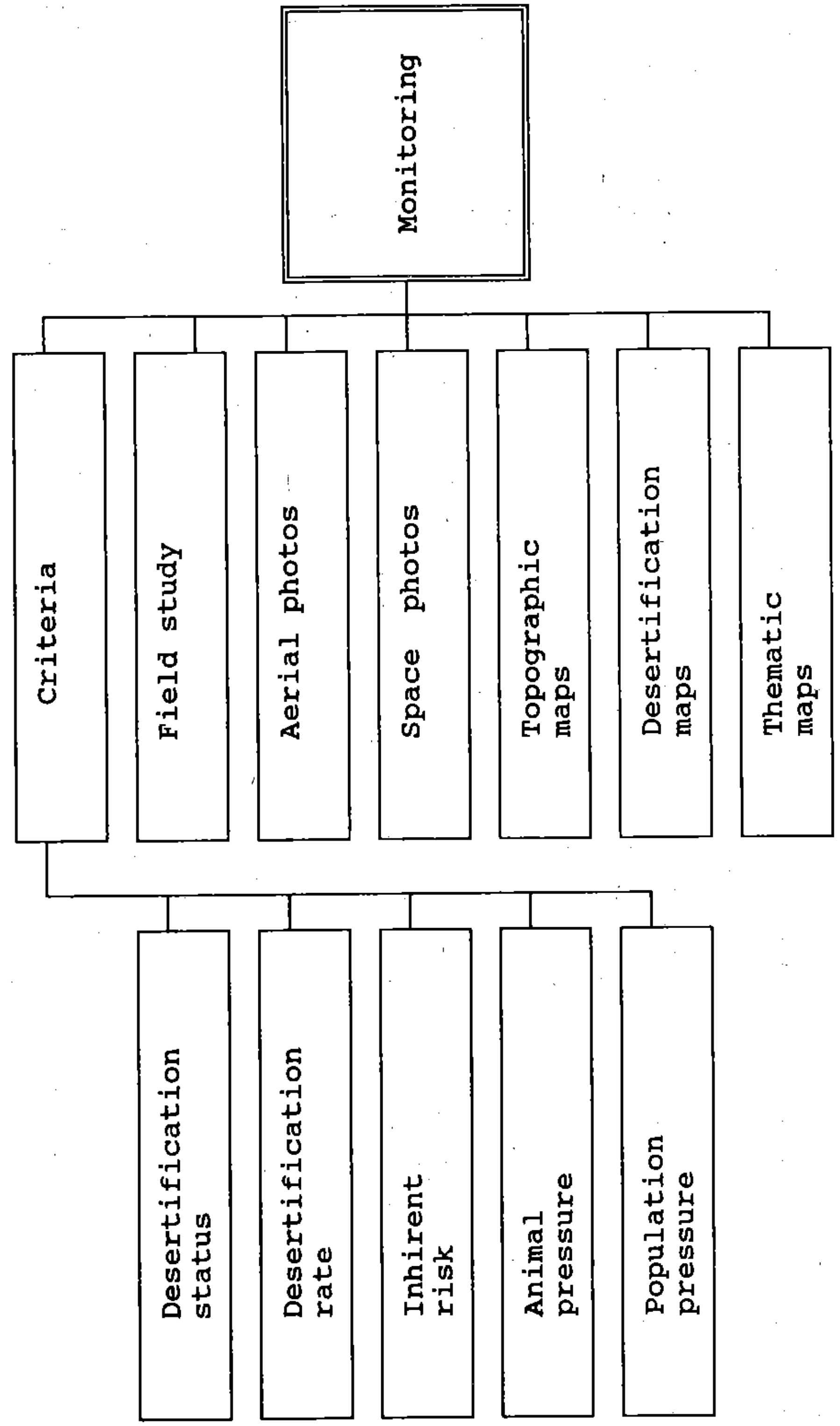

Monitoring
Criteria
Field study
Aerial photos
Space photos
Topographic maps
Desertification maps
Thematic maps
Desertification status
Desertification rate
Inhirent risk
Animal pressure
Population pressure

Fig. 4d

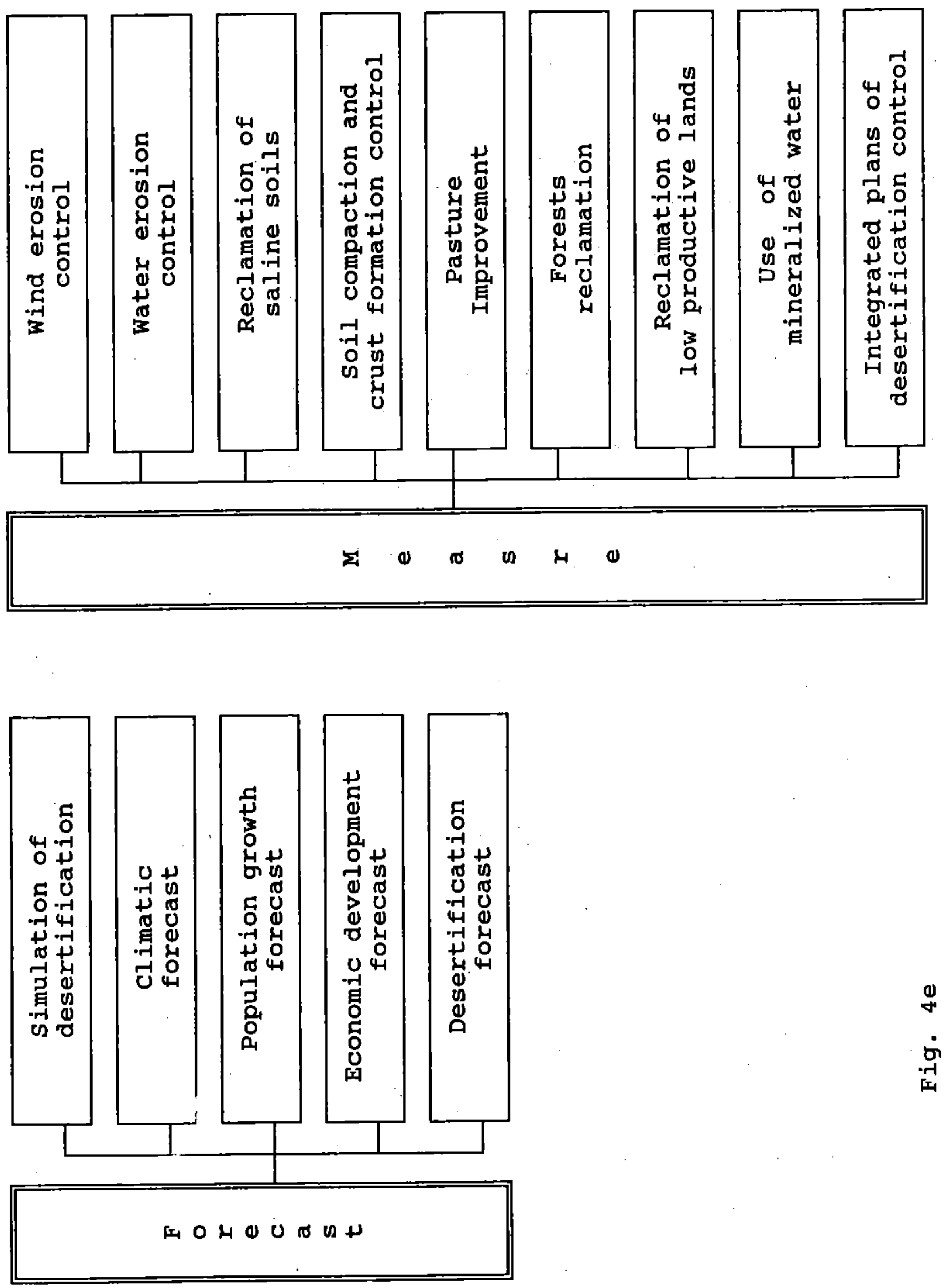


Fig. 4e

Economic changes go along with social ones, and that is reflected on the diagram (Fig. 4). The block of the main economic changes consists of 7 files (Fig. 4c). In various arid regions economic after-effects manifest themselves differently but go along the same way- they cause the reduction in the living standard of people.

Negative social and economic changes deteriorating living conditions of people necessitate the implementation of desertification control measures. Desertification control comprises 3 interrelated blocks. They are: monitoring (Fig. 4d) desertification control measures and desertification forecast (Fig. 4e).

Monitoring of desertification has 6 database - files, but out of them only elaboration of desertification criteria is characterized in detail. Here it is possible to hierarchically arrange data classification.

There are 9 main groups of measures - files in desertification control block. Each of these files, in its turn, can be transferred into the chain of files when detailing is needed.

Desertification forecast comprises simulation and 4 types of forecasts. Although it is not indicated in the diagram, desertification forecast block can be subdivided into more detailed chain of files.

Let's consider an approximate structure of a database on desertification based on the conceptual model and the analyses of UNEP terminology on desertification.

I. Desertification Causes [C]

CN - natural
CNa - air temperature
CNb - albedo
CNc - precipitation
CNd - air humidity
CNe - wind velocity
CNi - sand storms
CH - man-induced
CHa - directive figures of the economic development of a country for the perspective
CHb - scheduled figures of economic development of isolated regions
CHc - data on implementation of economic plans in isolated regions
CHd - population density
CHe - areas of removed forests
CHf - livestock pressure on pastures
CHg - area, non-used for crop production
CHg1 - area under roads
CHg2 - built-on area
CHg3 - are under industrial enterprises
CHh - areas of ploughed virgin lands
CHi - irrigated lands area

II. Desertification process [D]

DV - degradation of vegetation
DVa - species composition of vegetation
DVb - biological productivity
DVc - forests area ranged according to its productivity
DVd - forest resources
DVe - pastures area
DVf - pastures productivity
DVg - dried up forests area
DVh - disappeared species of plants
DS - soil degradation
DSa - area of lands prone to wind erosion
DSb - area of lands prone to water erosion
DSc - area of lands with reduced amount of humus
DSd - area of lands with compaction and crust formation
DSe - area of salinized and water-logged lands
DE - water resources depletion
DEa - water discharge in rivers
DEb - water amount in lakes
DEc - surface runoff value
DEd - ground water level
DEe - surface and ground water quality
DA - fauna changes
DAa - fauna population
DAb - fauna species composition
DAc - fauna disappeared species
DAd - animal diseases

III. After-effects of desertification [A]

AS - social after-effects
ASa - nomadic population
ASb - population migrations
ASc - number of new settlements
ASd - sanitary situation in the locality
ASe - birth rate
ASf - mortality
ASg - specific diseases of people
ASh - life expectancy

AE - economic after effects
AEa - structure of crop areas
AEb - farm crop yield
AEc - livestock population
AEd - food consumption
AEe - water consumption
AEf - fuel composition
AEg - per capita income

IV. Desertification control [L], and archives [AR]

LS - monitoring of desertification
LSa - desertification criteria
LSa1 - present state criteria
LSa2 - rate criteria
LSa3 - inherent risk
LSa4 - livestock pressure
LSa5 - population density
LSa6 - identification techniques
LM - desertification control measures
LMa - areas, where wind erosion control measures have been taken
LMc - areas, where soil salinization control measures have been taken
LMd - areas, where soil compaction and crust formation control measures have been taken
LMe - areas of reclaimed pastures
LMf - areas of reclaimed low-productive lands
LMg - areas of reclaimed forests
LMh - mineralized water use
LMh1 - mineralized water amount
LMh2 - irrigated crops area
LMh3 - irrigated crops yield
LM1 - areas, where integrated measures on desertification control have been taken
LP - desertification forecast
LPa - desertification patterns
LPb - climatic forecast
LPc - population growth forecast
LPd - economic development forecast
LPe - desertification forecast

AR - archives
ARa - topographic maps
ARb - subject map
ARc - aerial photographs
ARd - space images
ARe - field records
ARf - references on desertification
ARg - manuscript archives

Some of the above-listed files are given together with the main attributes, others require additional description. Below, there is an example of a detailed description of one of the files.

AEa file - structure of crop areas

Let's consider the pattern of file compilation on the example of AEa file for the territory of Mali. We accept as attributes:

- names of agricultural crops (in the way they are listed in the system of state registration of the country):

1.	Millet	11.	Saccharum
2.	Sorghum	12.	Cotton
3.	Vigna sinensis	13.	Sesamum
4.	Corn	14.	Rumex
5.	Rice	15.	Nicotiana
6.	Wheat	16.	Plantago
7.	Tuberous plants	17.	Garden crops
8.	Cucurbita pepo condensa	18.	Fruit trees and bushes
9.	Voandzeia subterranea	19.	Digitalis
10.	Arachis hypogaea	20.	Tea

- year
- territorial units
- community
- province

Each file recording contains information on the fact that in each region at a certain time such crops as miller, sorgh ım etc. occupy a certain number of hectares of crop lands. Our flat file table is given in Figure 5. An example of another file is given below.

	Region
	Year
	Millet
	Sorghum
	Cow peas
	Maize
	Rice
	Wheat
	Tubers
	Calabash
	Bambara peas
	Peanuts
	Sugarcane
	Cotton
	Sesame
	Jamaica sorrel
	Tobacco
	Foxglove
	Vegetable gardening
	Orchards
	Plantations
	Tea

Fig. 5 File AEa - area under crops

Table A1 Species composition of arborescent-shrub stratum of soil-vegetation complexes in western regions of Mali

98 species
25 SVC (regions)
VIII SVC groups

Names of plants	Vegetation of over-grown sands	Vegetation of grown sands	Vegetation of plains with clay soil	Vegetation of plains with heavy clay and loamy soils	Vegetation of laterite crusts with temporary excessive - humidification	Vegetation of depressions and temporary flooded depressions	Vegetation of aluvial plains	Vegetation of mountains
Species / SVC	D5	DA4 DA5	PA1 PA2 PA3	PL4 PL5 PL8 PL11	TC1 TC3 TC4 TC5 TC6	TH8	T15	TR2 TR4 TR5 TR6 TR7 TR9
Acacia adansonii		0,3	0,27	0,45				0,33

"Species composition of arborescent-shrub stratum of soil-vegetation complexes in western regions of Mali". We shall also consider several processing programmes and their realization by means of database II. There are initial data on species composition of 98 plant species in soil-vegetation complexes (SVC) of western regions of Mali. (Les resources terreses....., 1988). This data is given in the realization of the file (refer to supplement 1.) The fields (attributes) of the file are: species; coefficient - mean number of species participation in phytogenesis; SVC (region); group; year (not to be filled in). The mean number is referred to the following scale: 1 - of rare occurrence; 2 - occurring on the selected ground, but not abundant; 3 - of frequent occurrence; 4 - abundant; 5 - extremely abundant.

To reproduce the initial table of data, it is necessary to specify the name of each of SVC groups: I - vegetation of overgrown sands - this group consists of one SVC-D5; II - vegetation of broken sands - two SVC-DA4 and DA5; III - vegetation of plains with clay soil (SVC sets of this group and the following ones are specified in file records); IV - vegetation of plains with heavy clay and loamy soils; V - vegetation of laterite crusts; VI - vegetation of depressions with temporary excessive humidification; VII - vegetation of alluvial plains and temporary flooded depressions; VIII - vegetation of mountains. The pattern of the initial table of data and the first line of the data are presented in table A1. Further ale 98 species are subdivided into three groups, depending on their role in phytocoenosis composition.

Group A comprises species, having mean number 3, these are the species prevailing in phytocoenosis (dominants).

Group B comprises species, having mean numbers higher than 2 and lower than 3, that are the species participating in phytocoenosis but not dominant.

Group C comprises species with mean number 2, the species, are not very important for the phytocoenosis structure.

Criteria of the inherent risk of desertification, subdivided into four groups DR1, DR2, DR3, DR4 in table A2. All SVC are subdivided into these four groups.

There are two tasks, suggested for processing:

1. To get an access to species of A, B, C groups for each of 8 SVC groups.

2. To get an access to species of A, B for four classes of the inherent risk of desertification (DR1, DR2, DR3, DR4).

These tasks were implemented by means of dBaseII, that is the proper instruction files were made (they are listed in appendix I).

2. SIMULATION MODEL OF A REGION AND A SET OF PARTICULAR MODELS

The problem of man and nature interaction in the arid zone is very complex and topical. Nowadays it is evident that to take any decision there should be an integrated, system approach to nature management.

System analysis, as a branch of science, envisages elaboration of a simulation system - an automated, research complex with the needed software and information supply for an object study (in our case the object is a part of the territory of Mali).

Computer simulation not only enables to give up costly field experiments (often even impossible to carry out), but also to increase the quality of forecasts and decisions to be taken. Such calculations are even more valuable because of the shortage of some resources, high sensitivity of an ecosystem to the impact of man and the lack of accurate patterns of making a decision.

Table A2 Inherent risk of desertification (for the type of desertification: degradation of vegetation cover)

Criterium	Desertification risk classes			
	Low DR1	Moderate DR1	High DR3	Very high DR4
Ecosystem stability	Stable ecosystems of plains with clay soils (PA1, PA2, PA3) and of plains with heavy clay and loamy soils (L4, L5, L8, L11, L12).	Relatively stable ecosystems of laterite crusts (TC1, TC3, TC4, TC5, TC6)	Non-stable mountain ecosystems (TP2, TP3, TP4, TP5, TP6, TP7, TP9) ecosystems of depressions with temporary excessive humidification (TH8), ecosystems of aluvial plains and temporary flooded depressions (T16)	Very unstable ecosystems of over-grown (D5) and broken (DA4, DA5) sands

Information shortage can often be compensated by simulating various ways of development. It is also possible to use the system of guaranteed evaluation etc.

Let's enumerate the main stages of the modern system research (Moiseev N. N., 1981; System researches......... 1986; Ovezgeldyev O. G., Gurman V. I., Dmitriev M. G., 1988).

o Aims and criteria of functioning of an object

A region or an object as an integral part of economy, nature, fauna and population has a set of aims and criteria of functioning. The main task of the system analysis is to find a compromise not disturbing system stability, that is not to take the object out of homeostasis area. At this stage it is important to identify what is principal, what is minor, what should be neglected etc. Correct identification of aims and criteria will enable, when simulating, to reveal the mechanism of functioning.

Specifically, in our work, when describing the system at macro level, the indicator of total risk of desertification (TRD) can serve as one of the criteria of the state of environment evaluation.

o Models, variables and state, limitations

The dynamics of indicators of the state of object components is described here. At this stage it is important to understand what characterizes the state of an object (phase variables), what characterizes the active external impact (control), what characterizes the relation between variables of state and control (equation of state) etc. Particularly, limitations for variables of state and control are to be determined, this or that language for equations of state) etc. Particularly, limitations for variables of state and control are to be determined, this or that language for equations of state description (ordinary differential equation, discrete systems, mathematical physics equation etc.) should be chosen. For describing of desertification processes development an indicator of the present state (PS) can be chosen as the variable of state than an indicator of desertification rate (DR) can be chosen as a rate of changing of this variable of state (this, by the way, is in compliance with the accepted definition of DR).

o Development scenarios, controls

Description of the possible scenarios of development is needed for good simulation. Along with scenarios of evolutionary type, scenarios of "revolutionary" development should be presented. For example, for western regions of Mali one of such scenarios of "revolutionary" development (when priority is given to strategic targets) can be the following one: maintaining investments into the established economic system at the level minimum required to keep up a certain achievable living standard, major investments, out of the money left, are made into education, health protection, agricultural development, desertification control measures (nowadays they are practically not carried out). Basing on this, in the future, introduction of new technologies into agriculture is accelerated, living standard of population increases and the major factor, impeding development - degradation of the environment - is restrained.

o Elaboration of software, information supply and hardware

An acceptable simulation of regional processes is rather complex, as to collection and processing of information. On the one hand, this task can be simplified by using aggregated variables, and, on the other hand, for a consistent solution it is necessary to set up a service of data bank (DBk), the conceptual model of which is given in the previous paragraph. The main files and logic relations between them are also given there. The conceptual model presented in § 4.1. enables to pass over to the creation of a knowledge base with mechanisms of logic output.

o Elaboration of mathematical support

As a rule, making use of system approach to the analysis of large objects, a multi-criteria problem of optimum management with the number of variables of state no less than several dozens can be considered as a mathematical model. Such a number of variables, that can increase in detailed description, causes difficulties for numerical solution. That is why analysis of algorithms of solution of multi-criteria problems is needed. Problems, related to the choice of notion of solution of a multi-criteria problem. There should be noted that, as a rule, new applied problems make it impossible to use ready mathematical support, that's why one should be ready to make one's own effort.

Before presenting the structure of a region model we shall offer an original approach to desertification processes forecast and dwell on a number of particular models - simulation model components.

Our task was to formalize the approach to description of desertification processes, that is found in the works of the staff of the Institute of Deserts of Turkmen Academy of Sciences. This task is logic, because initially trying to make a mathematical model to study desertification processes, it is necessary, on the one hand, to make a description at the qualitative level, on the other hand, to take into account established methodologies of expert assessments, available here, and then it is desirable to remember that additional information required for macro description (for verification, for model parameters adjustment) can be obtained with the help of remote sensing techniques. The concept of desertification processes study meets, to our stand point, all the requirements (Methodological basis of studying......, 1983).

Despite of relative simplicity of economic ties in the studied region of Mali and obvious great dependency of occurring here processes, desertification processes inclusive, from climatic factors, we didn't bring to one and the same the impact of all the factors on desertification process.

The indicator CC (present state) of desertification is chosen as a variable of state X (t), dependent on time t. The relation between desertification rate (TO) and CC is the following
$dCC/dt = TO$. Time is measured within the period of (O, T), T equals approximately 10 years.

In different countries of the arid zone dominant causes of desertification are different, and not everywhere economic activity of man is, in this respect, of increasing importance. It is evident, that ecosystems of natural regions can nowadays be regarded as passively managed systems.

Having revealed the regulations of functioning of these ecosystems, the task of man is to actively manage them.

Now comes the description of desertification factors. Let's assume that the dominant type of desertification in the studied region is degradation of vegetation cover. The second assumption is related to identification of administrative regions with ecosystems. It is done because of the lack of the proper data on ecosystems.

The indicator CAB (man-induced impact rate) seems to be related with the density of rural population the cost of capital funds. Rural population density in Kayes region in 1986 was 8.56 people per km^2, and the total density was 12.03.

In 1956 the average population density all over Kayes region was 5.2. As far as Yelimane region is concerned, there are data on rural population density only for the year 1986 (it is equal to the total density since there are no towns in the region) - 17.57 people per km^2.

Because of the lack of proper information on summary indicators of economic development of our test region, we'll try to make an assessment of economic activity proceeding from indirect data. Let's conditionally relate capital fund changes with national per capita income changes and assume that in 1965-1980 per capita increase in capital funds was 2.1% and in 1980-1986 it was 0.5% (the amount of funds per

capita decreased). Let's assume this tendency to be true for the whole territory of the country as well as the tendency of CAB changing (per capita). Then the table of funds values (per capita) will be the following (funds in 1965 are accepted as 1 unit):

year	funds
1965	1
1970	1.105
1975	1.21
1980	1.315
1986	1.29

CAB is the following:

$$CAB = C_1 N_1^{\alpha} V_1^{1-\alpha}, \qquad 0 \le \alpha \le 1, \quad C_1 > 0$$

where N_1 is rural population density, V_1 is per capita funds value, that is we'll assume CAB as a function of Kobb-Duglas type. It is known that this "production" function is flexible - the action of its arguments is interchangeable (Moiseev, 1981). Indeed the same value of CAB can be achieved by increase in rural population density with constant V_1, or by development of economy with constant N_1, or by changing of both of its arguments. Constant C_1, α will be chosen by retrospective.

Inherent risk of desertification (BOO) is a factor that also contributes to the development of desertification processes. It depends on the relief, steepness of slopes, soil composition ecosystem stability factors, suitability of lands for new development and, of course, it is a function of CC, that is X. But so far we failed to get information from the available works on desertification to plot such a relation, and we shall adhere to some average idea of BOO in this region. This averaging is, obviously, a result of processing of observation data and estimates of experts and can be constant. In our work we determined BOO separately for each type of desertification. Doing that we took into account soil texture, steepness of slopes, relief, occurrence of floods, properties of vegetation cover. In the studied area territories with very high inherent risk of desertification comprise 22%, those with high risk - 44%, moderate - 20% and low - 14%. Weighted average (via area) indicator of inherent risk of desertification (BOO) (if we take very high BOO for 4, high for 3, moderate for 2 and low for 1) will be 2.728, that is very close to high inherent risk of desertification.

IAN (influence of animals on nature) is the last factor to be described for our model. Methodology of IAN defining is given in the work (Explanatory note........, 1987) and is linked with the determination of correlation of actual and potential pressure. All this is, of course, done within the framework of the defined natural-vegetation complexes (NVC). For our work we need a more aggregated indicator of IAN for the region, comprising several NVC.

To determine IAN it is necessary to have data on forage supply, feed consumption rate and data on actual livestock population. Consumed forage supply is calculated with the help of FAO methodology (Provisional methodology.......,1988).

IAN determination for the studied regions of Mali is done in part 3.1 of this paper. There it is shown that the actual pressure exceeds the allowable one by 2.24 times. For the experimental plot, as a whole, this indicator is assumed to be equal 2.0.

As to the dependency of IAN from CC, the remark can be made, analogous to BOO case. There, certainly, is a direct dependency of IAN from population density. The data, that will be used for the construction of equation of population dynamics can also be used for the construction of the above-mentioned dependency. So our equation is the following:

$$\frac{dX}{dt} = \frac{(C_1 N_1 \alpha V_1^{1-\alpha} + C_2 BOO + C_3 IAN - C_1 V_1(t)}{x(t)} \qquad (1)$$

$$x(o) = X^{\circ} \geq 0, \quad t \in 10,+1, \quad V_1 \geq 0, \quad 0 \leq X \leq 100$$

Here X is CC or the per cent of the territory with severe or highly severe desertification, X° is an initial CC value, V1(t) is a function related to investments into desertification control, X(t) is a "climatic trend", in our case it is a curve of the mean annual discharge of the Senegal river near town of Kayes. This function at each time instant (year) is an integrated mean annual indicator of the state of climate humidification. Increase in the discharge should cause slowing down of desertification rate and vice versa, decrease in the discharge should be linked with intensification of unfavourable tendencies. It is reflected in the equation. Numerical experiments with this equation are presented in the next paragraph.

Now, let's consider the equation for population forecast, which is closely related with (1), since N1 (rural population density) is part of the right side of (1).

Equation (2) will form the basis of population forecast:

$$\frac{dN}{dt} = an - BN + G(y\ mean,\ y), \quad y = \alpha(p/n, R - R*) \qquad (2)$$

Here N is total population, G is a function of migration that by all means should be taken into account here.

But we are evidently short of data for migration modelling, that's why one can only suggest various versions for simulation. It is evident, however, that migration level is connected with climatic factors in the studied and adjoining regions.

Mean value of water discharge in the Senegal of many years can be suggested as an indicator. Statistical data on this is available since 1906. Migration G is positive when $R > R^*$ and negative when $R < R^*$, and non-linear effect should be present here. When R slightly differs from R^*, G should be almost equal to zero, but beginning from certain $R - R^*$ value migration can to some extent be proportional to $|R - R^*|$.

Then, birth rate coefficient A is evidently a function of the standard of living and depends, first of all, on climatic indicators. According to the data given in table 23 birth-rate maximum in 1979 during the period 1973-1982 in the town of Kayes is closely related to the local maximum of precipitation during that period, which was observed in 1978. Relatively sharp decrease of the birth-rate in 1982 can be linked with the steady reduction of the annual mean precipitation beginning from 1978.

Climatic factor influences mortality as well. For example, maximum mortality in the town of Kayes during the period of 1973-1983 was observed in the year of the local precipitation minimum (1973). Although in this case the curve should be analysed with regard for the increase in investments into health protection and the overall tendency for the rise of the mean life expectancy (35 years in 1960, 35 years in 1987). So, indicator "b" can be considered to be a function V_2 of investments into health protection. In our calculations, as it was already mentioned above, we shall use the indicator N of the total population.

Transfer to rural population will be determined by assigning of this or that scenario, since so far it is not possible to foresee the tendency for a change in proportions. Although proceeding from the available data one can observe a certain tendency for the increase of urban population rate (there were 8% of urban population in Mali in 1960, and 21% in 1976), it is still not the time to make any conclusions.

Variant II. 8% of urban population in 1960, 21% in 1976, 25% in 1992, 30% in 2000, 35% in 2010 (the variant of industrial development).

Variant I. 8% of urban population in 1960, 21% in 1976, 34% in 1992, 25% in 1992, 30% in 2000, 35% in 2010 (the variant of agricultural development).

Thus:

$$N_1 = \frac{[100 - F(t)]\ N(t)}{100S}$$

Where S is the area of rural regions, f(t) is a function at each instant of time t, showing the per cent of urban population. N(t) is the change of total population in time.

Before passing over to numerical experiments we shall consider the structure of the simplest simulation model of desertification.

The main interrelated processes in the studied region are desertification, population change and economic activity. So, at the initial stage of modelling one can limit oneself to consideration of the model, taking into account three processes, namely: the process of desertification, the process of population growth and the process of funds' changes.

Simulation scenarios can envisage various nature strategies (climate), various investment policy strategies, related to desertification control and social programmes.

Input variables of the model are investments V_1, V_2, V_3.

Let us assume that the sum of V_1, V_2, V_3 can not exceed a certain part α of the budget.

$$0 \leq V_1(t) + V_2(t) + V_3(t) \leq \alpha \qquad (3)$$

Quality criterium for the evaluation of decisions, taken in the region will be the criterium of the total description risk (COO). Thus, our model can be presented as a problem of the optimum management. It is necessary to choose Vi, i = 1 - 3 out of (3) the way that in the section (O, T) along trajectories of the system:

$$x = \frac{(C_1 N_1^{\alpha} V_1^{1-\alpha} + C_2 BOO + C_3 IAN - C_4 V_1(t)}{X(T)} \qquad (4)$$

$$x(0) = x^0, \quad t \in (0,T), \quad 0 \leq x \leq 100$$

$$N = C_5[aN - BN + G(y_{mean}, y)], \quad N \geq 0, \quad N(0) = N_0$$

$$V = C_6[V_3 - \Delta V], \quad V(0) = V^0, \quad V \geq 0, \quad \Delta > 0$$

to minimize the functional[1)]

$$\frac{COO}{t} - T - X(T) + X(T) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where Ci, i = 1,6 are normalizing and scaling factors, $0 \le \alpha \le 1$.

To make calculations with the help of model (3) - (5) it is necessary:

1. To determine α - part of the budget in per cent ($0 \le \alpha \le 100$).
2. To assign X^o, N, R^*
3. To construct dependencies a(t), b(t, V2), f(t).
4. To choose the type of functions of migration as a function of a climatic factor.
5. To construct a dependency X(t).
6. To assign Δ (t) function of funds' depreciation.
7. To determine proportions of factors Ci, i = 1-4, with a view to qualitatively describe by the model the available statistical data (Ci = ßCi, i = 1-4, ß>0).
8. To retrospectively determine C5, C6.
9. To retrospectively determine α, ß.

Our problem can be attributed to the problems with vague information. In scientific works there are two approaches to the analysis of systems with vague information. The first approach is related to statistical data processing and obtaining of statistical dependencies (probabilistic approach). The second one is based on guaranteed evaluations plotting (the principle of guaranteed result).

According to Tchernousko F. L. (1988) "The probabilistic approach enables to get better results in average (for realizations), but the guaranteed one provides with more reliable results for each separate realization. It is expedient to use the first approach possessing reliable data on statistical characteristics of disturbances and noises (such information is often not available) and for numerous realizations of the process. The guaranteed approach is more suitable for cases, when it is needed to provide with a reliable evaluation in each realization of the process and there is a lack of reliable information on disturbances, except for their possible limits."

It is evident that when modelling natural processes there will always be situation with the availability of reliable information and with the lack of it. So one should make use of both of the approaches.

Equation (1) in an uncontrollable situation may loose its physical meaning with great changes of X(t) and other functions of its right side, because the variable X(t) may exceed 100. To avoid this the right side of the equation should be multiplied by the difference (100 - X).

---

1 commands in (5) should by all means, be "weighted", because proceeding from COO minimization the importance of each of them is different.

3. NUMERICAL EXPERIMENTS

Let's consider on uncontrollable variant of the model, $V_1 = 0$, $V_2 = 0$, $V_3 = 0$. Population change in our region can be described by the following equation:

$$N - (aN - bN)/T, \qquad N(t_0) - N^0$$

where T = 1000, a = 50, b = 21. Rural population density is determined by the formula:

$$N - \frac{(100 - f(t))\,N(t)}{100S}$$

where f = 0,25 (urban population), S = 27840 (rural regions area). So

$$N - N^0 \exp(0{,}029(t - t_0)), \quad N - \frac{N \cdot 0{,}75}{S}$$

Then the approximation X(t) is determined of the Senegal discharge, so that it might qualitatively describe the available statistics.

Programme I (appendix 2) provides for the approximation of function y, assigned by the table, with the help of polynomial

$$y - Ao + A1x + \ldots + AmX^m$$

where the power of polynomial is m = n-1, and n is the number of observation points. The approximation is done on the basis of the smallest squares method, that here leads to the solution in relation to the system of linear algebraic equations.

Further on, equation parameters α, ß for X are "adjusted" on the basic period ϵ (1974-1980) by misclosure minimization

$$\sum^{10} - (x(t_i, \alpha, \beta) - Y_i^*)^2$$

with $\alpha \epsilon$ (0,1) and ß > 0. BOO = 2,728, IAN = 25. X (t_i, α, ß) are calculated values of X in the model, Y_i^* are assumed values of X at instants t_i, $t_i \epsilon$ (1974-1980).

Programmes in BASIC language are made on the basis of programmes presented by V. P. Diakonov (1989). Operational system is MSDOS, dialect is GWBASIC.

After α and ß have been found, programme 3 is used to calculate deviation of the model on the basis of remaining observations and forecast calculations.

Now comes numerical experiment. First of all, approximations of dependencies X(t) and V_1(t) were made with the help of programme 1. Polynomial of the power of 8 was obtained for the first function and one of the power of 4 was obtained for the second function. The error of approximation for the chosen systems of points was 54 and 0,015 correspondingly. Both approximations "capture" very well qualitative behaviour of experimental curves (Fig. 6 and 7).

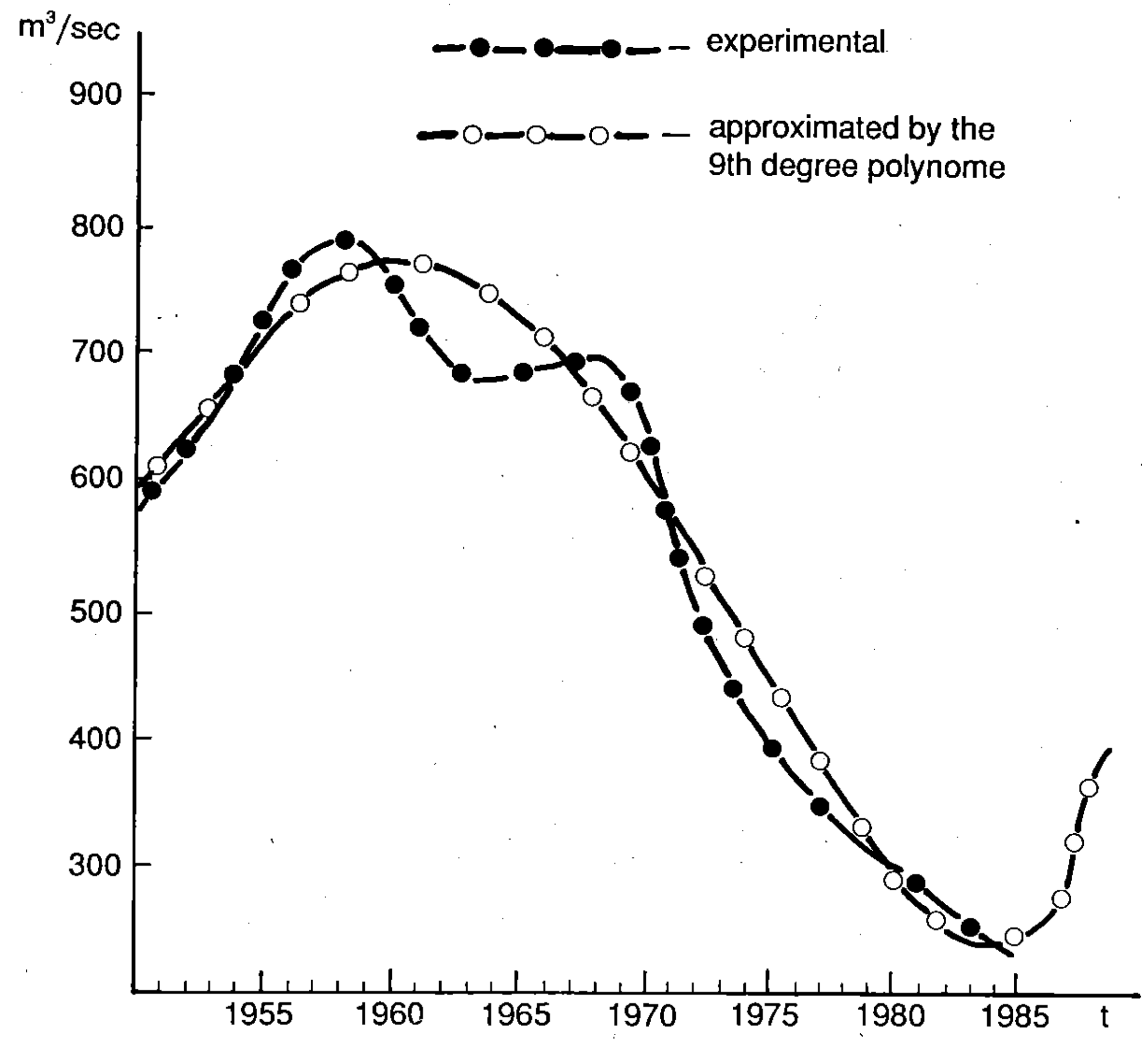


Fig. 6. Flow of Senegal, m^3/sec

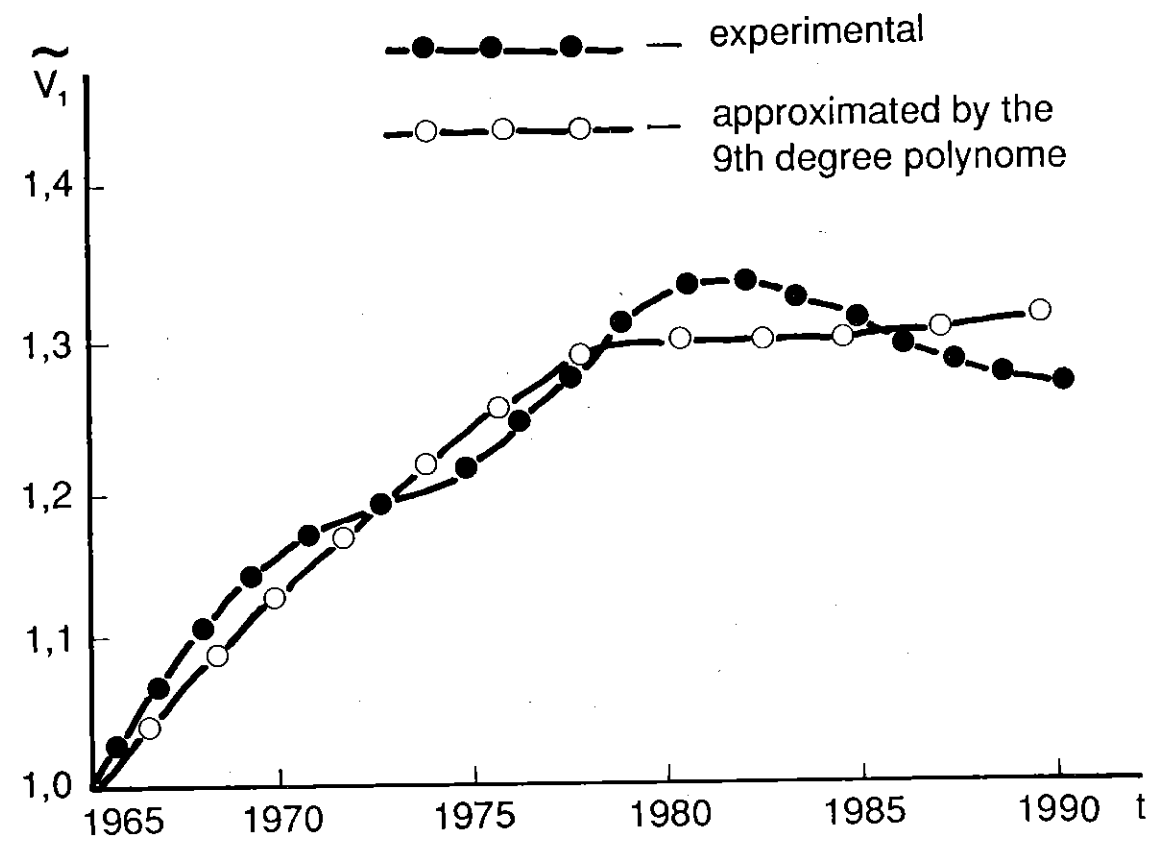


Fig. 7. Change of funds per capita (V_1)

The results of Programme 2 operation (appendix 5)

$$(H - 0.1; \quad E - 0.1; \quad N - 2; \quad A(1) - \alpha - 0.5; \quad A(2) - \beta - 1)$$

$$\alpha - 0.666 \sim \frac{2}{3}; \quad \beta - 3.56$$

Obtained α, ß were used (Programme 3, appendix 6) to calculate desertification forecast.

As calculations on the obtained model showed despite population growth, raters of desertification (TO) are variables and can be explained by the behaviour of climatic component. But its fluctuating character in this scenario doesn't cause any considerable deviation from the linear law of changing of X(t)o, which is in full conformity with experts evaluations. That's why an approximate forecast can be done with the help of the proper linear model.

Forecasts on desertification in Kayes and Yelimane regions were done on the basis of the linear increase hypothesis within the framework of uncontrollable variant of simulation model and with the use of data from space imagery.

So, what is the forecast for the future? Basing on the linear approximation one can expect further increase in desertified areas.

In 1980 85% of Yelimane region area suffered from severe and very severe desertification. By 1990 this per cent increased up to 98%
(Here X = 1,44, t - 30). By 2000 about 14% of Yelimane region area will turn into "absolute desert" deprived of vegetation cover.

In Kayes region severe and very severe desertification affected 73% of the area (in comparison with 60% in 1980). By 2000 the per cent of the territory with severe and very severe desertification will approximately be 89% (here X = 1,44, t - 55).

A very important observation is that desertification rates are equal for both cases.

4. DESERTIFICATION CONTROL MEASURES

When elaborating desertification control measures the following main problems should be solved (they can also be considered as desertification control stages):

1) The process of degradation of arid ecosystems should be arrested.

When resolving the first problem (that's at the first stage of work) it is practically impossible to achieve considerable improvement of socio-economic living conditions of people using local resources only. This stage should comprise no less than 5 years.

2) The productivity of natural ecosystems should be restored to the background level.

Restoration of natural ecosystems productivity can be achieved in two ways - passive and active. The passive method consists in protection (fencing) and promotion of restoration of productivity of arid ecosystems. The experience testifies that restoration of ecosystems can be achieved in 15-25 years, and sometimes in a longer period of time. The active method consists in phytoreclamation. In this case restoration of ecosystem's productivity can be achieved in 5-10 years. At the second stage it is possible to improve to a certain extent socio-economic living conditions of people.

3) The productivity of natural ecosystems should be increased with a view to population growth and necessity to improve socio-economic living conditions of people.

After natural productivity of ecosystems has been restored, one can consider that the main target of desertification control is hit. At this stage the system man-nature becomes stable. But because of the population growth, infrastructure development and development of the economy there arises the danger of the achieved balance distortion. Further socio-economic development can be ensured only with permanent increase in productivity of natural ecosystems. This task has no time limits. It should be considered as permanently needed tools for maintaining ecological and economic stability.

Desertification control measures should be taken at three levels:

1) At the national level, when it is necessary to implement national measures, that are important for the whole country. This work is planned by ministries and departments of the country. Creation of a green barrier, for example, can be attributed to such measures. The work is to be done at government's expense.

2) At the regional level, that is at the level of provinces. This work is done at the expense of province budget with the support of departments and organizations of the province.

3) At the local level, that is at the level of countries and communities. These measures are taken by local population using local resources. This work is mainly done at the expense of local budget or as "peoples construction". Public organizations should actively participate in such work.

To hit this target much attention should be paid to publicizing of ideas of environmental protection. For each community and for each family within a community a specific task on desertification control should be determined.

Eight types of lands that require implementation of similar desertification control measures have been singled out on the territory in question:

- territories with severe and very severe degradation of vegetation;
- shrub pastures;
- river, valleys and flooded lands;
- territories, prone to water erosion;
- agro-pastoral regions, where pastoralism prevails;
- agro-pastoral regions, where farming prevails;
- farming regions;
- useless lands.

The main factor in desertification control is the removal of reasons for nature degradation. As it was mentioned above, the distortion of the ecological balance in the region in question is mainly related with the irrational use of land, water and vegetation resources. Determination of ways, means and programmes of rational nature management and rational territorial arrangement of economy would, at the same time, contribute to restoration of the ecological balance and to the development of the economy of this region.

Projects aimed at desertification control in the region in question require specific research. That's why here we shall enumerate only priority measures, planned to prevent negative after-effects of pastoralism, dry farming, irrigation and sylvicultural reclamation.

Desertification control measures, recommended by us, are united into 8 groups and do not contradict the universal Plan of Action to Combat Desertification, elaborated by UNEP experts.

The first group of measures envisages increasing of the carrying capacity of pastures and is aimed at creation of a more stable and reliable nutritive base. In the regions of extensive pastoralism measures to improve natural pastures management are most reasonable. Ban on livestock grazing in fenced areas with further vegetation planting, ban on livestock grazing in some areas of tramped pastures, elaboration of rational grazing system and first of all introduction of pasture grass rotation are envisaged for the regions with severe degradation of pasture vegetation.

From time to time it is reasonable to stop economical utilization of large areas for a long period of time so that to promote regeneration not only of herbaceous but also of arborescent vegetation.

The problem of rational water supply to pastures is still very topical for the regions of traditional cattle breeding. When creating new water sources it is necessary to study fodder resources of pastures, to plan the location of water sources, to monitor grazing in the adjoining pastures.

Because of rather low fodder resources potential in Sahel the most rational way to use pastures would be creation of emergency fodder resources in dry and irrigated farming areas to feed livestock during unfavourable periods. Additional fodder production should be based on fodder crops growing a) with well water irrigation; b) on flooded lands;
c) on irrigated lands.

Dry farming prevails in the region in question: Main economic and scientific problems of dry farming are related with the know-how of collecting, storing and proper use of rain water and surface runoff, with combating shortages of water in soil, with development and impact of wind and water erosion, with maintaining and increasing of soil fertility.

To prevent negative phenomena, linked with the development of dry farming, one should follow the whole system of recommendations (Kovda 1977):

1) regular application of manure compost, artificial fertilizers, utilization of leguminous in crop rotation, that leads to increase of human content in soils and to improvement;

2) strip-contour arrangement of fields and alternation of high-stem crops, cereals, grasses, fallow lands, that reduces the velocity of winds and water streams;

3) reasonable limitations of areas under tilled crops;

4) introduction of drought resistant and rapidly growing plants;

5) creation of wind-break screens and belts of drought-resistant and salt-resistant trees and shrubs;

6) construction of reservoirs, ponds, water bodies;

7) rational combination of forests, farm lands and pastures;

8) system of non-moldboard cultivation.

To combat wind erosion it is recommended to ban livestock grazing in the regions prone to it, setting of forest shelter-belts and tree planting around settlements.

In the regions prone to water erosion planting of shelterbelts is envisaged; planting of trees around fields and farms, introduction of soil-protection crop rotations and terracing of slopes are recommended.

Special attention in combating soil erosion is paid to planting of some species of trees, that at the same time would improve soil fertility, be an additional source for fodder and fuel.

Irrigation is the most effective means of overcoming the deficiency of natural soil humidification and increasing of the productivity of lands. In Sahel region there are two systems of irrigated farming - irrigation and lagoon (flooded). Specific complex of agro-technical, reclamation and management measures is typical for each type of land-use systems in the regions, prone to wind and water erosion.

Forest reclamation is very important for combating desertification. Apart from a very essential ecological impact, forest plantations contribute to the economy, being a source of fuel, building materials, food etc. Thus artificial plantations of trees are necessary for meeting of certain economic requirements and for prevention of deforestation, which is one of the major factors of desertification.

Along with the reproduction of forests it is important to preserve tree-shrub vegetation. Full ban on felling trees should be introduced in some regions, as well as overall ban on felling valuable tree species. It is essential to elaborate the rational system of forest management and supply of population with the alternative sources of energy. All these measures will enable to reduce pressure on natural forests and contribute to desertification control.

Annex II

List of tables and figures

REGIONAL ASSESSMENT OF DESERTIFICATION: USSR/ASIA

N.G. Kharin
Turkmen SSR Academy of Sciences
The Labour Banner Order Desert Institute
USSR

February 1990

Desertification is a complex process caused and accelerated either by natural and by man-made factors. Desertification accounts for the reduction of the quantity and deterioration in the quality of renewable natural resources. This in turn leads to a reduction of the economic potential of arid semi-arid lands and the worsening of living conditions of people. Thus, desertification can also be regarded as a socio-economic process, the process of destruction of social, economic and sometimes political stability in the regions prone to desertification.

During two years (1987-1989) the Desert Institute, Turkmenistan Academy of Sciences, implemented the USSR/UNEP project **"Support to West African Countries in Strengthening National Desertification Control Activities Through Research and Training"**. Experts from the USSR and Mali participated in the project activity.

The test area occupies 27890 km^2 with population of 367.3 thousand. The climate of the area is arid. According to precipitation rate there are the following climatic sub-zones: Sahelo-Sudanian (400-600 mm), Sudanian (600-800 mm) and Sudano-Guinean (800 mm and above). The year is divided into two climatic seasons: wet (May-September) and dry (November-April).

During the field study we tested the FAO criteria for desertification mapping and developed other criteria taking into account the local physical conditions.

Degradation of the vegetative cover is the most widely spread degradation of the arid ecosystems. It is caused by overgrazing, cutting trees and shrubs for fuel and construction, and also ploughing of the fallow lands.

The FAO criteria on the vegetative cover degradation cannot be exactly applied due to the following reasons:

1. The crown density of the tree and shrub vegetation is very insignificant (7-10%), so the scale needs to be corrected;

2. In savanna the number of palatable plant species is not a desertification criterion. Shrubs and trees survive under overgrazing, only their abundance decreases;

3. During many centuries of the human impact, the estimation of potential productivity is of theoretical value only: we proposed a new criterion of desertification, namely change in crown density of tree and shrub layer.

Specific criteria for degradation of vegetation cover are shown in Table 1. The ecosystem stability is considered as a criterion of the inherent risk of desertification (IRD). It includes such parameters as soil mechanical composition, slopiness, stoniness, "gravelness", flooding, etc. In view of the existing classification of soil-vegetation complexes represented in the Atlas of Mali (Les Resources...., 1983) they were further classified by the ecosystem stability.

Field tests showed that these criteria did not completely reflect the state of eroded area on the tested territory. Wind erosion is wide-spread in the northern and north-eastern parts of the Yelimane district. The present state of deflation depends on overgrazing, cutting of woody-shrub vegetation, and collection of grass for fuel and domestic purposes, and also on the spreading rainfed agriculture in the semi self-sufficient and self-sufficient rainfed areas. Farmers here obtain some harvest in the anomalous humid years, while in medium and below medium humid years the harvest is poor or zero. In such years the ploughed lands are subject to strong wind erosion.

Therefore the soil and vegetation cover and climate conditions favour desertification process, particularly deflation and wind erosion, while economic activities also contribute to them.

Table 2 shows new criteria to evaluate the present wind erosion, inherent risk of desertification, and rates of desertification.

The inherent risk of desertification (IRD) is characterized by a group of soils according to their mechanical composition with due account for the vegetation cover, i.e. by the soil-vegetation complexes. Soils with heavy mechanical composition, clays and heavy clays have low risk of desertification, medium-textured and clay loam soils have moderate IRD, loamy sand soils have high IRD, and sandy soils - very high IRD.

Water erosion is one of the most wide-spread types of desertification. It was tested using the FAO/UNEP methods, and also guidelines worked out by the Institute of Deserts, Turkmen SSR Academy of Sciences. Therefore we proposed using the following additional criteria to evaluate the inherent risk of desertification density of erosion network, slope steepness, mechanical composition of soil, soil profile thickness, and cover of vegetation (Table 3).

The soil profile thickness is listed among the FAO/UNEP criteria. Hence we propose using specific parameters to assess a profile thickness to suit the local conditions. Classification of soil-vegetation complexes by the IRD was carried out on the basis of mechanical composition of soil, profile thickness, and projective vegetation cover.

Therefore, the PA1 and PA2 soil-vegetation complexes on the flat weak clay plains have a low risk of desertification. Moderate risk of desertification is observed on PL5, PL11, PL12, TC4, TC5, and TC6 soil-vegetation complexes, and also on laterite with stony soils found on the stony terrain with steep slopes or loamy mechanical composition (including very grittly) with heavy and very heavy drainage (TR3, TR9).

Soil compaction is a unique feature of desertification. Compaction and soil crusting occur on virgin and fallow lands flooded in rainy season, and also on lands cultivated for various crops. Soil structure of the arable lands is affected by crusting, flooding, compaction of sub-ploughed layers, and formation of the so-called **"plough pan"**.

While assessing the desertification processes in Mali, soil compaction and crusting were considered as major soil criteria. They are typical of all soil types and arable lands (virgin, fallow, flooded and irrigated).

The most reliable criteria for the Kayes and Yelimane districts are ferrum accumulation and compactness. Other criteria are either unrecorded at the studied area or found on limited plots (e.g. carbonate concretions or gypsum accumulation). Therefore, to assess this type of desertification we proposed new indicators describing the inherent risk of desertification (Table 4).

However they do not adequately describe all desertification classes. The mechanical composition of soil alone is typical of all desertification classes. Other criteria (e.g. flooding by rain and flood water, land use pattern) have relative values.

Table 1 Specified criteria to assess degradation of vegetation cover in Western Mali

Aspects	Criteria	Desertification classes: Slight	Moderate	Severe	Very Severe
Present state	1. State of the vegetation cover				
	a) wood-shrub	Thicket with protective cover above 5%, minor damage by man.	Vegetation cover damaged by man. Protective cover 2-5%.	Vegetation cover heavily damaged by man. Thorn and weed trees are predominant. Protective cover of 1-2%.	Trees and shrubs are almost totally absent.
	b) Grass layer	The grass cover is grazed by cattle to a large extent		Grass cover is totally grazed by cattle. Sporadic water and wind erosion.	
	2. Fire-damaged vegetation cover				
	a) Wood-shrub layer	Less than 25% trees and shrubs damaged by fire	25-50% trees and shrubs damaged by fire	Over 50% trees and shrubs damaged by fire	Trees and shrubs totally damaged by fire
	b) Grass layer	Grass cover sunburnt at less than 50% of the area		Grass cover sunburnt at over 50% of the area.	
Desertification rates	1. Decreased protective cover of wood-shrub layer	< 25%	25 - 50%	50 - 75%	> 75%
Inherent risk of desertification	1. Ecosystems stability	Stable ecosystems of clay plains (PA1, PA2, PA3) and plains with heavy loamy sand (PL4, PL5, PL8, PL11, PL12)	Relatively stable ecosystems with laterite crust (TC1, TC3, TC4 TC5, TC6)	Unstable mountaineous ecosystems (TR2, TR3, TR4, TR7, TR9), ecosystems of depressions with seasonal excessive humidity (TH8), ecosystems of alluvial plains and depressions, temporarily filled with water	Very unstable ecosystems of grass-covered and damaged sands (D5, DA4, DA5)

Table 2 Specified criteria to assess wind erosion in Western Mali

Aspects		CRITERIA	Desertification classes: Slight	Moderate	Severe	Very Severe
Present State wind erosion	1.	Percentage of area with	<5	5-15	15-30	>30
	2.	Thickness of eroded surface layer, cm	<5	5-10	10-20	>20
	3.	Alluvial soil thickness, cm	<5	5-10	10-20	>20
	4.	Volume of discharged soil, t/ha per year	<0.5	0.5-1.0	1.0-3.0	>3.0
Desertification rate	1.	Percentage of increased eroded lands	<10	10-25	25-50	>50
Inherent risk of desertification	1.	Mechanical composition of soils and ground	Silt, heavy loam	Medium and light loam	Sandy loam	Sand
		Distribution of soil and vegetation complexes according to inherent risk of desertification	PA2, PA3, PL8, T15 TR9, X5	PA1, P11, P12, TC1, TC4, TC5, TC6, TH8, TR3, TR4, TR5	PL4, PL5, TC3, TR2, TR6, TR7	DA4,DA5, D4

Table 3 Specified criteria to assess water erosion in Western Mali

Aspects		CRITERIA	DESERTIFICATION CLASSES: Slight	Moderate	Severe	Very Severe
Present state	1.	Surface state	Gravel and stones occupy less than 10%	Stones and boulders occupy 10-20%	Boulders and rocks occupy 25-50%	Boulders and discharge occupy over 50%
	2.	Erosion type	Sheet washing and flow erosion from slight to moderate	Sheet washing and flow erosion from moderate to severe	Sheet washing, flow and gully erosion, severe.	Sheet washing and deep gully erosion, very severe
	3.	Topsoil runoff, % of the area	< 10	10-25	25-50	> 50
	4.	Percentage of area under gullies.	< 10	10-25	25-50	> 50
	5.	Erosion network density, per 10 sq. km	< 2	2-5	5-10	> 10
Desertification rate	1.	Increased area of eroded land (%)	< 10	10-25	25-50	> 50
	2.	Increased area under gullies.	< 10	10-25	25-50	> 50
Inherent risk of desertification	1.	Slope steepness (%)	Flat and almost flat, 2	Low steep slopes, 2-6	Medium steep slopes, 6-13	Steep slopes, 13.
	2.	Mechanical composition of soil.	Sandy	Sandy loam	Loamy soil	Clay soils
	3.	Soil profile thickness (cm)	> 100	100-50	50-25	< 25
	4.	Protective cover of vegetation (%)		5-2		< 2
	5.	Soil and vegetation complex distribution in classes	PA1,PA2	DA4,DA5, PA3, PL4,PL5,PL11,PL12, TC4,TC5,TC6	D5, PL8, TC1,TC3, TH8, T15, TR4,TR5,TR6,TR7	TR3, TR9

Table 4 Specified criteria to assess soil crusting in Western Mali

Aspects	CRITERIA	DESERTIFICATION CLASSES: Slight	Moderate	Severe	Very Severe
Present State	1. Ferrum accumulation and tumors at a depth, cm	Tumors and concretions, 30-50cm	Crusting and tumors and concretions, <30	Ferrous ore (10-30cm) and crusting	Ferrous ore <10
Inherent risk of desertification	1. Flooding by rain and flood water	Not flooded or flooded for a short period of time (in rainy season)		Long-term flooding by rain and flood water (over six months)	
	2. Landuse pattern	Lands and fallow lands unused in agriculture		Rainfed and irrigated lands	
	3. Mechanical composition of soils	Sandy and loamy (with gravel) sand	Sandy loam (silty and gristly)	Clay loam (silty and gravel)	Clayey (silty and gristly)
	Distribution of soil and vegetation complexes according to inherent risk of desertification	D5, DA4, DA5	TR2, TR3, TR4, TR6, TR7, TR9, TH8	TC1, TC3, TC4, TC5, TC6	PA3, PA1, PA2, PL4, PL5, PL8, PL11, PL12, PL15, T15

Soil compaction and crusting are slow going processes. It requires special studies to determine their dynamics within a short interval (from 1980 to 1989). These studies lie beyond the present paper. Yet we can state that the processes are ongoing. The soil and climatic conditions favour these processes. Therefore we assumed that desertification rate was slow which was reflected in the map of desertification.

To determine the total risk of desertification (TRD) it is necessary to find the following: present state (PS), desertification rate (DR), inherent risk of desertification (IRD), animal impact on environment (AIE), and the degree of anthropogenic impact (DAI). Using the FAO methods the total risk of desertification is determined as follows:

$$TRD = PA + DR + IRD + AIE + DAI$$

The animal impact on environment (AIE) in the tested area was found empirically due to the absence of reliable data on the rangeland productivity. The FAO recommended formula was used:

$$CE = 1.03p. + 42.2$$

where: p is precipitation, mm/y;
CE is estimated consumption, kg/ha.

The livestock in Mali was estimated in UBT. According to the Atlas of Mali the fodder rate per UBT is 6.25 kg/day and the total amount is 2281.25 kg.

In the Yelimane district and northern Kayes district with a mean annual precipitation of 550 mm/year this amount is as follows:

$$CE = 1.03 \times 550 + 42.1 = 608.7 \text{ kg/ha.}$$

According to our expert assessment carried out in the field the bioproductivity (and hence the CE) decreases by 75% during desertification. Therefore the CE in the dryest season in the northern Kayes district and in the Yelimane district amounts to 25% (152.17 kg/ha) of the estimated value.

Having divided it by 2281.25 we will obtain a potential load per 1 ha equal to 0.067 UBT. In real life the total amount of 85333 UBT are grazing at 570000 ha in the Jelimane district which equals to 0.150 UBT per 1 ha. Hence the real load is 2.24 times the estimated value. It is slightly less in the southern Kayes district. The average overgrazing in the tested area is not less than -200% and higher at some plots.

Using the FAO methods the animal impact on environment (AIE) is estimated as follows:

The actual livestock in per cent to the estimated figure (potentially possible)	AIE
>200	very severe
100-200	severe
66-100	moderate
20-60	slight

Therefore the animal impact on environment (AIE) is very severe at the test area.

Table 5 Summed-up data on desertification areas, in sq. km and per cent

Desertification Types	Desertification classes				Total	%
	Slight	Medium	Severe	Very severe		
JELIMANE DISTRICT						
Vegetation degradation		89	1626	1204	2919	76
Wind erosion	-	-	149		149	4
Water erosion	-	-	-	-	-	-
Soil compaction	-	-	764	13	777	20
Unsuitable land	-		-	-	1945	-
TOTAL	-	**89**	**2539**	**1217**	**3790**	**100**
KAYES DISTRICT						
Vegetation degradation	499	3322	8619	1718	141158	64
Wind erosion			20	780	800	4
Water erosion		1627	810	51	2488	11
Soil compaction		520	3614	520	4654	21
TOTAL	**499**	**5469**	**13063**	**3069**	**22100**	**100**
TOTAL TESTED AREA						
Vegetation degradation	499	3411	10245	2922	17077	67
Wind erosion	-	-	169	780	949	3
Water erosion	-	1627	810	51	2488	10
Soil compaction	-	510	4378	533	5431	20
Unsuitable land					1945	
TOTAL	**499**	**5558**	**15602**	**4286**	**27890**	**100**

The FAO UNEP methodology recommends that the degree of anthropogenic impact (DAI) should be determined per the amount of food produced at the specific area. Other sources of food should also be taken into consideration. Having found the per capita food ratio expressed in calories per day it is possible to calculate the amount of population that could be fed at the specific area. Due to the absence of reliable data on the size and potential productivity of the arable land it was impossible to make these calculations in the test area.

The Institute of Deserts, Turkmen SSR Academy of Sciences proposed a method to assess the degree of anthropogenic impact (DAI) by the population density which was used at the tested area. The population density scale at the test area is as follows:

Degree of anthropogenic	Population density, persons per 1 sq.km
slight	<5
moderate	5-10
severe	10-15
very severe	>15

To compile the desertification map use was made of the following space imageries:

1) LANDSAT (1980);

2) Soviet space imageries made on 8 May, 1989 using the MSU-SK scanning system on board the "KOSMOS -1939" satellite (Selivanov, Touchin, 1988).

The LANDSAT imageries were used during the 1988 field tests to compile a preliminary desertification map of the tested area. The map and desertification criteria were specified during the 1989 field studies.

The final map of the present state of desertification was compiled upon the digital processing of the Soviet space photographs. The MSU-SK scanner had the following parameters:

- resolution, m	243 (per shot)
	175 (per line)
	590 (per heat channel)
- spectral channels, mkm	1. 0.5-0.6
	2. 0.6-0.7
	3. 0.7-0.8
	4. 0.8-1.1
	5. 10.4-12.6

The initial data comprised the magnetic tape recorded multi-zonal heat image along channels 1-4. The image size was 1490 by 1398 units, the total volume was 1490 by 1398 by 4 bytes.

The radiometric correction was performed at the first stage of processing. Then the spectral classification of multizonal images was carried out. The aim of processing was to code each unit by a separate class number according to its brightness within the given band of the electromagnetic spectrum.

The following three desertification maps were compiled:

- map of the present state of desertification;
- map of desertification rates and inherent risk of desertification;
- map of the total risk of desertification.

The map of the present state of desertification shows different classes (weak, moderate, heavy and very heavy) marked by different colours. The desertification types are indicated by the non-scale symbols. The map comprises 70 sub-sections. The average sector class size is 370.6 sq.km, the minimum size is 14 sq.km, maximum - 1753 sq.km. The analysis of digital data shows a great diversity due to an intricate structure of the natural and territorial complexes, and also due to the anthropogenic impacts.

The total data on desertification area is shown in Table 5. It is clear that desertification processes are not prominent in the northern part of the tested area. Precipitation here is low and the anthropogenic impact is very high since practically 10% of the Yelimane district is subject to heavy and very heavy desertification.

Desertification processes are more ardent at a higher rate in the northern part of the tested area. The inherent risk of desertification is a factor of ecosystems stability. Most stable are the ecosystems in the central part of the tested area. Ecosystems of sandy soils are unstable and subject to desertification.

The map of total risk of desertification shows the trends for its development. It should be noted that degradation of arid ecosystems in the Kayes district is heterogenous. Severe desertification processes are observed in the northern part of the district. Slight desertification areas are found in the southern part of the district.

Analysis of the 1980 and 1989 space photographs (imageries) and also field observations enable us to arrive at a conclusion that degradation of arid systems is a successive process. Very heavy degradation of the vegetation cover is accompanied by intensified water and wind erosion which finally results in total degradation of the arid ecosystem. At this stage the bioproductivity is close to zero, vegetation cover is completely destroyed and water and wind erosion are intensified.

CONCLUSIONS

1. Field tests of the FAO/UNEP provisional methodology were carried out in two countries of Mali (Yelimane and Kayes). It was found that the methodology proposed by FAO and improved by the Desert Institute (USSR) could be applied to study desertification in other geographical regions of the world. The methodology includes: classification of desertification processes, identification of the classes and aspects of desertification, and integrated cartographic representation by a series of thematic maps.

2. It was found that criteria of desertification should be zonal, regional or local. In this context new specified criteria were proposed to reflect the physical and economic features of the region.

3. We propose that a new criterion of inherent risk of desertification should be used namely, stability of ecosystems.

4. Desertification mapping should be carried out on the basis of automated space systems (LANDSAT, RESOURCE, etc.).

5. The elaborated criteria for assessment and mapping desertification could be used to study desertification in the whole of the Sahelian zone. The criteria could be extrapolated within similar landscapes in a longitudinal direction and on a limited scale latitudinally (i.e. northward and southward of the tested area.

REFERENCES

1. I.D. Mandel. Cluster analysis. Moscow, 1988 (in Russian).

2. A.S. Selivanov, Yu.M.Touchin. "REFERENCE-1" operational system of Earth watch. Remote sensing of Earth, 1988, No. 3 (in Russian).

3. N.G. Kharin et al. Methodological basis for studying and mapping desertification processes (at the example of Turkmenistan arid lands). Ashkhabad, 1988, pp.97 (in Russian).

4. Les resources terrestres au Mali (Atlas). Vol.I, II, III, New York, 1983.

5. Kharin, N.G., Orlovsky, N.S., Babayeva, T.A., Kiril'tseva, A.A. Redzhepbaev, K. 1988 Explanatory note to the map of man-made desertification of the USSR arid lands, scale 1:2500000.

6. Provisional Methodology for desertification assessment and mapping, FAO/UNEP, Rome, 1981, 65 p.

7. Provisional methodology for assessment and mapping of desertification, FAO/UNEP, Rome, 103 p.

8. Provisional methdology for assessment and mapping of desertification, FAO/UNEP, Rome, 1984, 83 p.

EXPLANATORY NOTE TO THE MAP OF MAN-MADE DESERTIFICATION OF THE USSR ARID LANDS, SCALE 1:2500 000[1]

N.G. Kharin, N.S. Orlovsky, T.A. Babaeva,
A.A. Kiriltseva, and K. Redzhepbaev

Turkmen SSR Academy of Sciences
the Labour Banner Order Desert Institute
Ashkhabad, USSR

Ashkhabad, 1988

The explanatory note is a supplement to the desertification map. It contains the criteria of desertification defining the status of desert environment, desertification rate, inherent risk, animal pressure and population pressure. Information is also given on the size of areas prone to desertification. This information is necessary to develop measures on desertification control.

CONTENTS

<u>List of tables</u>

---

[1] The document was presented as background material for the discussion of the meeting.

PREFACE

The arid lands of the USSR possess an important economic potential. They are mostly used as grazing lands although the irrigated lands produce valuable agricultural products and mineral resources are also intensively exploited. The increased use of the solar energy is planned in perspective.

Unfortunately, intensive human activity and utilization of natural resources often bring about the disturbance of the ecological equilibrium which triggers desertification processes. Appearance of desertified patches is as a rule connected with the traditional practices of arid lands utilization throughout the centuries of human occupation. E.g., we have desertification spots around desert wells inherited from the past.

The appearance of new desertification spots in our country is not always the result of planners' mistakes. It can also be caused by various objective factors, e.g. large scale projects of desert lands development usually exert inevitable technogenic pressure on desert environment. While these works new tracts of technogenic sands are formed, the vegetation cover is destroyed and other change in desert environment occur. If a project includes measures on desertification control new desertification spots can be eliminated in 5-10 years.

To combat desertification we need an initial information on the status of the desert environment. Man-made desertification map of the USSR arid lands contains this information. The map has been compiled by the Desert Institute taking into account the methodology of FAO and UNEP. The map reflects further development of the concept of desertification assessment and mapping proposed by the "Methodological principles of desertification processes assessment and mapping", 1983. The worked out criteria of desertification are more universal, they are zonal criteria suitable for assessment of land degradation in the whole arid zone of the USSR. The map compiled is also of a methodological interest especially taking into consideration the widening international cooperation in desertification study at the regional and global levels.

The following institutions have participated in preparation of the map: Desert Institute, Turkmen Academy of Sciences, Institute of Botany, Kazakh Academy of Sciences, Institute of Soil Science, Kazakh Academy of Sciences, Department of Geography, Uzbek Academy of Sciences, V.I. Lenin Tashkent State University, Uzbek Branch of "Priroda" Centre, V.A. Bugaev Middle Asia Research Institute, A.M. Gor'ky Turkmen State University, Institute of Soil Science, Gooagroprom of the Turkmen SSr.

The authors of the map are : Turkmen SSR - N.G. Kharin, T.A. Babeava, V.N. Nikolaev, L.G. Dobrin, A.A. Kiril'tseva, K. Redzhephaev, Kasakh SSR - L. Ya. Kurochkina, G.B. Makulbekova, I.S. Kumachev, K.Sh. Faizov, T.F. Nekrasova, A.V. Chigarkin, Uzbek SSR - N.A. Kogai, A.A. Rafikov, S.Yu. Smol'nikov, V.A. Popov, U. Allanaszarova, L.E. Markova, L.Kh. Gulyamova.

PYSICAL FEATURES OF DESERT LANDS INCREASING SUSCEPTIBILITY TO DESERTIFICATION

Climatic characteristics, hydrology, surface water regime, geological features, soil and vegetation cover belong to the natural preconditions to desertification.

The USSR deserts form a wide belt between 36°-48° North and 48°-82° East. They include vast areas stretching covering a distance of 1500 km from North to South and more than 2800 km from West to East. In this vast area different types of desert are found namely sandy, gravely-gypseous, loamy and solonchak. On each type of desert desertification processes have their own peculiarities depending on natural features.

One of the most characteristic features of the natural environment in the Middle Asia and Kazakhstan is the extreme aridity re-inforced by periodical droughts. Within the global climatic scheme the northern part of the USSR deserts is under the influence of moderate zone air masses, their southern parts belongs to the subtropical air masses. The boundary between the northern (Kazakh) and southren (Turan) provinces runs along the plains of the Turan lowland, from the Kenderli bay in Mangyshlak, between the Karabau upland and the Assake-Audan depression in the Usturt, it crosses the Amudary'ya lowland near Nukus, then runs along the Kyzylkum desert and reaches the north-western extreme of the Karatau ridge.

The Turan province is the hottest part of the desert region. The duration of the hot seeason ranges from 200-215 to 230-260 days. The Kazakh province is less dry and belongs to the hot part of the desert region. The hot season lasts 164-200 days. There is a difference in atmospheric moisture distribution in the Turan and the Kazakh provinces. The ratio between winter - spring - summer - autumn precipitation in per cent in the Turan provinces (110-135 mm annual rate) is as follows : in Tamdy - 33:48:5:14, in Bairam-Ali - 40:48:I:II. In the Kazakh province under annual precipitation rate of 117-144 mm 22:27:21:30, the same ratio is on the Balkhash - 244:27:24:25. The difference in hydrothermic features affects the soil processes and vegetation cover. These features determine the vulnerability of landscape to human pressure.

In addition to the acarcity of precipitation and its irregular distribution within the year precipitation rate changes markedly from year to year. As a result of these phenomena and under the influence of periodically occuring drought the conditions are created which lead to the degradation of soil and vegetation and finally to desertification.

Drought is a common phenomenon to the deserts of Middle Asia and Kazakhstan. In northern and eastern parts of the Kazakh province drought occurs often, the probability of its ocurrence ranges from 30% to 50%. Drought in the Turan province occurs more often. The territory of the Karakum and Southern Kyzylkum belongs to the zone of regular drought with the probability of 75 - 95% (Kovda, 1977).

The extreme dryness of desert climate, instability of soil cover and scarce vegetation are some of the factors favouring deflation processes which occur even with low increases in the wind velocity. The main physical features preditermining the potential risk of deflation are as follows: climate, especially the regularity of deflation winds and atmospheric precipitation (their annual rate, distribution in cold and warm seasons, and in warm season - their ten-days and monthly distribution); soil ccover (mechanical composition of the upper 10 cm layer, the amount of particles larger than 1 mm in the upper layer, compactness of the soil, moisture content and water permeability); natural vegetation (plant composition, density in per cent, the degree of pasture degradation), topography.

Dust storms are common during the whole year depending on local features. Maximum annual number of days with dust storm is observed in the Central Karkum and in the western parts of Turkmenistan. Here the mean number of days with dust storms is as high as 50 days per annum. In the most part of the Karkum, in the low and upper floor of the Syrdar'ya the number of days with dust storm reaches 30 - 50 days per annum, in the northern part of Turkmenistan, in the Kyzylku, and the Fergana valley - 10 - 30 days, in the eastern part of the Usturt - 5-10 days.

The amount of dust in the air is an important factor predetermining the climatic influence on desertification.

Dust is an integral part of the atmosphere above desert lands, its amount increases during the period of dust storms, so the radiation and microphysical features of air masses change. Dust in the atmosphere actively absorbs the solar radiation, thus decreasing the amount reaching the earth surface and causing the warming up of the lower layers of the atmosphere (Kondrat'ev, 1983). It furthers the creation of the inversion in the atmosphere and binders the convection which may result in cloud formation. Increase in the amount of dust in the atmosphere results in the decrease in precipitation and creates general climatic discomfort.

High surface albedo is a characteristic physical feature of arid lands. Under prolonged drought leading to desertification, albedo is raised, soil moisture decreases or soil may even desiccate. All that causes changes in the radiation and heat balance. The quantity of heat necessary for evaporation decreases and turbulent heat exchange increases highly. At that the rate of annual turbulent heat exchange is close to the rate of radiation balance.

Hydrological and hydrogeological features of the region also affect the desertification processes. Hydrological features determine a meliorative properties of land. Hydrogeological features determine the trends in development of soil ameliorative properties of irrigated lands and pasture ameliorative status of ecosystems. This status depends on the depth of the ground water table, its mineralization rate, chemical composition and velocity of water flow. The greater part of the underground water in the desert is mineralized which affects the degree of soil salinity.

The difference in hydrothermic features of the Kazakh and Turan provinces shows itself in the general aspects of their soil and vegetation cover. Soil factors in their turn determine the possibility of land utilization for irrigation, natural fertility and vulnerability of soil to wind and water erosion. The occurence of deflation processes depends upon mechanical composition of soil and wind activity. Secondary salinazition of soil and soil ameliorative properties of land depend upon the content of water and salts.

The difference in mechanical composition and agro-hydrological properties of different soil types affect the changes in water content. That, in its turn, combined with climatic conditions affects composition, rhythm and productivity of vegetation cover. Vegetation cover diminishes erosion or prevents it completely. Vegetation plays an important role in improvement of soil structure, in soil permeability and in general improves the erosion resistance of soil cover. Soil protective role of herbacious vegetation depends upon its floristic composition, degree of density and thickness of turf and root system. Plant density is 12-15%, reaching sometimes 20-25% and dropping up to 1-5% on the tops of sand ridges. In gypseous desert it is 10-20% (Ovezliev, 1981).

In the Kazakh province are common desert gray brown soils with the features of solonets and solonchaks. The wild hydrothermic regime prevents the accumulation of carbonates, so the content of carbonates is very low.

The precipitation is low but it is evenly distributed within the year. That allows the development of perennial dwarf semishrubs, such as Artemisia and Salsola species. The vegetation cover is rather sparse.

Gray brown and serozem soils with high content of carbonates are common in the Turan province. High content of carbonates is connected with dry and hot summer. Under such hydrothhermic regile carbonates are accumulated in soil horyzons and underlying parent rock. Here spring maximum of rainfall allows the development of more abundant vegatation as compared with the Kazakh province which does not have such rainy season. Warm and humid springs provide the development of specific vegetation - ephemers and ephemeroids. After the beginning of hot and dry summer ephemeral vegetation wither.

Thus seasonal characteristics of soil-forming process and vegetation development in the Turan and Kazakh provinces also assist in creating natural preconditions to desertification.

DESERTIFICATION CRITERIA AND THE MAP LEGEND

Man-made desertification is a process of degradation of arid ecosystems leading to the reduction of biological productivity, development of erosion, soil salinization and other undesirable processes. All that is caused by the human acitivity. The map shows the status of desert environment and man interference as observed in 1985. We have estimated the changes in desert environment which occured during last 20 years. The direct meaning of these changes is given by such criteria as desertification rate.

The map legend includes conventional symbols, numerical indices and colour illumination. In a printed black-and-white version of the map colour illumination is absent. But the map can be illuminated in each mapping unit using the legend.

On the map desertification process is characterized by a number of quantitative criteria elaborated specially for the USSR arid zone. First of all the map shows types of desertification processes. They are: (1) degradation of vegetationcover caused by overuse, (2) desertification around desert wells (as a subtype of vegetation degradation resulting due to concentration of livestock around watering points), (3) degradation of vegetation cover caused by undergrazing (this desertification is identified in the areas with the dense cover of desert moss), (4) deflation (wind erosion), (5) water erosion, (6) salization of irrigated farmlands, (7) soil salinization caused by the sea level lowering and withdrawal of the river flow, (8) technogenic desertification (caused by the movement of heavy transport vehicles in the desert). We have elaborated the criteria of desertification given in Tables 1, 2, 3, 4, 5.

Desertification criteria are given on the map by conventional symbols. Letters stand for desertification aspects: status (DS), rate (DR), inherent risk (IR), domestic animal pressure (AP), population pressure (PP), estimated by population density. Letters for this designation are given in Table 6.

In the map desertification hazards (DH) can be shown by colour illumination. This aspect is calculated by the equation :

$$DH - DS + DR + IR + AP + PP$$

DH is calculated from the indices given in Table 7. Let's consider an example of calculation for the mapping unit in which the formula is given:

$$2\,c\,m\,IV\,P$$

The content of this formula can be explained in the following way:

Symbol	Aspect	Index
2	DS (moderate)	6
c	DR (severe)	12
m	IR (moderate)	6
IV	AP (very severe)	26
P	PP (severe)	8
	Total	52

Table 1 Criteria for assessing degradation of vegetation cover

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
Status	1. Characteristics of vegetation cover	Climax communities, slightly changed	Long existing secondary communities	Ephemeral secondary communities	Destruction of vegetation cover
	2. Present productivity, per cent of potential productivity	< 90	90 - 60	60 - 30	< 30
Rate	1. Decline in biomass production, per cent per year	< 10	10 - 25	25 - 50	< 50
	2. Pasture conditions degradation, per cent per year	< 2.5	2.5 - 5.0	5.0 - 7.5	> 7.5
	3. Cutting of forests (percentage of non-restored forest area per year)	< 2.5	2.5 - 5.0	5.0 - 7.5	> 7.5
	4. Decrease in forage production, per cent per year	< 1	1 - 4	4 - 7	> 7
Inherent risk	1. Stability of ecosystems	Stable ecosystems of clay, loam and gravel deserts	Comparatively stable ecosystems of loess desert, ecosystems developed on sandy loam soils and mountain slopes	Non-stable ecosystems of river, vallies, ecosystems of gentle mountain slopes and clay piedmont plains	Non-stable ecosystems of sandy deserts, ecosystems of steep mountain slopes and badlands
	2. Potential for reclamation, per year according to project	< 3	3 - 5	5 - 10	> 10

Table 2 Criteria for assessing wind erosion

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
Status	1. Wind erosion features	25 per cent are covered with precipiced blowouts	25-50 per cent are covered with blowouts, sand ripples on bare surface	Slip slopes formation on shifting sand	Movement of sand on the total area
	2. Sod cover, per cent	50 - 30	30 - 10	10	none
	3. Ratio of shrub density (per cent) and sod cover (per cent)	20 - 30 / 40 - 80	20 - 5 / 40 - 10	5 - 1 / 10 - 5	1 / 5
	4. Depth of blowing out of root layer (for non sandy sandy soil in per cent)	< 10	10 - 25	25 - 50	> 50
Rate	1. Increase in eroded area, per cent per year	< 1	1 - 2	2 - 5	> 5
	2. Amount of sand transported over 1 running metre per year, m^3	< 0.5	0.5 - 1.0	1.0 - 5.0	> 5.0
	3. Decrease in biomas production per cent per year	< 1.5	1.5 - 3.5	3.5 - 7.5	> 7.5
Inherent risk	1. Wind erodibility groups	Silt, clay, clay loam	Loam, sandy loam	Loamy sand	Sand
	2. Human impact on sandy surface	Streamline disturbance relief features	Shrub cutting, overgrazing	Destruction of sod cover	Earth works without sand stabilization

Table 3 Criteria for assessing water erosion

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
1	2	3	4	5	6
Status	1. Surface features	Gravel and stone cover 10 per cent or less	Gravel and stone cover 10-25 per cent	Boulders and rocks cover 25-50 per cent	Boulders and rocks exposures cover 50 per cent or more
	2. Type of water erosion	Slight surface run off and rill erosion (from slight to moderate)	Moderate surface run off and rill erosion (from moderate to heavy)	Heavy surface run off and gully erosion	Very heavy surface run off and gully erosion
	3. Number of ravins, gullies and ruts per 1 running km	5	5 - 10	> 10	
	4. Subsoil, exposed, per cent	< 10	10 - 25	25 - 50	> 50
	5. Soil thickness, cm	> 90	90 - 50	50 - 10	< 10
	6. Loss of soil depth over root layer, per cent				
	a) Original soil depth 1 m	< 25	25 - 50	50 - 75	> 75
	b) Original soil depth 1 m	< 30	30 - 60	60 - 90	> 90

Table 3 Criteria for assessing water erosion (continued)

1	2	3	4	5	6
Rate	1. Increase in eroded area, per cent per year	< 1	1 - 2	2 - 5	> 5
	2. Soils loss, MT ha/year	< 0.5	0.5 - 1.0	2 - 5	> 5
	3. Sediment deposition in reservoirs, m^3/km/year				
	a) watershed 500 km	< 60	60 - 200	200 - 500	> 500
	b) watershed 500 km	< 40	40 - 100	100 - 250	> 250
	4. Annual loss of storage, per cent	< 0.2	0.2 - 0.4	0.4 - 1.0	> 1.0
Inherent risk	1. Topography	Slightly undulated	Hilly	Mountains with gentle and steep slopes	Mountains with steep slopes and talus
	2. Slopes	< 5	5 - 15	15 - 30	> 30
	3. Density of shrub and tree vegetation (or semi-shrubs) per cent	> 30	30 - 15	15 - 5	< 5
	4. Percentage of area covered with sod (in the areas with dominant herbacious vegetation	> 50	50 - 30	30 - 10	< 10
	5. Co-efficient of hydrographic net density (ratio of the total length river-beds, km, to watershed size, km^2)	–	< 0.5		> 0.5

Table 4 Criteria for assessing soil salinization

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
1	2	3	4	5	6
Status	1. Salinization rates:				
	a) Dense residue, per cent	0.21 - 0.40	0.40 - 0.60(0.80)	0.60(0.80) - 1.00	1.00
	including Cl	0.001 - 0.03(0.06)	0.30 (0.06) - 0.100	0.100 - 0.230	0.230
	Na	0.23-0.046	0.046-0.092	0.092-0.184	0.184
	b) Toxic salts, total amount+)	0.28	0.28 - 0.40	0.49 - 0.69	0.69
	2. Salt layer location in soil profile	Deep solonchak salinization, (salts are below 80-100 cm)	Solonchak salinization (salts are below 30-60 (80) cm)	Solonchak-like salinization (salts are in 30 cm layer)	The whole soil profile is saturated with salts
	3. Morphological features of salinization, new formation	Salts are not visible	Rare small specks of salts in the dry part of profile or in clay horizons	Frequent small spots of mould, salt coating in C-60 (100)cm horizon, salt accumulation in clay horizons	Salts in the form of nests, mould spots specks, crystals throughout the profile or a salt crust
	4. Salinization chemistry	Chloride-sulphate, sulphate	Chloride-sulphate, sulphate-chloride	Sulphate-chloride and chloride	Chloride
	5. Decrease of agricultural crops production (cotton), per cent	< 15	15 - 40	40 - 80	> 80
	6. Percentage of area under salinization	< 5	5 - 20	20 - 50	> 50
	7. Density of cotton plants, thou per ha	80 - 50	50 - 30	30 - 10	< 10
	8. Cotton height in the stage of ripening, cm	120 - 80	80 - 40	40 - 20	< 20

Table 4 Criteria for assessing soil salinization (continued)

1	2	3	4	5	6
Rate	1. Increase in salinized area per cent per year	< 1	1 - 2	2 - 5	> 5
	2. Decrease in agricultural crops production per cent per year	< 2	2 - 4	4 - 8	> 8
	3. Seasonal accumulation of salts, $\frac{\text{per cent}}{\text{MT per ha}}$	$<\frac{0.11 - 0.20}{16 - 30}$	$\frac{0.20 - 0.30}{31 - 45}$	$\frac{0.30 - 0.60}{45 - 90}$	$>\frac{0.61(1.2)}{90}$
Inherent risk	1. Mean annual depth of underground water, cm	500 - 3000	300 - 100	100 - 50	< 50
	2. Ground water mineralization g/ℓ	3-6	6 - 10	10 - 30	> 30
	3. Drainage quality of the aeration zone	Moderate	Weak	Low	Very low
	4. Topography of the terrain	Plains and high plains	Flat plains	Depressions and remnants in river vallies	Depression remnants in river vallies, depression between ween cones
	5. Present drainage network, in per cent of the projected length	> 80	80 - 50	50 - 10	< 10
	6. Violation of agrotechnical recommendations (leaching, watering soil treatment, application of mineral fertilizers), in per cent of the project	< 10	10 - 40	40 - 90	> 90
	7. Lithology of soil in the aeration zone	Sandy loam, sandy soils underlayed by clay at the depth of of 3-5 m	Heavy and light soils in equal proportion	Loamy soil dominates in the aeration zone	Clay or parent rock outcrops on the surface

+) Excluding heavy and very heavy saline soils and solonchaks of the piedmont flexure, of chloride-sulphate and sulphate composition, related to the soil formation conditions.

Table 5 CRITERIA FOR ASSESSING TECHNOGENIC DESERTIFICATION

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
Status	1. Destruction of the vegetation cover a) Cutting tree and shrub vegetation in per cent	< 25	25-50	50-70	> 70
	b) Destruction of sod cover, in per cent	< 25	25-50	50-70	> 70
	2. Percentage of eroded area caused by irregular movements of vehicles and machines	< 10	10-50	50-70	> 70
	3. Percentages of area with technogenic features, in per cent per year (for 5 year period)	< 10	10-25	25-50	> 50
Rate	1. Increase of area with technogenic features, in per cent per year (for 5 year period)	< 2	2-5	5-10	> 10
Inherent risk	1. Wind erodibility groups (texture of soil)	Silt, Clay, clay loam	Loam, Sandy loam	Loamy sand	Sand
	2. Percentage of area involved by projects in road construction and other technogenic transformation (except the construction works in the populated areas)	< 10	10-30	30-50	> 50

Table 6 Symbols designated for desertification criteria

Desertification Classes	Colour Showing DH	Aspects				
		DS	DR	IR	AP	PP
Slight	Yellow	I	a	I	I	L
Moderate	Orange	2	b	m	II	M
Severe	Brown	3	c	f	III	F
Very severe	Red	4	d	h	IV	H

Table 7 INDICES FOR CALCULATION OF DH

Desertification Classes	Indices					DH (Sum of indices)
	DS	DR	IR	AP	PP	
Slight	3	3	3	4	2	30
Moderate	6	6	6	8	4	30-45
Severe	12	12	12	15	8	45-60
Very Severe	18	18	18	25	12	60

According to the sum of indices the mapping unit under consideration should be illuminated brown. That means under this condition DH is severe, according to Table 7 slight DH is illuminated by yellow, moderate by orange and very severe by red colour. We recommend to illuminate green the areas without slight changes occuring during last 20 years. In these areas desertification is practically non-existent.

AP is calculated in the following way. We estimate the present livestock density in per cent of potential livestock carrying capacity. The scale is:

Present livestock density in per cent of potential livestock carrying capacity	AP
200	Very heavy
100-200	Heavy
66-100	Moderate
66	Slight

PP is estimated by population density : The following scale is proposed:

Slight	-	1 person per 1 Km^2
Moderate	-	1-10 persons per 1 Km^2
Heavy	-	10-25 persons per 1 Km^2
Very heavy	-	25 persons per 1 Km^2

Table 8 Desertification hazards of the USSR arid lands (in km² and per cent)

Soviet Republics	Desertification Types											
	Degradation of vegetation cover caused by overuse	Degradation of vegetation cover caused by undergrazing	Areas with partial desertification around desert wells	Deflation	Salinization of irrigated farmlands	Technogenic desertification	Soil salinization caused by the sea level sinking and withdrawal of river flow	Water erosion	Total desertified areas	Sand lands	Areas non prone to desertification	Total
Kazakh SSR	481513	-	8714	-	6536	61006	75162	-	632931	19609	436835	1089375
	44.2	-	0.8	-	0.6	5.6	6.9	-	59.9	1.8	38.3	100
Uzbek SSR	47127	-	51256	11024	3993	41884	7993	-	163227	13507	98841	275625
	17.1	-	18.6	4.0	1.4	15.2	2.9	-	59.2	4.8	36.0	100
Turkmen SSR	135547	3758	42168	48012	10875	12942	11960	12228	277220	25468	114812	417500
	32.6	0.9	10.1	11.5	2.6	3.1	2.8	2.9	66.5	6.1	27.4	100
Total	664187	3758	102138	59036	21404	115832	94845	12228	1073428	58584	650488	1782500
	37.3	0.2	5.7	3.3	1.2	6.5	5.3	0.7	60.2	3.3	36.5	100

PRACTICAL APPLICATION OF THE DESERTIFICATION MAP

Planners strongly need information on the status of the natural environment which is necessary for elaborating measures on reclamation of desert lands and development of some branches of the national economy in the arid zone. The lack of this information can lead to irreparable changes in the future even if the level of the planner's ecological thinking is very high.

The desertification map can be used when elaborating complex projects of the natural resources development in the USSR arid zone.

The map gives the general view of the arid ecosystem degradation within the whole USSR arid zone. Desertification hazards have been estimated and the results are given in Table 8. Percentage of areas prone to DH is almost the same in the Kazakh SSR and the Uzbek SSR. But it is higher in the Turkmen SSR. That can be explained by physical conditions, different ways of economic development and by differences in direct impact on the natural environment.

Using this map we can also calculate other characteristics of desertification aspects. First of all we can measure the size of areas with severe and very severe DS. These areas need desertification control measures in the first place.

Special attention should be paid to the areas with severe and very severe classes of desertificiation, e.g. DS is severe and DR is very severe. Desertification control measures should be planned and performed here earlier than in other places.

Lands with slight and moderate degradation have minimal risk of desertification. In these areas general measures on nature protection should be enought and only in some places active measures on desertification control will be necessary.

The map doesn't give specific measures on desertification control. But it can be used for the assessment of lands for amelioration. According to methodology proposed by the Desert Institute. Turkmen Academy of Sciences, the main trends in desertification control are as follows: control of moving sand dunes, control of water erosion, melioration of salinized soils, rational utilization and improvement of grazing lands, agricultural reclamation of sands.

The map can also be used for desertification forecast. DH is an integral criterion showing the trend in desertification processes taking into consideration DS, DR, IR, AI and PP. If one or more criteria will change in future it will also be possible to calculate the value of DH. The Table of indices given above should be used for this calculation.

Let's consider an example. In the calculation given below (page 21) the sum of indices is 57, which means that DH is severe. What can we expect in future if this example relates to deflation? Let's assume that construction works are planned without sand stabilization measures. In this case according to Table 7 IR will increase to very severe (index 18). So, DH will have index 69 instead of 57. It serves the basis to forecast DH one class higher, e.g. under construction works without sand stabilization measures DH will be very severe.

Using the map we can also estimate the status of natural environment 20 years ago. It can be calculated by the value of DR.

REFERENCES

Бабаев А.Г. Оазисные пески Туркменистана и пути их освоения. Ашхабад, Ылым, 1973.
(Oasis sands of Turkmenistan and methods of their reclamation)

Бабаева Т.А. Изучение и борьба с процессами опустынивания на аридных территориях Туркменистана. В кн.: Кормовая база пустынь Туркменистана. Ашхабад, Ылым, 1984.
(Desertification study and control in arid lands of Turkmenisten)

Бояджиев Т.Г. Оценка и картографирование процессов опустынивания. Проблемы освоения пустынь, 1982, № 3.
(Assessment and mapping of desertification)

Герасимов И.П. и др. Проблема Аральского моря и антропогенное опустынивание Приаралья. Проблемы освоения пустынь, 1983, № 6.
(Problem of the Aral sea and man-made desertification of the Aral bordering area)

Каленов Г.С. Эколого-географический анализ распространения Tortula desertorum в пустынях Средней Азии. Ботанический журнал, 1977, т. 62, № 2.
(Ecological and geographical analysis of Tortula desertorum in the Middle Asia deserts)

Кирота Б.Т. Гидрологические особенности западных районов Средней Азии. Ашхабад, Ылым, 1976.
(About hydrology of the western regions of Middle Asia)

Ковда В.А. Аридизация суши и борьба с засухой. М., Наука, 1977.
(Aridisation of dry lands and drought control)

Кочерга Ф.К. Горномелиоративные работы в Средней Азии и Южном Казахстане. М., Изд.лесн.пром., 1963.
(Mountain melioration works in Middle Asia and south Kazakhstan)

Нечаева Н.Т. Проблема разработки индикаторов опустынивания. Проблемы освоения пустынь, 1978, № 4.
(On elaboration of desertification indicators)

Нечаева и др. Продуктивность растительности Центральных Каракумов в связи с различным режимом использования. М., Наука, 1979.
(Productivity of vegetation in Central Karakum depending on different degree of utilization)

Овезлиев А.О. и др. Фитомелиорация пустынь Туркменистана. Ашхабад, Ылым, 1979.
(Phytomelioration in the deserts of Turkmonistan)

Петров М.П. Пустыни мира. Л., Наука, 1973.
(Deserts of the world)

Харин Н.Г., Каленов Г.С. Изучение антропогенного опустынивания по космическим снимкам. Проблемы освоения пустынь, 1978, № 4.
(Study of man-made desertification on space photos)

Харин Н.Г. Комплексные карты опустынивания и методика их составления по космическим снимкам. Исследование Земли из космоса. 1985, № 1.
(Complex desertification maps and preparation of them by space photos)

Харин и др. Методические основы изучения и картографирования процессов опустынивания (на примере аридных территорий Туркменистана). Ашхабад, Ылым, 1983.
(Methodological principles of desertification processes assessment and mapping. Arid lands of Turkmenister taken as example)

Maps of desertification hazards. Explanatory note, FAO/UNEP, Rome, 1984.

Provisional methodology for desertification assessment and mapping, FAO, Rome 1981.

Provisional methodology for assessment and mapping of desertifiation. FAO, Rome, 1983.

Provisional methodology for assessment and mapping of desertification. FAO/UNEP, Rome, 1984.

EXPLANATORY NOTE TO THE "DESERTIFICATION MAP OF ARID AREAS IN MONGOLIAN PEOPLES REPUBLIC", SCALE 1:2500 000

N.G. Kharin
The labour Banner Order Desert Institute
Turkmen SSR Academy of Sciences
USSR

February 1990

Mongolian People's Republic is situated in the medium latitudes of Central Asia within the temperate climatic zone of the Northern Hemisphere. It is crossed by the so called global watershed to the south of which lies closed drainage area, occupying 2/3 of the country's territory. The total territory of the Monglian People's Republic is 1566.5 thousand km^2, its population is 1914.7 thousand.

The territory of the country can be divided into the following zones and belts : high-mountain (Alphine) belt, mountain (sub-Alpine) steppes and forests, steppe zone, desert steppe zones, and desert zone. The territory under investigation includes desert steppe zone and desert zone. The present day Mongolia is a developed agrarian-industrial country. According to the published statistics its per-capita produce in 1985 was:

	Mongolia	World Average
coal (fuel equivalent) kg.	1766	590
meat, (kg)	117	30
sheep wool (greasy) kg.	10	0.6
milk, (kg)	139	104
wheat, (kg)	366	107
potatoes, (kg)	60	64

The total irrigated area of the country is over 1.2. million ha. The country is self sufficient in meat, wheat, and vegetables.

The main form of agriculture is nomadic stock-breeding. In 1985 the total tock number was:

camels	559.0
horses	1971.0
cattle	2408.0
sheep	13248.8
goats	4298.8
Total	22485.5 thou. heads

Collective farms of agricultural associations (AA) make the basis of the country's stock-breeding. AA are functioning within the administrative units (somons). There are 314 somons altogether in the country. The area under rangeland in the country. The area under rangeland in each somon is about 434 thousand ha with the average stock number of 63 thousand heads. Each somon has about 19 tractors and 18 lorries and cars.

Somons are divided into brigades and brigades into sur's. A sur' is a kind o nomadic camp. A Gobi sur' consists of2-3 tents (yourtas) with the population of about 40 persons. Sur' is functioning on the basis of the productive interests of its members and common social methods of management. There are about 15 thousand sur's in the country. The distance between the extreme limits of a nomadic sur' is within the range of 50-100 km. but during unfavourable years the lifestock is sometimes covering up to 500 km. The present range management practice affects adversely desertification processes. Construction of permanent settlements (centres of somons and brigades) in the arid areas of the country contributes to the formation of desertification spots around them.

The fact that water supply of different rangelands varies markedly also contributes to desertification. In arid regions the rangelands with watering rate of 40% are considered to be optimally watered. Optimally watered rangelands are those which can supply water to the grazing stock during the whole grazing season. At present there are three types of wells in Gobi: 1. primitive arat wells (up to 5 m deep) with hand water lifting (hand pump), 2. shaft wells of engineering type with a screw pumps (up to 13-15 m deep), 3. bore wells (30-200m deept) with piston and well pumps. Desertification spots are being formed around each deep well. Due to the construction of new deep wells the total number of wells has decreased, however, the number of animals being watered from one well has increased. Old arat wells are falling out of use and degrading. Their main disadvantage is that they ar drying up in drought periods.

At present there are several source maps of the arid zone of Mongolia which can be used for studying desertification processes. They are :

1. Topographic maps 1: 100 000, 1: 500 000, 1: 200 000, 1: 1000 000
2. Aerophotos of different scales;
3. Climatic map 1:2000 000;
4. Space images 1: 1000 000 and of larger scale;
5. Soil map 1:2 500 000;
6. Geomorphological map 1:1 500 000;
7. Vegetation map 1:1 500 000;
8. Botanical map of fodder resources 1:1 000 000;
9. Soil utilization map 1:1000 000.

Soviet and Mongolian scientists have jointly developed criteria, based on the methodology worked out by the Desert Institute of the Turkmen Academy of Sciences and shown in Tables 1, 2, 3,. Several criteria site-specific of Mongolia have been added to them.

It was established onthe bases of field surveys and study of literature that three different types of desertification are common to Mongolia: degradation of vegetative cover, wind erosion, and water erosion.

Table 1 Criteria for assessing degradation of vegetation cover

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
1	2	3	4	5	6
DS	State of vegetative cover	Slightly changed changed climax communities	Long existing post-climax communities	Ephemeral post-climax communities	Total destruction of the vegetative cover
	Present productivity as compared with undisturbed vegetation in %	> 90	90 - 60	60 - 30	< 30
DR	Rangeland degradation per cent per year	< 2.5	2.5 - 5.0	5.0 - 7.5	> 7.5
	Decrease in forage production per cent per year	< 1	1 - 4	4 - 7	> 7
	Drop in nutritive value of fodder, per cent per year (fodder units)	< 1	1 - 2	2 - 3	> 3
	Decrease in vegetative cover, per cent per year	< 2.5	2.5 - 5.0	5.0-7.5	> 7.5
IR	Soil, climatic, and geomorphological conditions responsible for the stability of vegetative cover against various impacts	Stable ecosystem of pebble plains, intermountain depressions with thin eolian sediments and ecosystems developed on loamy clay deposits	Comparatively stable ecosystem on gentle slopes, piedmont plains, and undulating hilly plains and those developed on loamy deposits	Non-stable ecosystems on slopes of moderate steepness and sandy deserts with sand horizon over 50 cm of depth	Non-stable ecosystems of stony deserts (hammad), badlands, steep stony slopes, sandy deserts with sand horizon more than 50 cm deep, and ecosystems of dry river beds

Table 2 Criteria for assessing wind erosion

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
1	2	3	4	5	6
DS	Presence of deflation hollows	Deflation hollows without precipices	Deflation hollows occupy up to 25% of the territory	Deflation hollows occupy 25-30% of the territory	Total lack of vegetation, blow-out of sand on the total area
	Amount of sand transported (m^3) over 1 running m per year	< 5	5 - 10	10 - 20	> 20
	Depth of eolian sediments (cm)	0 - 10	10 - 30	30 - 50	> 50
	Sod cover (per cent)	50 - 30	30 - 10	10	-
	Ratio of shrub density and sod cover (per cent)	$\frac{20 - 30}{40 - 80}$	$\frac{20 - 5}{40 - 10}$	$\frac{5 - 1}{10 - 5}$	$\frac{1}{5}$
DR	Increase in eroded area per cent per year	< 1	1 - 2	2 - 5	> 5
IR	Mean annual wind velocity 2 m above the surface m/sec	< 2.0	2.0 - 3.0	3.0 - 4.0	> 4.0
	Repeatability of active winds, per cent per per year	< 5	5 - 15	15 - 25	> 25
	Days with dust storms within active wind period (March - May)	< 5	5 - 12	12 - 20	> 20
	Atmospheric precipitation mm/year	150 - 200	100 - 150	500 - 100	< 50

Table 3 Criteria for assessing water erosion

Aspects	Assessment Factors	Class Limits			
		Slight	Moderate	Severe	Very Severe
1	2	3	4	5	6
DS	Length of dry river beds per 1 km^2	< 0.5	0.5 - 1.5	1.5 - 3.0	> 3.0
	Per cent of soil washed from the soil profile	< 25	25 - 50	50 - 75	> 75
DR	Increase in eroded area, per cent per year; mean percentage for last 10 years	< 1	1 - 2	2 - 5	> 5
	Soil losses, t/ha/yr	< 0.5	0.5 - 1.5	1.5 - 2.5	> 2.5
IR	Slope steepness in grades	< 5	5 - 15	15 - 30	> 30
	Depth of soil horizon, cm	> 40	40 - 30	30 - 20	< 20
	Soil texture	Loamy, heavy loamy and clay soils	Light loamy soils	Sandy loams	Sandy soils

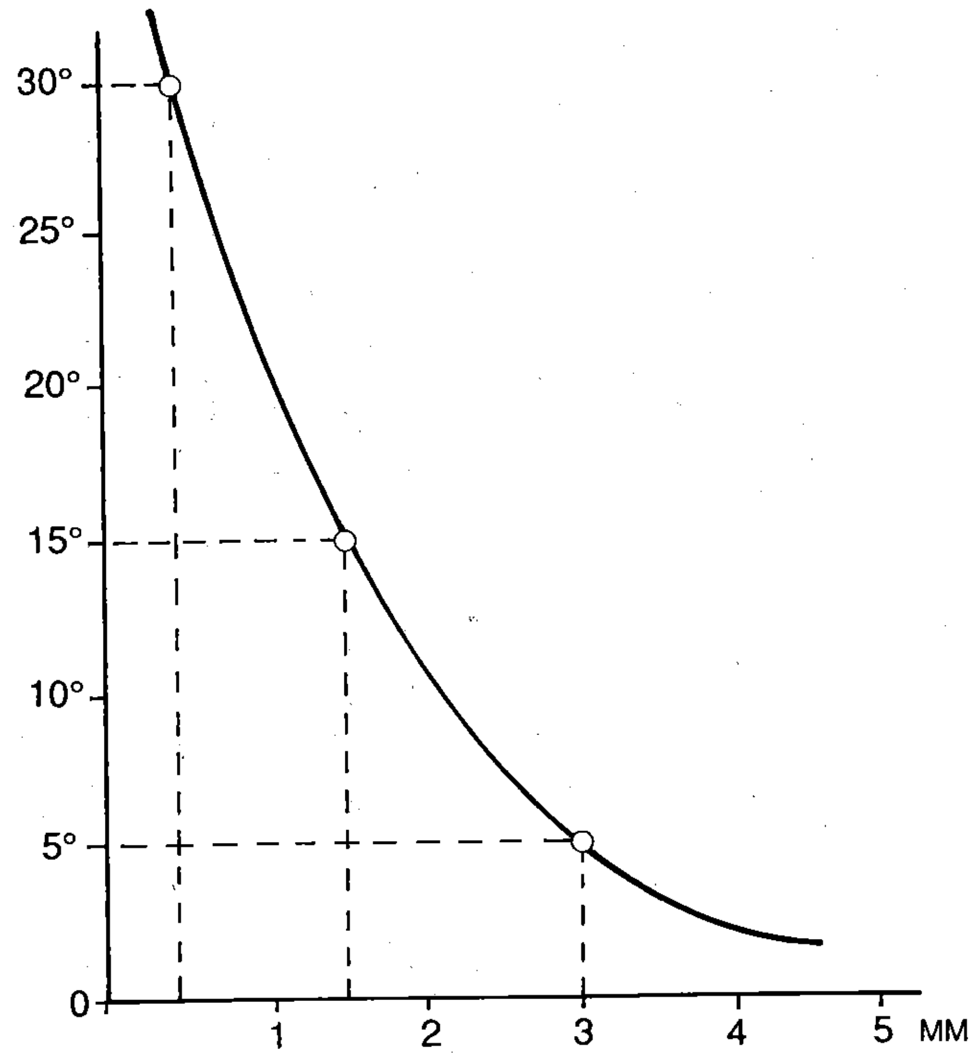


Fig. 1. Graph for calculation of slopes by distance between contour lines on topographic map of 1:100 000 and contour interval of 20 m

The following groups of criteria are taken for the aspects of desertification.

- desertification state DS
- desertification rate DR
- inherent risk IR
- animal pressure AP
- population pressure PP
- desertification hazard DH

DH is calculated from the equation :

$$DH = DS + DR + IR + AP + PP$$

Soviet scientists have developed special methodology for utilizing topographic maps when assessing IR and DS for water erosion which is a common phenomenon in arid areas of Mongolia. Our suggestions are as follows.

Topographic maps are the primary and necessary cartographic sources for compiling desertification maps of arid areas. They give information on landforms and hydrology of the teritory, show roads, wells, settlements, and transport facilities.

This information can be used when assessing vegetation, wind erosion, soil slainization as well as anthropogenic factors of desertification.

Topographic maps show what are the relations between the object under investigation and the surrounding territory. For example, it may be necessary to establish whether the territory in question is a zone of intensive water erosion or a zone of transport and dissemination. They also help to show whether the negative topographic elements are accumulating loose material and elevated elements are the source of sheet flow of varying intensity.

Topographic maps contain information on geomorphological elements which make up the territory in question and their characteristics which may be as follows: intemountain valleys, piedmont plains, alluvial fans, river terraces, basins, degraded mountains, low hills etc. Information on mesorelief is also present : its positive and negative elements, its main and subordinate forms, their relations and combinations.

Karst and suffosion processes as well as the contemporary water erosion and deflation are also shown on large scale topographic maps.

When working out criteria for water erosion much attention should be paid to the characteristics of surface runoff, its most important precondition being the steepness of the slope which is calculated in relative values by dividing the difference between the upper and lower marks of the surface expressed in meters by the distance between them. For example, the absolute height of A is 118 cm, or B - 116 cm the distance between them is 1200 m so the slope can be calculated in the following way:

$$\frac{A - B}{1200} = \frac{1180 - 1160}{1200} = \frac{20}{1200} = 0.016 \quad \textit{which makes up } 0°55'.$$

However, determination of slope values for large areas is connected with a lot of complicated calculations. That is why we suggest simpler and comprehensible graphic way for such calculations.
The graph shows that on the 1:100000 map with the section height of 20m the distances between the contour lines (in mm) correspond to definite surface slopes which in its turn correspond to the adopted classes of IR. (Fig. 1).

For example, if the distance between the horizontals is more than 3.0 mm the slope value is less than 5°. Proceeding from this we obtained the table. As far as their steepness is concerned the slopes may be:

Slope	**Steepness**
Slightly sloping	Less than 5°
Sloping	3-5°
Slightly inclined	5-10°
Inclined	10-15°
Highly inclined	15-20°
Steep	20-45°
Precipice	More than 45°

Slope exposition corresponding to the main compass points can also be determined from topographic maps.

In addition to exposition and steepness the topographic map can supply information on the character of the surface: slopes can be smooth and rought, rought slopes can be undulating, terrace-like, hammocky etc.

The number of dry river beds per k km^2 is very important factor for assessing water erosion processes.

This factor is usually determined by means of curvimeter. Trasparency developed by our laboratory may save a lot of cartographic work. One can determine the number of dry river beds per 1 km^2 by this method with fairly good precision. Transparency is made of some transparent material, Fig. 1 is an example of such transparency. Further generalization of separate sheets will produce the map of dry river-bed network for large territories. Desertification rate is determined by comparing increase and decrease in eroded areas for a specified territory during a certain period of time.

Topographic maps contain information on hydrology of the region - its rivers, lakes wells etc., on its flood-plains, terraces, regime of river floww, salinity of lakes and dynamics of their surfaces.

Special symbols are used for takyrs, solonchaks, outcrops of parent and basic rocks etc. Information contained in topographic maps is rather variable and can be used for general description of the territory in question. It may serve the primary basis for studying and mapping desertification processes.

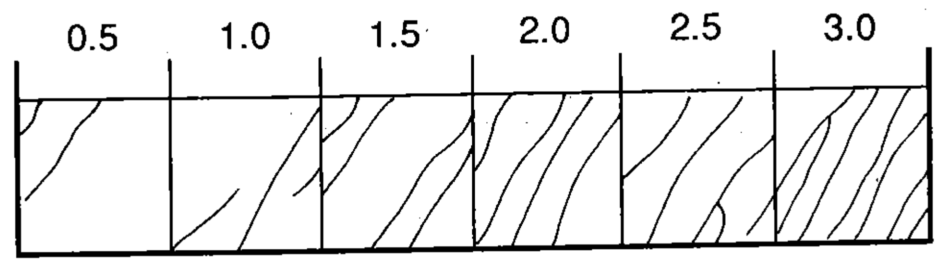


Fig. 2 Transparency for estimation of the number of dry river beds on topographic map, 1:100,000.

Table 4 Determining inherent risk from topographic maps

N	Assessement Factor	Class Limits			
		Slight	Moderate	Severe	Very Severe
1.	Distance between contour lines, mm	>3.0	3.0-1.5	1.5-0.4	<0.4
2.	Slopes in grages	< 5	5-15	15-30	>30

EXPLANATORY NOTE TO THE MAP OF THE PRESENT STATE OF DESERTIFICATION IN NORTHERN AFGHANISTAN

G.S. Kalyenov and N.G. Kharin
The labour Banner Order Desert Institute
Turkmen SSR Academy of Sciences
USSR

February 1990

Plains of the Northern Afghanistan are within the arid zone and are used as rangelands transhumant (migratory) stockbreeding. There are some large oases with developed agricultural production.

Intensive exploitation of desert natural resources upsets the ecological balance within the arid ecosystems. Desertification is one of the most significant manifestations of this imbalance. It may be caused by both natural and human factors. That is why Investigations into the present status of deserts is of great importance for developing scientifically based measures for rational utilization, improved production, and conversation of their natural resources. The desertification map of the Northern Afganistan was compiled to this end.

Methodology developed by the Desert Institute of the Turkmen Academy of Sciences serves the basis for this map (N. G. Kharin et al. 1983).

A number of factors contribute to development of desertification in the Northern Afganistan, the main one being its dry and hot climate. Mean monthly temperature in Andhoi in June is 32.4°C, in Shabargan - 31.2°C, in Mazari-Sharif - 30.1°C, in Kunduz - 29.4°C.

Precipitation is mostly confined to autumn - winter and spring periods, 90% of it occurs in October - May. In summer there are practically no rains.

Western winds prevail in Adeli - Turkoman region. Strong winds cause dust storms. The annual number of dust storms in Mazari-Sharif is 23.5 and in the vicinity of Kunduz -38.9.

Annual evaporation in Shabargan is 2089 mm, in Mazari - Sharif 2353 mm, in Kunduz - 2110 mm. These climatic factors testify to the truly arid climate of the Northern Afganistan. As a result the ecosystems of this region exist under the most unfavorable conditions and are extremely fragile especially under intensified human pressure. As for the vegetation and geographical sub-division of this area, it belongs to the South Turanian vegetation and geographical type. (Rachkovskii, Safronova et al.,1989).

Regularity in spatial structure of land forms in the Northern Afganistan rests on its lithological belts which have been formed within the alluvial - deltaic plains of its rivers.

Mythological criteria may to a certain degree serve as indicators of ecological stability of natural land forms against various exogenic factors: deflation, water erosion, salinization.

The territory adjacent to the Amudar'ya river is mainly covered with sand tracts and barchan ridges.

Deflation processes are most prominent here. These ecological conditions have drastic effect on vegetation which is represented by sparse communities of tall shrubs (*Amodendron connoli, Calligonum arborescens*) sometimes, together with tall wind grass *Stipagrostis karelini*.

To the south lies the belt represented by a complex of sandy and clay deserts, its width being 5 - 20 km. Sand tracts are covered with barchans. Rather rarified stands of *Salsola richteri, Calligonum* Sp., *Stipagrostis Karelini, S. pungens* are confined to these areas. Annual salt tolerant plants (*Salsola carinata, Gamantus gamocarpus*) and *Roa bulbosa* prevail on takyr-like soils. Sometimes there occur separate specimens of *Haloxylon aphillum*.

Farther to the south there lies the belt of clay desert, represented by takyrs and takyr-like soils. The prevailing vegetation here consists of semi-shrubs (*Artemisia turanica, Salsola orientalis*) with the admixture of annual salt tolerant plants (*Salsola carinata, Gamanthus gamiocarpus*). Here and there have persisted separate stands of *Haloxylon aphillum*. This tall shrub was intensively cut for fuel by the local population. Human pressure was so strong here that its role as an edifactor is now practically reduced to nil.

Due to the compactness of their substrate clay surfaces are highly resistant to deflation but they are prone to water erosion.

The belt of light Sierozem soils has formed on the leoss substrate within the transitional zone. Grass-type vegetation is characteristic of this area where ephemeroidal *Synusia* (*Poa bulbosa, Carex pachystylis*) and herbs (*Agropirum repens, Argusia sogdiana, Aegilops truncalis, Aphanopleura leptoclada, Diartron vosiculosum* etc.) predominate.

Next belt includes hills and mountain slopes where shingle sierozems are the most common feature. Mountain xerophytes represented by thorny semi-shrubs (*Acantholimon crinascum, Ziophyllum artiplicoids*) and sparse stands of pistachio (*Pistacia vera*) and almond (*Amigdalus spinosissima*) are the most characteristic species there.

The impact of human factor on the territory of Adeli-Turkoman is extremely vivid on space photos. The whitish grey tone of the most of desert lanscapes shows that their vegetative cover was destroyed in many places through overgrazing and cutting. Intensive progress of desertification processes in the Northern Afghanistan is especially vivid when one compares space photos of this area with those of the Obruchev Steppe in the South'-Eastern Karakum whose darker tone is in contrast with whitish grey tone of degraded areas in the Northern Afghanistan.

When considering desertification processes it is necessary to connect them with litho-edaphic types of deserts because their lithology is of great importance for the stability of desert geosystems against exogenic factors (deflation, water erosion etc.).

The desertification map shows that the most severe desertification occurs on sand tracts for their substrate undergoes deflation (wind erosion) as soon as the vegetative cover is destroyed.

Blown barchan sands have whitish grey tone and characteristic ripples on cosmic photos with high resolution. Vegetation degradation and deflation are the most characteristic types of desertification in sandy deserts.

Clay surfaces (takyrs and takyr-like soils), however, are much more stable to exogenic processes. Only water erosion may play a significant role in triggering desertification processes here. However, no marked natural erosion is visible on cosmic photos of the Northern Afghanistan clay deserts. Perhaps it is due to the fact that all water in the river network is taken for irrigation and does not reach the plain.

Clay deserts on black and white photos are shown by whitish tone which differs greatly from the gray tone of sandy surfaces. Combination of sandy and clay deserts is characteristic of this region. Cosmic photos show them as indistinct spotty (mottled) pattern for sandy cover and usually lacking definite orientation.

Vegetative cover of these complexes is usually lacking definite orientation.

Vegetative cover of these complexes is usually disturbed mainly due to cutting of *Halloxylon affilum* and other shrub species for fuel.

Loess deserts situated in the zone transitional from the plain to mountain hills are prone to desertification under irrational economic activity of man. Such degraded deserts are impassable for transport and become an additional source of dust storms. So it is very important not to disturb the dominating plant communities which prevent deflation of soil.

Technogenic (caused by transport means and other technical appliances) desertification occurs under implementation of various construction objects (roads, oil and gas pipelines etc.) It is least destructive in clay and stony deserts. In sandy deserts construction work requires special protective measures: sand fixation, phytoamelioration etc. All these factors should be taken into consideration when planning prospecting, construction, phytoamelioration, and irrigation works as well as in rational utilization and improvement of rangelands.

Desertification maps are of great value for study, reclamation and rational utilization of natural resources in the Northern Afghanistan where desertification processes spread over large areas in arid zone.

GEOGRAPHICAL APPROACH TO LANDSCAPE ZONATION

Dr. E.V. Milanova
Geographical Faculty,
Moscow State University
USSR

February 1990

An important role in the study and solving of nature conservation problems is attributed to Geography. It considers the natural environment as a complex of hierarchically subordinated geosystems of different taxonomic ranks and their anthropogenic modifications. This kind of approach is necessary for the development of ecologically sound methods of running an economy and keeping up principles of geosystems natural functioning by appropriate adaptation of economic activity to them.

Geography has great prospects in the field of studying anthropogenic processes on the earth's surface consisting of various landscapes. One of the most widely-spread of these processes is desertification.

Here one is offered a map entitled **"Geographic belts and zonal types of landscapes"** at a scale of 1:15.000.000, compiled at the Geographical Faculty of Moscow State University. Various taxonomic units of landscape differentiation are given on the map. The unit used in each case is the geographical belt.

The following geographical belts are distinguished: equatorial, sub-equatorial or monsoon - trade wind, tropical, sub-tropical, temperate, sub-polar and polar.

Solar radiation is the energetic basis of a landscape. It is expressed through differentiation of heat and humidity each with a seasonal variation, and it is quite natural that the classification of geographical belts should be based on climatic factors. Such principles were promoted by V. V. Dokuchaev, L. S. Berg, A. A. Grigoriev, M. I. Budyko in substantiating the geographical zonality law.

Latitude-extended geographical belts of land, distinguished by their heat regimes, basic atmospheric masses and their circulation characteristics are heterogeneous in humidity, the degree of landscape continentality and in relief. But even in the case of homogenous relief, sectoral variations remain significant.

The reasons for the sectoral division are based on variations in quantity and seasonal dynamics of atmospheric humidity in this or that part of the geographical belt, depending on different atmospheric mass transfer. Correlation of the heat and humidity regimes determine the zonal structure of landscapes (the set of zones and their succession) in each sector.

Two oceanic, and one continental, sectors are distinguished within the continents in most geographical belts. During special studies, when characteristics of humidity (or aridity) are used, transitional sectors are distinguished besides the basic ones. Thus the sectoral division reflects the impact of the main regional factor - subdivision of the earth surface into land and ocean - by means of the dominating transfer. Thermal differences of land and ocean determine the emergence of seasonal centres of atmospheric impact and give the belt-sectoral character to the overall circulation of the atmosphere. If the earth surface consisted of land mass only, geographical zonality and the geographical zones proper would have been quite different: humidification of such a geosphere would have been several times lower and distributed strictly according to the belts. In Europe, for instance, only 19 per cent of the total precipitation is obtained through process of inland moisture circulation, and the rest (81 per cent) are brought mainly from the Atlantic.

And yet, we consider belt division to be of the prime significance, and sectoral division of the second one, as far as it displays itself differentially in each belt. The general plan of geographical zonality of terrestrial landscapes is determined by a total combination of belt and sectoral regularities.

In polar and sub-polar belts the lack of heat causes over-humidification almost everywhere. That's why sectoral division is not as clearly expressed as in the other belts. There are two oceanic, and one continental, sectors relatively warm and dry in summer, distinguished in the North-American and Euro-Asian sub-arctic belts.

Westerly air transport and cyclonic activity, weakening in an easterly direction are characteristic of the temperate belts. Such occurrences take place in winter, in particular. Non-tropical monsoon activity takes place on the eastern coasts of continents as a result of thermal differences between the land and the oceans. Average annual precipitation and humidity decrease in the direction from oceans to the middle of continents.

The following sectors are distinguished in temperate belts: western oceanic, continental, extreme-continental, and eastern oceanic or monsoonal, as well. oceanic sectors (especially eastern ones) are characterized by the predominance of meridional extension while continental sectors are characterized by latitudal extension of zones. This proves the fact that the direction(s) of heat and humidity gradients change more rapidly on moving away from the sea than do heat gradients along the meridian. Consequently, zones stretch in parallel to the coast (East of the USA, and Far East of Asia). In places of equal values, zones are characterized by indefinite extension, often determined by morpho-structural peculiarities of the territory (Western Europe). In continental sectors where zonal division is based on the heat gradient with the more or less homogenous humidity, zones have a latitudinal extension (Russian Plain, West Siberia). It must also be mentioned that the predominance of latitudinal zonation in Africa is caused by the coincidence of directions of humidity and heat gradients over large areas to the north of equator.

The seasonal variation of air masses, differentially expressed in the basic sectors takes place in subtropical belts. In winter, temperate air, westerly air transport and cyclonic activity, weakening in the east direction, predominate all over the belt. But in autumn and spring cyclonogenesis is very intense in the east as well (hurricanes, typhoons). In summer tropical air predominates everywhere. Non-tropical monsoon develops over the eastern periphery of the continents as well as over the temperate belt. That is why in summer precipitation is rather high. The rest of the belt is characterized by anticyclonic weather, heat, and aridity.

Thus, three main sectors are clearly distinguished in sub-tropical belts: western, oceanic or mediterranean, with winter humidity; continental with scarce humidity all year round (deserts and semi-deserts are widely spread) and eastern oceanic or monsoon with summer humidification. Besides, western and eastern transitional sectors are also distinguishable.

In the hot belt (especially on the vast land masses of the northern hemisphere) atmospheric pressure gradient is directed in general from tropical belts with high pressure towards an equatorial depression. In tropical belts the western air transfer is weakly expressed, and anticyclonic type of weather predominates. It is dry and hot. Trade winds emerge in the eastern peripheries or anticyclones, moving eastwards (that is why they are called dynamic belts of high pressure). Owing to these winds, deserts and semi-deserts often extend up to the ocean in the west of the major continents. Though coastal deserts are characterized by increased relative humidity of the air, moisture condensation is insignificant and results only in mists. It practically never rains there.

Monsoon circulation takes place over the eastern periphery or tropical belts. That is why only two main sectors are distinguished in tropical belts: continental, or desert sector, extending up to the western coast, and the eastern, or monsoon, with humidification in summer. Eastern sectors are characterized by meridional extension of zones: from forest zones on the coast to the zones of scrub and bushes at the border of semi-deserts of continental sectors. Besides, small areas of desert climate with increased relative humidity, related to the west oceanic sector (coastal deserts) are distinguished in the western peripheries. An eastern

oceanic sector is separated from the continental one by the transitional sector with savannas and bush landscapes.

Winter-summer exchange of air masses from the neighbouring belts, caused by the seasonal shift of the "thermal equator" and stable centres of atmospheric activity is typical of sub-equatorial belts. In winter tropical air predominates, and trade winds causing dry seasons within the major part of the territory of the belt blow, but on the eastern coasts, if the trade wind comes from the sea, it rains even during this season. In summer equatorial air predominates. Equatorial monsoon, covering mainly equatorial parts of the belt, blows in the direction, opposite to the trade wind.

Two sectors can be distinguished in the sub-equatorial belts: eastern oceanic and equatorial sectors, with precipitation in winter and summer and tropical sector with precipitation in summer, covering the rest and the largest part of the belt.

In the equatorial belt two sectors are also distinguished on the continents: seasonally humid eastern oceanic sub-equatorial sector, and a constantly humid equatorial sector.

Geographical zones are distinguished within the limits of geographical belts and sectors according to heat and moisture ratios. It influences the direction and dynamics of geographical processes and determines variability of vegetation. Heat and moisture ratio is estimated with the help of different coefficients and indexes.

Desert and semi-desert landscapes are typical of tropical and trade wind belts. Together with similar landscapes of subtropical belts they occupy 1/5 part of the earth's terrain. Only eastern sectors of continents are covered with monsoon and thin forests. Strong heating of land under conditions of dynamic maximum of atmospheric pressure in tropical latitudes causes expansion of the outer limits of tropical belts in the centre of earth's land mass towards the poles (up to 32° N. in the northern hemisphere). Annual radiation balance is equal to 60-70 Kkal./cm^2. It is warm and dry all year round. In January temperature does not fall below 10°, average July temperature is 30-35°C. Annual amount of precipitation is 50-200 mm, K coefficient almost never rises above 10.

Due to the lack of moisture the weathering crust is small and biomass production is negligible. Annual production of the surface plant mass in tropical semi-deserts is about 1 ton per hectare, in deserts it is almost 10 times lower and the amount of the root biomass is significantly larger than that of the surface biomass. During short seasons of rain biogeochemical processes are rather intense (for example, ephemers growth), but for the rest of the time, they are in long periods of dormancy. Physical weathering (especially wind and thermal erosion) predominates over chemical weathering. During rainy seasons, the work of temporary water and floods is intense.

Due to steady trade winds circulation, western oceanic sector subdivision in these belts does not exist like in the previous ones: deserts stretch out up to the ocean and in southern hemisphere the borders of all the belts of the western coast are shifted towards the equator (including the borders of deserts) under the influence of strong cold air streams. Vegetation in semi-deserts and deserts is rather sparse and is mainly located along dry river beds and in other places of relatively shallow occurrence of ground water.

Towards the eastern monsoon periphery of the continents, deserts give way to semi-deserts, bushes and thin forests, and finally to humid seasonal monsoon tropical forests. Their heat and humidity regimes are almost the same as that of sub-equatorial monsoon forests.

Mountainous landscapes are distinguished by altitudinal zonation. Their character depends first of all on their location in one or another geographical belt and sector, and certainly on the altitude of mountains themselves.

We have built two standard profiles of zonal structure in the mountains on the basis of base columns of altitude zonality. One of them represents altitude zonality in humid coastal sectors of continents (Fig. 1), the other - in continental sectors (Fig. 2). Both humid and arid types of landscapes are usually represented

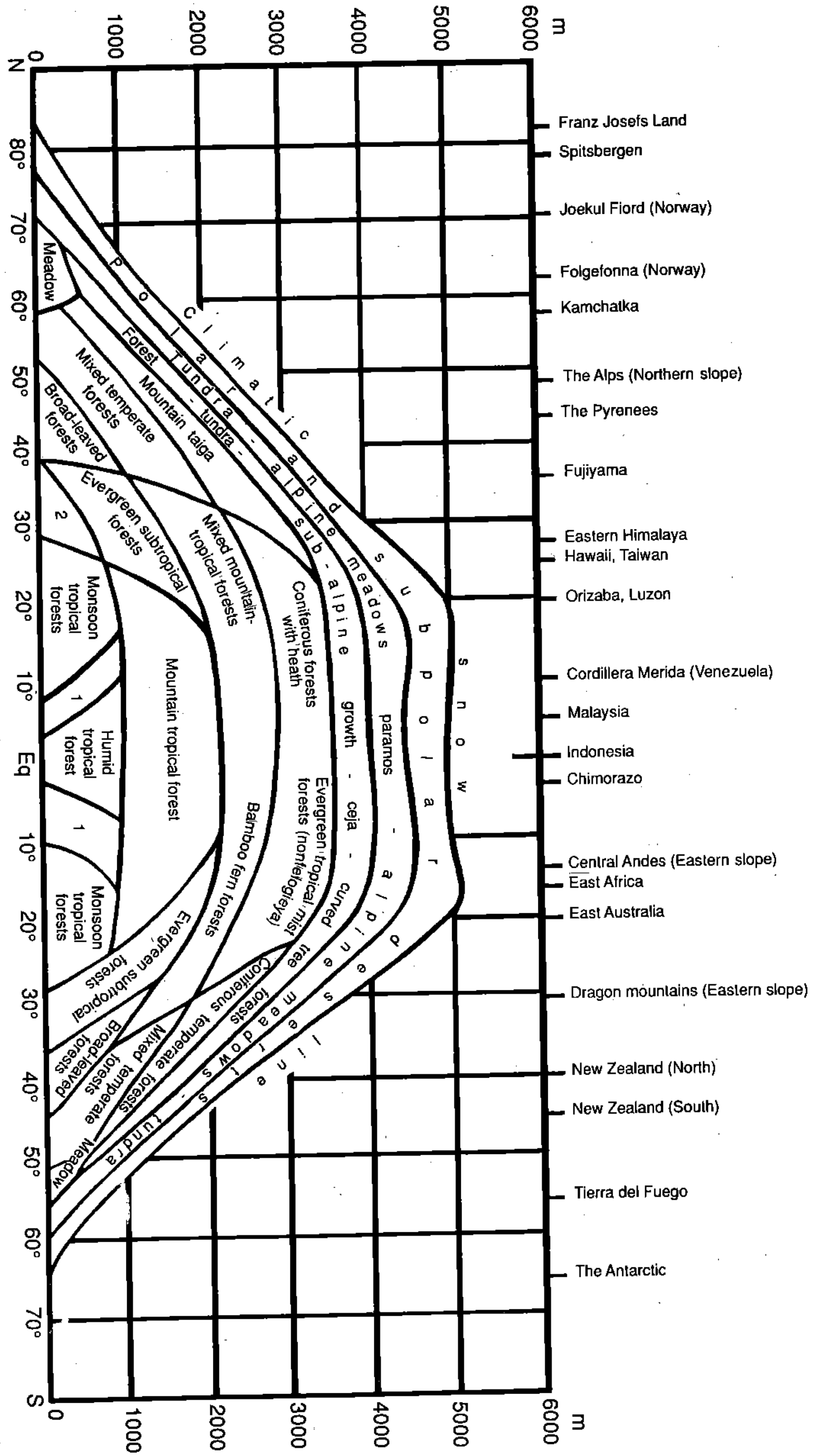


Fig. 1. Structure of altitudinal zonation of landscapes in wet near-oceanic sectors of the continents:
1—deciduous-evergreen (subequatorial) forest landscapes, 2—subtropical monsoon forest landscapes

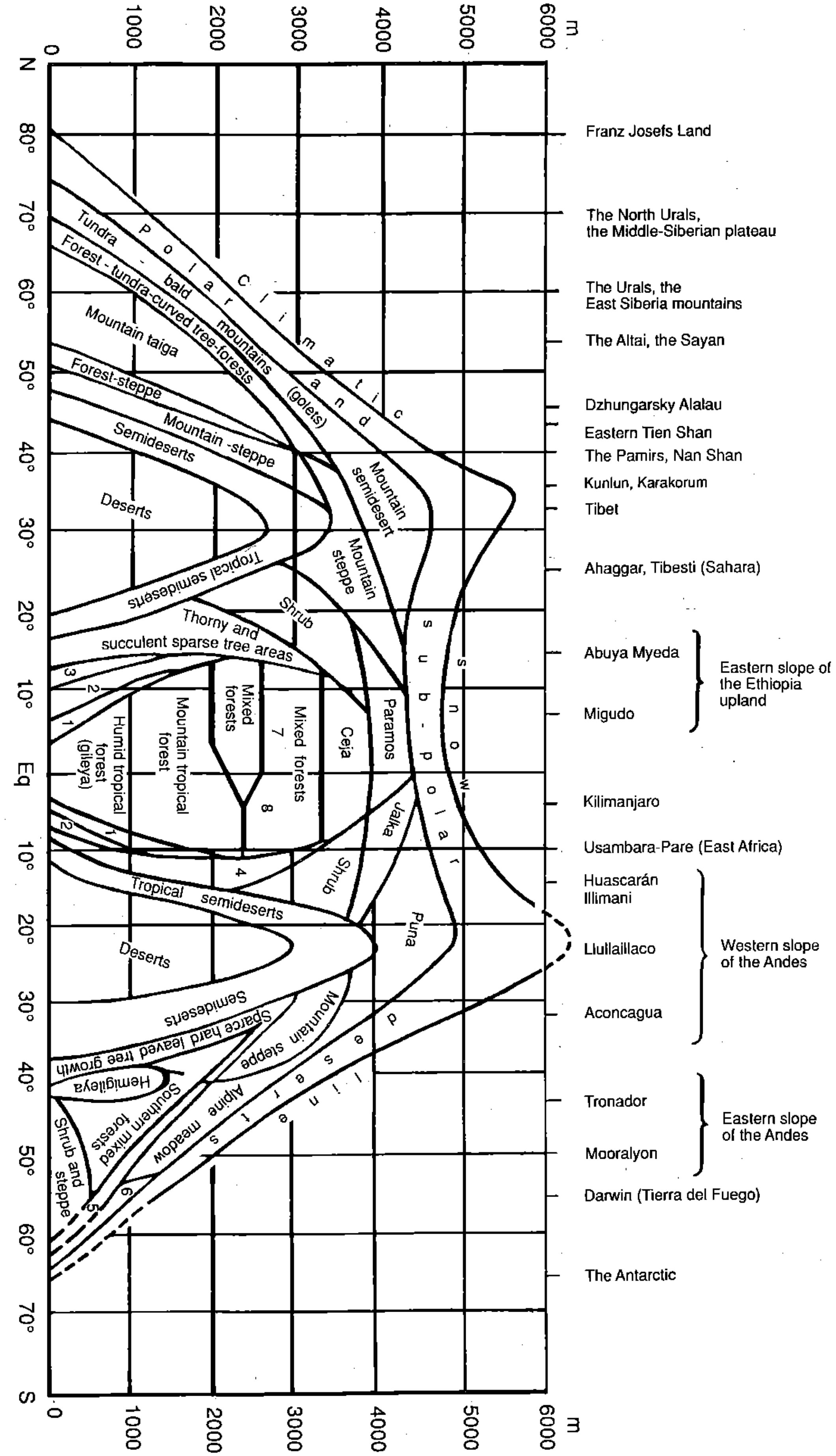


Fig. 2. Structure of altitudinal zonation of landscapes in continental sectors:
1—deciduous-evergreen subequatorial forest landscapes, 2—monsoon forest landscapes, 3—savanna landscapes, 4—thorny and succulent sparse-tree areas, 5—crooked beech trees, 6—near-oceanic meadows, 7—coniferous forests with heath, 8—bamboo-fern forests. **Terminology**: Paramos—equatorial mountain meadows with arboreal compositae (Senicio, Espletia and others) and shrub. Jalka—subequatorial mountain cereal steppe with shrub. Puna—tropical mountain semi-desert (with evergreen shrub). Ceja de la Montanya—crooked-tree forest, upper forest border. Southern mixed forests—deciduous-evergreen leadbearing and coniferous forests with Podcarpus, Libocedrus, Araucaria, Fitzroya (pines and firs are absent).

in transitional sectors in the altitude zonality structure but the degree of their development is reduced and there is no clear expression of sectoral differences. It is useful to examine two extreme sector types of altitude belts. It is clear from comparison of the figures that their main difference lies in the fact that desert and semi-desert zones are well developed in the mountains of continental areas as a result of the influence of high pressure and anticyclone belts. It also explains the rise of the snow-line there up to 700-1000 metres higher than in humid sectors. On the western slope of Lyuljaljako volcano (6723 m) in the Andes the snow line lies in the phenomenal height of 6500 metres (L. Lyibutry, 1956). It is connected probably with the closeness of seven kilometres high mountain range of the Andes and an even more powerful steady South Pacific maximum of pressure.

Cold south winds, blowing in its eastern periphery, do not bring precipitation to the warmer latitudes.

Vast desert plain areas below the tropics (Fig. 2) are framed by high altitude zones of semi-arid landscapes of different widths. Equatorial main body of humid mountain landscapes is well-framed. It is much narrower than the one in the humid sectors of continents (Fig. 1 and 2). The whole spectrum of transitional zones, sometimes hardly distinctive, lies between them and the desert landscapes. The studies of altitude belts in these latitudes can clarify their location. It is necessary to take into consideration that high altitude zones of deserts and semi-deserts are lower and narrower in transitional sectors. The zones of semi-arid and semi-humid landscapes are better developed in continental sectors. On the other "pole" - in humid sectors - mountain arid landscapes disappear and are replaced by semi-humid and humid landscapes, as can be seen in Fig. 1.

The expansion of equatorial conditions of main body (Fig. 2) at altitudes of 1000-2500 m is quite natural. Within the limits of these altitudes the amount of precipitation is usually higher than that above and below them. At an altitude of 3000 m cloud forests (Nebel-waldes) - the zone of highest cloudiness is located. The zone of elfin woodland (seja de la montaigna) is situated above them. It must be considered as the upper forest line. Between it and rock debris deserts of equatorial latitudes, high altitude meadows (paramos) with shrubs and dendritic compositaes (dendritic groundsel, espeletia, etc.) are situated. High altitude grass steppe with bushes (halka) lies between them in the southern sub-equatorial latitudes. High altitude tropical semi-deserts (punas) with evergreen shrubs, dendritic gramineaes and deserts (tolas) with sparse thorny bushes and cushion-like opuntias are situated above mountain tropical deserts and semi-deserts in the southern hemisphere.

Local features of landscapes are individual and unique, but zonal features reiterate even on different continents, and with a certain degree of abstraction can be generalized. It gives an opportunity to reveal the objective laws of landscape types distribution not even separately on every continent, but in global range of all the earth terrain.

For a better understanding of geographical zonality display - distribution of geographical belts and zones on corresponding continents, we must imagine a hypothetic homogeneous continent (see fits on the map), the size of which corresponds to the half of the terrestrial earth in a certain scale and its configuration corresponds to its latitudinal location. Its surface is a low plain, washed by the ocean. Lets assume that another half of the terrain is situated in the opposite hemisphere. The conditions are the same - it is a continental-antipode. The outlines of these continents in the northern hemisphere remind us of something average between North America and Euro-asia with North Africa, and in the southern hemisphere - of South America, South Africa and Australia. Boundaries of belts and landscape zones, plotted on a hypothetical continent, correspond to their generalized (average) outlines on the plains of existing continents. They are reduced to the level of this plain in the location of mountain areas. As far as zonal objective laws of hypothetical continent-standard reflect really existing zonality on the plains of real continents, we can illustrate the general set-up by specific examples.

Planetary law of geographical zonality of terrestrial landscapes is most fully revealed in the vast and compact Euro-Asian-African land mass. Due to this fact we decided to show the complete plan of geographical zonality of terrestrial landscapes on the scheme of the hypothetic continent. This plan was expanded by including the missing elements of zonality on other continents.

It is clear from the scheme given above that the larger than in the southern hemisphere terrestrial area in the northern hemisphere leads to significant stretching of zones in the continental sectors of northern temperate and subtropical belts. In the southern hemisphere these sectors are narrow and in the form of a wedge. Still in general the zonality of southern hemisphere follows zonality of northern hemisphere. Secondly, the majority of geographical zones break their latitudinal extension one is used to. Latitudinal extension of zones predominates only on the territory of the USSR and partly on the territory of Canada, which are situated mainly in continental sectors of arctic, sub-arctic and temperate belts, and also in a wide northern part of lowland Africa, where west oceanic sector is not expressed due to the trade wind circulation. Latitudinal extension of zonality is not typical of the remaining part of the earth's terrain.

At present the systems-geographical analysis of natural environment is enriched by the studies of changes in natural environment taking place under anthropogenic economic impact. Such kind of approach makes it possible to estimate the degree of use and destruction of natural environment and its potential resources for expansion of production, and to foresee negative consequences of anthropogenic interference in order to find ways of its optimal use. Special researches are being held for this purpose at the Geographical Faculty of Moscow State University. Their aim is to create a map of present continental landscapes in the same scale of 1:15.000.000. Initial natural landscapes, specific character of economic activity impact and its results will be shown on this map.

3 groups of zonal landscape types are supposed to be marked out: practically unchanged landscapes, only high altitude tropical landscapes, landscapes of sub-polar and polar deserts and some extremely arid desert landscapes can be attributed to them with a certain degree of approximation. But even these landscapes are often influenced by interstate transfer of pollutants of industrial origin.

A significant part of landscapes that was still recently considered as natural (forest landscapes, steppes, savannas, semi-deserts and deserts) in fact must be classified as anthropogenic landscapes, influenced by economic anthropogenic activity to a certain extent.

A group of anthropogenic landscapes modifications is of special interest. Agricultural and forest husbandry modifications of landscapes are the most interesting among them. Yet these transformations are not as deep and intense as settlements, mining industry or engineering transformations, which have mainly focus spreading.

Studying of inner structure of present-day landscapes and processes taking place in them, can be the next step in their research work. Systems-landscape approach to natural environment studying can be the basis for understanding present-day processes in landscapes including desertification process. It will make it possible to estimate the resistance of natural landscapes to impacts, to compose trends of their changes to foresee their development. This work will not only be of theoretical but also of practical significance.

GLOBAL ASSESSMENT OF DESERTIFICATION: WORLD ATLAS OF THEMATIC INDICATORS OF DESERTIFICATION: Proposal Document

M. Mendoza
Atlas project co-ordinator
Desertification Control Programme Activity Centre
United Nations Environment Programme

February, 1990

TABLE OF CONTENTS

1. BACKGROUND

Desertification is a complex process, linked to the overexploitation of land resources. It is a major international environmental issue. According to the UNEP evaluations and analysis, (UNEP/GC.12/9, 1984), between 1977 and 1984 desertification affected more than 100 countries and annually caused the loss of some 6 million hectares of productive land and the reduction to zero economic return of 21 million hectares of productive land. During this period it continued to spread and intensify in developing countries, and particularly in Africa.

The 1977 UNESCO/UNEP World Map of Desertification and the 1984 experimental map covering Africa are the most significant contributions to the assessment and mapping of desertification at global and regional levels. These maps have encountered some criticism, because of the scale and methodologies utilized in their preparation.

Since desertification is a dynamic process, the UNEP Governing Council at its twelfth session in 1984 pointed out that desertification could not be shown on one single map and recommended the production of a series of Thematic Maps on Desertification. (see Annex I for details of Legislative Authorities for the preparation of the Global Assessment).

2. THE GLOBAL ASSESSMENT OF DESERTIFICATION

2.1 DEFINITIONS

During the last thirteen years the term desertification has been used indiscriminately as synonymous with land degradation, ecosystems deterioration and resources degradation. This has created much confusion and there is no general agreement among the scientific community or the institutions working in this field. Some are inclined to use it as an ecological oriented expression; others prefer to use it as being more related to socio-economic factors associated with natural physical phenomena; while some define it almost all, in political terms. One of the outcomes of this meeting will perhaps be to formulate a more operational definition of desertification.

For the purposes of this project, however, the term desertification will be defined in terms of land degradation in arid, semi-arid and sub-humid zones.

2.2 OBJECTIVES

The long-term and short-term objectives are:

a. Long-term objectives

- Global application of the methodology to assess desertification, with possibilities for periodic updating.
- Improvement of anti-desertification management and the implementation of actions to combat desertification at the regional level.

b. Short-term objectives

- A better understanding, at the global level, of the land areas at risk from desertification, its geographical distribution and the factors underlying it.
- Digital information easily accessible to policy makers and the international community for a better understanding of the status and trends of desertification; and for formulating international and national programmes and strategies to ameliorate the impact of desertification.
- Strengthen the awareness of decision makers of the significance of desertification, its causes and on the problems generated by overexploitation of land resources.
- Update the existing datasets currently available at UNEP/GEMS/GRID.
- Incorporate new datasets to the DC/PAC database closely linked with the DC/PAC Q-R database.

2.3 CONCEPTS

The preparation of a global assessment requires global datasets of standard quality throughout. Only then can they be analyzed, compared, and interpreted to provide a clear image of the desertification process and a better understanding of its complexity, especially of the factors underlying it.

It is important to realise that a global assessment will therefore be meaningful only at global and regional levels, and it will be of very limited relevance or accuracy at national and local levels. The scale of the global assessment demands a specific methodology which is quite different from those used at national or local levels.

The single most important dataset for our assessment is the 1:10 million scale Global Assessment of Soil Degradation (GLASOD) map, sponsored by UNEP and by the International Soil Reference and Information Centre (ISRIC) based in the Netherlands, in association with the Food and Agriculture Organization of the United Nations (FAO), the International Soil Science Society (ISSS), the Dutch Soil Survey Institute (STIBOKA) and the International Institute for Aerospace Survey and Earth Sciences (ITC). Leading regional institutes and experts working in this field are also cooperating in the project.

This global assessment identifies a number of aspects of soil degradation including type (water, wind, physical, chemical, biological degradation); degree (none, slight, moderate, severe, extreme); and rate (slow, medium, rapid).

It is our intention to combine this global assessment with a climatic classification into arid, semi-arid and sub-humid areas, and thus present an integrated view of the different aspects of degradation within these three climatic zones. The type and degree of soil degradation will be maintained together in order to reflect a better picture, of the status of degradation.

Other global datasets will be incorporated into the GLASOD map and database including:

- World Population Data, at country level, from the UN Statistical Office. New York, USA.
- World Vegetation Map, from The Institute for the International Map of the Vegetation, Tolousse, France.
- World Climate data (Temperature, Precipitation and Evaporation) from CIAT (Cali-Colombia), East Anglia University (U.K.), NCAR (Colorado-USA) and other sources to be contacted.
- NDVI (Normalized Difference Vegetation Index) from AVHRR (Advanced Very High Resolution Radiometer) Data - Patterns of the Earth's vegetation, from NOAA (United States National Oceanic and Atmospheric Administration).
- World Digital land and seafloor elevations (ETOPO5), grid spacing of 10 minutes and 5 minutes of latitude by 5 minutes of longitude, from the National Center for Atmospheric Research and National Geophysical Data Center, Boulder, Colorado, USA.
- Geographical Belts and Zonal Types of Landscape Map, from Moscow State University - USSR.
- World Land Use Map, from Moscow State University - USSR.

The global desertification assessment will be expressed through an index calculated from a combination of these variables. The index will thus reflect the physical, biological and social factors underlying the process.

This global index will be supported by regional, national and local assessments where datasets are of a much higher quality.

3. THE THEMATIC ATLAS OF DESERTIFICATION

3.1 GENERAL

The Thematic Atlas will be the medium through which the results of Global assessment of Desertification will be published. The global assessment itself will be backed up by examples at the regional, national and local scales to demonstrate the different approaches and methods required at each scale and the different results that can be obtained from them.

The Atlas will be in A3 format and will be accompanied by two wall charts at a scale of 1:10 million.

The Atlas will contain some 40 pages of maps, each accompanied by explanatory text, tables, figures and diagrams.

It is planned to distribute 1000 copies of the Atlas, in English.

All thematic data used in the assessment will be available in magnetic format in the form of a digital database on desertification, for use on micro and mini computers.

3.2 THE GLOBAL ASSESSMENT

The Global Assessment will consist of 2 wall charts at a scale of 1:10 million and 8 thematic maps at a scale of around 1:80 million.

A global Map (scale 1:10 million) of the desertification index, showing the distribution of population in areas with moderate, severe and extreme degrees of degradation, caused by water and wind erosion. The map will have descriptive legend and simple tabular data to regional level.

A global Map, scale 1:10 million, of aridity index, showing the arid, semi-arid and sub-humid areas; including descriptive legend and simple tabular data to regional level.

8 global maps, A3 format, approximately 1:80 million scale. Each map will be accompanied by a page of descriptive text, and tables, figures and diagrams.

2 maps will be devoted to the desertification and aridity index shown on the wallcharts, but at a smaller scale, and with more description of the methods underlying the assessment and of the results of the assessment.

6 maps will be devoted to individual themes underlying the assessment and which demonstrate our approach. Possible thematic maps include climatic indices, population, land use, NDVI, vegetation and individual soil degradation processes.

3.3 REGIONAL ASSESSMENT

The Atlas will include at least one regional assessment of desertification, most probably from a country in Africa from where more reliable datasets are available. The assessment, at A3 format, will show six variables, or combinations of variables, underlying the desertification process, with accompanying text, figures and tables.

The range of possible thematic maps will be similar to that available for the global assessment, but at much larger scale and resolution. The maps may include monthly climatic and NDVI indices, individual soil degradation processes, population, or vegetation types.

3.4 NATIONAL AND LOCAL ASSESSMENT

Three national/local assessments will be included in the Atlas, to demonstrate methods and approaches applicable to this scale. Each assessment will again be limited to 6 pages of maps and accompanying text, tables and figures.

The assessments will be selected from those commissioned by UNEP and recently completed, and from those nearing completion by other agencies. Candidates for selection include the Kenya Case Study, the USSR study in Mali and the Sahel Transect Study by IGN - France.

4. PROJECT ORGANIZATION

The team participating in this will be as follows:

- Mauro Mendoza	Project Co-ordinator DC/PAC

Technical and Scientific support:

GEMS/GRID:

- Kaspar Kundert	Data Analyst
- Lars Eklundh	Data Analyst
- Rhonnie Semakula	Digitizer
- Mick Wilson	Systems Supervisor

EM/Soils:

- Miriam Schomaker	Cooperating Expert

Internal Scientific Advisory Group (ISAG):

- Till Darnhofer	DC-PAC
- Stan Sangweni	DC-PAC
- Ali Ayoub	EM/Soils
- Michael Gwynne	GEMS-PAC
- Harvey Croze	GEMS-PAC
- M. Norton-Griffiths	GEMS-PAC

This group will meet every two weeks or when necessary to review and advise in the project development.

International Scientific Advisory Group (ISAG):

- Members to be defined

This group will act as a consulting body to define or clarify any important issue which could affect the normal development of the project. It will meet by request of the Internal Scientific Advisory Group.

Annex I

UN/UNEP RESOLUTIONS RELATED TO THE GLOBAL ASSESSMENT OF DESERTIFICATION

The Legislative Authority or UN official background documents that support this project are:

- UN Conference on Desertification, 29 August - 9 September 1977 Round-up, Plan of Action and Resolutions.
- UNEP GC Decision 12/10, paragraph 4, of 28 May 1984, reconfirming the validity of the Plan of Action to Combat Desertification.
- UNEP GC Decision 12/10, paragraph 14 (a), of 28 May 1984 urging Governments and international bodies to consider examining their ongoing and planneddevelopment projects to ensure maximum effectiveness in combating desertification.
- UNEP GC Decision 12/10, paragraph 15, of 28 May 1984, emphasizing the importance of regional co-operation as an effective means of increasing the efficient use of financial and technical resources, with particular emphasis accorded to co-operative research, training and information exchange.
- UNEP GC Decision 12/10, paragraph 17, of 28 May 1984, reaffirming the central role of the United Nations Environment programme in catalyzing, co-ordinating and assessing the implementation of the Plan of Action at international level.
- UNEP GC Decision 12/10, paragraph 28, of 28 May 1984, deciding that a further overall assessment of progress in the implementation of the Plan of Action to Combat Desertification should be carried out in 1992.
- UNEP SWMTEP for the period 1990-1995, of 1988, Chapter V. The human Environment: Issues and Actions. C.2. Arid lands and desertification, (c) specific objectives, paragraph 116 (a) and close relation with 116 (e); (e) implementation of the strategy, paragraph 120 (a) and close relation with 120 (b), 120 (d), 120 (e) and 120 (h).
- UN General Assembly's forty-fourth session resolutions I.1, I.15 (g), 1989, deciding that the convened 1992 United Nations Conference on Environment and Development, in addressing environmental issues in the developmental context, should accord high priority to drought and desertification control and consider all means necessary, including financial, scientific and technological resources, to halt and reverse the process of desertification with a view to preserving the ecological balance of the planet.

DEVELOPMENT OF A NEW METHOD FOR ASSESSMENT AND MONITORING OF DESERTIFICATION IN SAHELIAN AND SUDANIAN REGIONS (1952 - 1987):

Presentation of the results obtained on the first transect: Mauritania-Mali.

L. Guyot
Project Manager
Institut Geographique National (IGN) - International
France

February 1990

INTRODUCTION

This mid-term study started in 1987 and planned to continue till the end of 1991, is co-financed by UNEP and the French Government.

It represents team work headed by the INSTITUT GEOGRAPHIQUE NATIONAL, FRANCE and in collaboration with the Universite de Reims (Professeur M. Mainguet) and Orstom (National Research Organisation for Overseas Development).

The origin of this study was to find a good and profitable use for the existing aerial photographs taken in the 1950s by the Institut Geographique National all over Western Africa for the preparation of topographic maps at a scale of 1:200,000, covering many countries in the sub-region.

From this baseline we decided to make another aerial photographic coverage in some selected areas and in comparable conditions, to make it possible to carry out a comparative interpretation (comparative, Multidate), to reveal any land use changes which had occured in the intervening period.

REALIZATION

Instead of making the new aerial coverage at random we chose to fly along a SPOT satellite track leaving the door open for further extension (extrapolation) to the whole satellite track. The SPOT track Number 40 has been arbitrarily selected and an aerial mission at a scale of 1:50,000 (Panchromatic emulsion) was flown in November 1987 along the track covering 10 km wide (1/6 of the satellite image width). This mission has been doubled at a scale of 1:36.000 by an IRC coverage and the corresponding SPOT images were acquired at the same time within a few days on either side of the aerial cover (photo) dates.

The interpretation made on the aerial photography for the 1950s and the year 1987 drove us to devise a legend in 16 themes easily interpretable in both aerial missions.

The problems related to geometric correction were solved through the use of SPOT images registered to correspond to existing topographical maps. The SPOT images were produced at a scale of 1:100,000 using landmarks selected from the existing 1:200.000 scale topographic maps. These registered images are metric documents and they provided the background against which the multidate interpretations were drawn.

A computer assisted cartography method (scanning and coding of areas delineated by interpretation) provided a database allowing for a comparison of land use for every hectare in the covered area at each date.

Three areas of sixty kilometres long by ten kilometres wide were studied - one along the main annual isohyet of 400 mm (NARA), the other round the isohyet 800 mm (MOURDIAH) and the last one along the 1200 mm isohyet (YANFOLILA).

The main results are summarized below:

1)	**NARA**		**60241**	**hectares studied**	
	Bare soils	1957	46	hectares	
		1987	519	hectares	
	Annual crop coverage	1957	2495	hectares	4.1% of total acreage
		1987	4406	hectares	7.3% of total acreage
2)	**MOURDIAH**		**69622**	**hectares studied**	
	Bare soils	1952	14	hectares	
		1987	5008	hectares	7.2% of total acreage
	Annual crop coverage	1952	4491	hectares	6.4% of total acreage
		1987	10601	hectares	15.2% of total acreage
3)	**YANFOLILA**		**67888**	**hectares studied**	
	Bare soils	1952	10	hectares	
		1987	280	hectares	
	Annual crop coverage	1952	2930	hectares	4.3% of total acreage
		1987	7202	hectares	10.6% of total acreage

For the "natural" vegetal cover the global trend was not always in one direction; in some instances a shift downwards in the vegetal cover (from tree savanna to shrub savanna f.i) was noticed. In other places, where the environment remained relatively untouched by human activities, the change was more dramatic (from shrub savanna to tree savanna or even open forest).

CONCLUSIONS

The results given by this objective method and the possibilities offered by the associated database allowed for the production of a map of the evolution of land use which should give more clues to the specialists to interpret the measurements achieved.

Other transects along the SPOT satellite tracks will add information and enlarge the sample areas where evaluation of the main features of land use is known at a scale precise enough for the specialist to make an interpretation of what is really occurring in those degradation prone areas of the Sahelian and Sudanian belt.

Appendix 1

GUIDELINES FOR GENERAL ASSESSMENT OF THE STATUS OF HUMAN-INDUCED SOIL DEGRADATION: GLOBAL ASSESSMENT OF SOIL DEGRADATION (GLASOD)

Guidelines for General Assessment of the Status of Human-induced Soil Degradation (Working Paper and Preprint 88/4)[1]

L.R. Oldeman (Ed.)
International Soil Reference and Information Centre (ISRIC)
Wageningen, Netherlands

April 1988

FOREWORD

The guidelines for general assessment of the status of human-induced soil degradation will serve as an operational manual in the description and global mapping of the status of soil degradation. The first draft was prepared by Dr. J. Riquier. His ideas were thoroughly discussed at a meeting in ISRIC, Wageningen, December 1987, which was attended by J. H. V. van Baren, E. Bergsma, L. R. Oldeman, W. M. Peters, I. Pla-Sentis, J. Riquier, W. G. Sombroek, C. R. Valenzuela, R. F. van de Weg. The second draft was then sent for comments to an international panel of reviewers. Comments were received from J. P. Abrol (India); A. Ayoub (Kenya); G. Aubert (France); T. T. Cochrane (Bolivia); F. J. Dent (Thailand); H. E. Dregne (USA); M. A. Garduno (Mexico); E.G. Hallsworth (Australia); B. G. Rozanov (URSS); I. Szabolcs (Hungary).

Their constructive criticism and comments were incorporated in a third draft, which was then discussed in detail during the first regional workshop on a Global Soils and Terrain Digital Database (GLASOD) in Montevideo, Uruguay (21-25 March 1988). Some revisions were suggested at that meeting by a special working group with the following members: M.F. Baumgardner (USA); T. Cochrane (Bolivia); D. R. Coote (Canada); L. R. Oldeman (Netherlands); M. Purnell (FAO, Rome); W. Reybold (SCS, USA); W. G. Sombroek (Netherlands); A. Szögi (Uruguay). Subsequently, additional comments were received from D. Sims, D. Sanders and A. Brinkman (FAO, Italy).

Based on the consensus reached at the Montevideo workshop this new version has been edited. The subject is complex and the scales envisaged (averagely 1:10 M for the world mapping; 1:1 M for some pilot areas) will force many arbitrary decisions to be made by the various regional and national collaborators, also in view of the limited time available for project execution. We nevertheless hope that this operational manual will serve its purpose.

W. G. Sombroek, Director
International Soil Reference and Information Centre (ISRIC)
Wageningen, the Netherlands

---

1. This document was prepared under an UNEP project *Global Assessment of Soil Degradation (GLASOD)* and the paper was presented as background material for the discussion of the meeting.

1. INTRODUCTION

Late September 1987 an agreement was signed between the United Nations Environment Programme (UNEP) and the International Soil Reference and Information Centre (ISRIC) for the execution of a project on: Global Assessment of Soil Degradation (GLASOD). The project has a duration of 28 months. It involves two separate activities:

a) to prepare a world map with an average scale of 1:10.000.000 on the status of soil degradation.

b) to prepare a detailed assessment on soil degradation status and risk for a pilot area in Latin America, covering portions of Argentina, Brazil and Uruguay, accompanied by a 1:1 Million map.

The guidelines discussed here are intended for the description and mapping of the status of soil degradation at a global scale. They will be used by institutions and/or qualified individual specialists, designated and contracted to prepare regional soil degradation status maps and complementary data sets at a working scale of 1:7,500,000. They should follow the procedures outlined in these guidelines as closely as possible to ensure a high degree of uniformity. The regional maps thus prepared will then be compiled and correlated to a final map of soil degradation status at an average scale of 1:10 million. The reduction in scale from 1:7.5 million to 1:10 million inevitably implies that certain units may disappear on the final map. The relative importance may be "flagged" by special symbols, this at the discretion of the compilation committee.

These guidelines will also be used for the detailed assessment of soil degradation status in the pilot areas; the basic concepts and the legend discussed below are also applicable for these pilot areas. They are therefore included in the "SOTER Manual for Small Scale Data Base Compilation, Volume II: Procedures for Interpretation of Soil Degradation Status and Risk".

2. OBJECTIVES OF THE GLOBAL ASSESSMENT OF SOIL DEGRADATION

A realistic understanding of global environmental changes is needed. Past and present intervention in the utilization and manipulation of environmental resources are having unanticipated consequences. It should be realized that not all interventions are negative. While there are many causes of soil degradation - such as those associated with agricultural and pastoral land use and those resulting from mining and non-rural use -, we should also recognize the many effective soil improvement and protection programmes, undertaken by national and international bodies. However, these successes tend to be obscured by the overall deterioration of the world soil resource potential. This project can be considered as a first step towards a global soil degradation assessment. The immediate objective as defined in the project document is: **"Strengthening the awareness of decision makers and policy makers on the dangers resulting from inappropriate land and soil management to the global well being, and leading to a basis for the establishment of priorities for action programmes".**

The most direct way to create awareness is a visual representation of the status of global soil degradation induced by human activity on a map, which should be accompanied by a small document illustrating not only where soil degradation due to inappropriate use of the land takes place or has taken place in the recent past, but also what the various off-site effects of soil degradation are, such as flooding; sedimentation of reservoirs, overblowing of structures, etc. etc.

Our aim is to present data on a map that can be conveniently displayed on an office wall. The map scale therefore is necessarily small. It has been agreed with UNEP to draw a base map from a world geographic map, which is prepared by means of Mercator projection. This implies a scale of 1:15 million at the equator; 1:13.7 million at latitude 60°. Such a map would cover a size of 270 x 130 cm. This small

map scale implies that many cases of soil degradation of local importance cannot be delineated, but may be indicated only by special symbols on the map. However, a base map, outlining the continents, country boundaries and major river systems at a working scale of 1:7,5 million will be supplied to the contractors.

3. DEFINITIONS

The balance between the attacking natural forces of climate - the climate aggressivity - and the natural resistance of the land against these forces determines the natural risk of degradation in a particular area. Human action can either increase or decrease this natural resistance of the land.

Definition: **Soil degradation is a process that describes human-induced phenomena which lower the current and/or future capacity of the soil to support human life.**

(The effect of perceived human-induced change in climate is not included in the framework of the objectives).

Although we will in general restrict ourselves to soil degradation, it is inevitable to indicate also important aspects of terrain degradation, particularly terrain degradation types such as deforestation, resulting in loss of biological diversity, and overgrazing, often - but not always! - leading to an infestation of undesirable weeds. "Terrain" being a more extensive concept than "Soils" includes soil, topography, vegetation cover, land use and hydrology.

It is not our intention to assess the relative fragility of an ecosystem. In other words, we do not intend to indicate and delineate the instantaneous present and future rate of degradation processes and the potential hazards that may occur under human influence. In our assessment we want to describe and delineate situations where the balance between climatic aggressivity and the potential resistance of the soil has been broken by human action. In other words, we want to describe the present status of human-induced soil degradation which can be defined mainly by the type and degree of soil degradation. However we also want an indication of the recent past medium-term estimated rate of soil degradation (i.e. averaged over the past 5 to 10 years).

Definition: **Type of soil degradation refers to the process that causes the degradation** (displacement of soil material by water and wind; in-situ deterioration by physical, chemical and biological processes).

Degree of soil degradation refers to the present state of degradation (slight, moderate, severe).

Recent past average rate of soil degradation refers to the apparent rapidity of the degradation process estimated and averaged over the past 5 to 10 years (slow, medium, rapid).

These three elements of soil degradation will be discussed in detail in section 4, 5, 6.

We have stressed repeatedly that we are only concerned with soil degradation types, degrees and recent past rates that are induced by human activity. This would exclude soil degradation occurrences that have occurred in the past as a result of geologic events or under past climatic conditions, such as the rising (uplifting) of mountain chains; volcanic eruptions and the subsequent erosion of fresh lava and ash materials; the melting of glaciers; rising and subsiding of ocean levels, occurrence of pluvial or interpluvial periods, etc. However, the final map should indicate those areas where natural erosion has lead to extreme conditions, such as deserts, salt flats, rock outcrops, etc. Deserts could still be a source of danger to the lands around its edges by sand blasting and drift. In an analogous manner a salt flat is a source of salt, capable of causing salinization of the terrain around it.

We are concerned in this project with the status of human-induced soil degradation at the present time. However it should be realized that soil degradation under human influence has taken place in the past as well. The following three periods are recognized.

a) Early civilization occurring in the ancient past and up to 250 years ago.

b) Era of European expansion in the Americas, Australia, Asia and Africa. 50 to 250 years ago.

c) Post Second World War period, very much related to the human population explosion, particularly taking place in the third world countries.

In many parts of the world soil degradation occurred at various times in the past, and subsequently the land surface has come to equilibrium with the causative factors. The time periods for these changes in rate to occur are very variable. (Much of the rangeland in Australia has eroded seriously in the past, but has now become stable again).

Finally we have to stress that only a limited number of events can be delineated and mapped on a world soil degradation map at an average scale of 1:10,000,000. This can only be done with the assistance of experts having a good knowledge of the soil conditions in the various regions. In these guidelines we provide a limited number of keys to facilitate the description of type, degree and present rate of soil degradation in order to enhance the uniformity of delineation. We realize that the interpretation is to a certain extent subjective, but believe that it will be possible to come to a cooperative effort to a first assessment of global soil degradation.

4. TYPES OF DEGRADATION PROCESSES

We recognize two categories of human-induced degradation processes.

The first category deals with soil degradation by displacement of soil material. In this category we can distinguish between on-site effects, which are effects at or near the site ("on-farm" effects), including local depositions, and off-site effects, which are effects at a distance from the site (at least one km. away).

The second category describes soil degradation types as a result of internal soil deterioration. In this category only in-situ effects are recognized on soil that has been abandoned or forced into less intensive usages. It does not refer to the cyclic fluctuations of soil chemical, physical, or biological conditions of relatively stable agricultural systems, in which gradual changes in the chemical composition as a result of soil forming processes.

There is another category of human-induced terrain degradation. We refer to vegetation related degradation processes, such as deforestation, overgrazing of the land, often leading to an invasion of undesirable obnoxious, unpalatable weeds or shrubs. These human-induced terrain degradation processes will be considered as causative factors of the previously indicated two categories of soil degradation processes.

The following types of soil and land degradation processes should be recognized and delineated on the map. Off-site effects will generally not be delineated but "flagged" by special symbols (see section 8.4.6).

4.1 DEGRADATION BY DISPLACEMENT OF SOIL MATERIAL

4.1.1 Water erosion

on-site: 1) Loss of topsoil. A uniform loss by surface wash and sheet erosion.

2) Terrain deformation. An irregular displacement of soil materials, characterized by major rills, gullies, or mass movement.

off-site: 1) Reservoir harbour and lake sedimentation.

2) Flooding, including riverbed filling; riverbank erosion; excessive siltation of basin land.

3) Coral, shellfish beds and seaweed destruction.

4.1.2 Wind erosion

on-site: 1) Loss of topsoil. A uniform displacement by deflation.

2) Terrain deformation. An uneven displacement characterized by major hollows, hummocks or dunes.

off-site: 1) Overblowing, such as encroachment on structures as roads, buildings and/or sand blasting of vegetation.

4.2 DEGRADATION BY INTERNAL SOIL DETERIORATION

4.2.1 Chemical deterioration

1) Loss of nutrients, often leading to seriously reduced production (e.g. accelerated acidification of soils in the humid tropics).

2) Pollution and acidification from bio-industrial sources. Excessive addition of chemicals (organic manure, acid rain, etc.).

3) Salinization, caused by human-induced activities such as irrigation.

4) Discontinuation of flood induced fertility. (This may occur as a result of any conservation method, that controls flooding and will lead to a discontinuation of natural replenishment of nutrients by flooding).

5) Other chemical problems, such as catclay formation upon drainage of some coastal swamps; negative chemical changes and development of toxicities in paddy fields. To be specified by the regional correlator.

4.2.2 Physical deterioration

1) Sealing and Crusting of topsoil.

2) Compaction, caused by heavy machinery on a soil with weak structure stability, or on soils in which humus is depleted.

3) Deterioration of the soil structure due to dispersion of soil material by Na (and Mg) salts in the subsoil (sodication).

4) Waterlogging; human-induced soil hydromorphism; flooding and submergence (excluding paddy fields).

5) Aridification; human-induced changes of the soil moisture regime towards an aridic regime, caused for instance by lowering of the local base ground water level (deep groundwater depletion excluded).

6) Subsidence of organic soils (by drainage, oxidation).

4.2.3 Biological deterioration

1) Imbalance of (micro)biological activity in the topsoil. This can be caused by deforestation in the humid tropics or by overemphasis of chemical fertilizer applications in industrialized countries.

4.3 CAUSATIVE FACTORS OF SOIL DEGRADATION

1) Overgrazing of pasture lands, when extensive areas of land have been completely cleared of its original vegetation.

2) Deforestation, caused by burning or logging: "slash and burn" system.
(In both types there is a loss of biological diversity often leading to a secondary type of vegetation with predominantly obnoxious and unpalatable weeds and shrubs).

3) Over intensive annual cropping

5. DEGREE OF PRESENT DEGRADATION

Recognition of the degree to which the soil is presently degraded, can be done in relation to its agricultural suitability, but also in relation to its biotic functions. In some cases the degree of present degradation can be related to declined productivity. We recognize the following degrees of soil degradation:

None: there is no sign of present degradation from water or wind erosion, from chemical, physical or biological deterioration; all original biotic functions are intact. Such land is considered stable (see also section 8.4.7).

Slight: the terrain is suitable for use in local farming systems, but with somewhat reduced agricultural productivity. Restoration to full productivity is possible by modifications of the management system. Original biotic functions are still largely intact.

Moderate: the terrain is still suitable for use in local farming systems, but with greatly reduced agricultural productivity. Major structural alterations are required to restore productivity (e.g. draining for water logging or salinity; contour banks if the land is eroding). Original biotic functions partly destroyed.

Severe: the terrain is unreclaimable at the farm level. Major engineering works are required for terrain restoration. Original biotic functions largely destroyed.

Extreme: the terrain is unreclaimable and impossible to restore. Original biotic functions fully destroyed. The terrain has become non-vegetated and non-used wasteland (see also section 8.4.8).

These generalized descriptions allow for some flexibility by the regional correlators to determine the present degree of degradation. Some descriptive terrain components and examples of possible circumstances are given for a slight, moderate, and severe degree of present degradation of water- and wind erosion; salinization, and nutrient decline.

5.1 DEGREE OF PRESENT DEGRADATION DUE TO WATER EROSION

1) Slight: In deep soils (rooting depth more than 50 cm): part of the topsoil removed, and/or with shallow rills 20-50 m apart. In shallow soils (rooting depth less than 50 cm): some shallow rills at least 50 m apart. In pastoral country the groundcover of perennials of the original/optimal vegetation is in excess of 70%*[2].

2) Moderate: In deep soils: all top soil removed, and/or shallow rills less than 20 m. apart or with moderately deep gullies 20-50 m. apart. In pastoral country: groundcover of perennials of the original/ optimal vegetation ranges from 30% to 70%*.

3) Severe: In deep soils: all topsoil and part of subsoil removed, and/or with moderately deep gullies less than 20 m. apart. In shallow soils: all topsoil removed: lithic or leptic phases or with exposed hardpan. In pastoral country: groundcover of perennials of the original/optimal vegetation is less than 30%*.

5.2 DEGREE OF PRESENT DEGRADATION DUE TO WIND EROSION

1) Slight: In deep soils: topsoil partly removed and/or with few (10-40% of the area) shallow (0-5 cm) hollows. In shallow soils: very few (10% of the affected area) shallow (0-5 cm) hollows. In pastoral country: groundcover of perennials of the original/optimal vegetation is in excess of 70%*.

2) Moderate: In deep soils: all topsoil removed; and/or with common (40-70% of the area) shallow (0-5 cm) or few (10-40% of the area) moderately deep (5-15 cm) hollows. In shallow soils: topsoil partly removed and/or few (10-40% of the area) shallow (0-5 cm) hollows. In pastoral country: groundcover of perennials of the original/optimal vegetation ranges from 30%-70%*.

---

[2] Known maximum coverage of perennials under good management as practiced during some time in the past.

3) Severe: In deep soils: all topsoil and part of subsoil removed and/or with many (>70% of the area) shallow (0-5 cm) or common (40-70% of the area) moderately deep (5-15 cm) or few (10-40% of the area) deep (>15 cm) hollows/blowouts. In shallow soils: all top soil removed: lithic or leptic phases or with exposed hardpan. In pastoral country: groundcover of perennials of the original/optimal vegetation is less than 30%*.

5.3 DEGREE OF PRESENT DEGRADATION DUE TO SALINIZATION

Salinization should be considered as the relative change over the last - 50 years in salinity status of the soil, the latter being defined as follows:

non-saline:	electrical conductivity	less than 5 dS/m;	E.S.P. <15%; pH<8.5.
slightly saline:	electrical conductivity	5-8 dS/m;	E.S.P. <15%; pH<8.5.
moderately saline:	electrical conductivity	9-16 dS/m;	E.S.P. <15%; pH<8.5.
Severely saline:	electrical conductivity	more than 16 dS/m;	E.S.P. <15%; pH<8.5.

The present degree of human-induced salinization can now be identified as a change in salinity status as follows:

1) Slight: from non-saline to slightly saline; from slightly to moderately saline, or from moderately saline to severely saline.

2) moderate: from non-saline to moderately saline; or from slightly saline to severely saline.

3) severe: from non-saline to severely saline.

5.4 DEGREE OF PRESENT DEGRADATION DUE TO NUTRIENT DECLINE

Criteria to assess the degree of present degradation are the organic matter content; the parent material; climatic conditions. The nutrient decline by leaching or by extraction by plant roots without adequate replacement is identified by a decline in organic matter, P, CEC (Ca, Mg, K).

1) Slight: Cleared and cultivated grassland or savannas on inherently poor soils in tropical regions. Cleared or cultivated formerly forestland in temperate regions on sandy soils, or in tropical (humid) regions and soils with rich parent materials.

2) Moderate: Cleared and cultivated grassland or savannas in temperate regions on soils high in inherent organic matter, when organic matter has declined markedly by mineralization (oxidation). Cleared and cultivated formerly forested land on soils with moderately rich parent materials in humid tropical regions, where subsequent annual cropping is not being sustained by adequate fertilization.

3) Severe: Cleared and cultivated formerly forestland in humid tropical regions on soils with inherently poor parent materials (soils with low CEC), where all above-ground biomass is removed during clearing and where subsequent crop growth is poor or non-existent and cannot be improved by N fertilizer alone.

4) Extreme: Cleared formerly forested land with all above ground biomass removed during clearing, on soils with inherently poor parent materials, where no crop growth occurs and forest regeneration is not possible.

6. RECENT PAST AVERAGE RATE OF SOIL DEGRADATION

Recognition of the recent past rate of human-induced soil degradation should be done in dependence of local population densities of human and animal form; also in dependence of climatic aggressivity or related to the degree of mechanization in the recent past. We are interested in an estimate of the present medium-term rate of soil degradation. Instances of soil degradation during critical periods should be totalled and averaged over the last 5 to 10 years in order to define whether the rate is slow, medium or rapid. In the report which will accompany the map, the reasons for indicating various rates should be explained as detailed as possible.

7. LAND AREA WITHIN MAPPING UNIT BEING AFFECTED

At the chosen scale it will not be possible to separate each type of soil degradation. Estimation of the frequency of occurrence of a certain type of degradation should come from local knowledge or through remote sensing. The frequency of occurrence of a certain type of degradation within each mapping unit is the percentage of land affected:

1. infrequent: 1-5 % of the terrain affected
2. common: 6-10 % of the terrain affected
3. frequent: 11-25 % of the terrain affected
4. very frequent: 26-50 % of the terrain affected
5. dominant: 51-100 % of the terrain affected

It should be noted that the category 0: 0% of the terrain affected, implies that no degradation occurs in the mapping unit. Therefore this category can be omitted.

8. METHODOLOGY:

On a regional level soil degradation induced by human action will be mapped using basemaps of an average scale of 1:7,500,000 presenting only the essential topographical phenomena like mountains, important rivers and townsites. These maps will be supplied by the GLASOD project.

The methdology of the assessment of human-induced soil degradation on a regional level will be the following:

8.1 PREPARATION

All the existing information on aspects related with soil degradation has to be collected and studied, included historic information. One of the tools might be the FAO Soil Map of the World scale 1:5.000,000. A list of relevant material available at ISRIC will be provided and if necessary black and white copies of maps will be provided on request. Other more detailed and most recent information about soils on a regional level is of utmost importance to update existing information. Copies or originals of maps and reports used and not present at ISRIC will be requested, and/or references of used materials should be listed.

Other specific fields of interest are climate, geology, hydrology, geomorphology, ecology, vegetation, erosion, land use, animal and population density. Existing small scale remote sensing material like satellite images are other tools that can be useful. Aerial photographs may also be used as these provide the possibility to see some soil degradation types on a test zone of the mapping unit, which are not visible on satellite images (e.g. gullies, siltation, relief, etc.).

8.2 CONSULTATION

To evaluate relevant aspects of human-induced soil degradation on a regional level it is suggested to consult specialists in related fields of each of the participating countries per region. Correlation of existing information on a regional level will be the main topic of these consultations together with the explanation of the GLASOD methodology.

8.3 MAPPING PROCEDURES

To map the state of soil degradation caused by human intervention the following steps are to be taken:

8.3.1 Subdivision of the region

Subdivide the region in physiographic units showing certain homogeneity of topography, climate, vegetation,ecology, soils, and land use. Animal and human population density (excluding town population density if possible) can be another diagnostic criterion. This subdivision must be done using existing soil association maps and others with the aid of remote sensing material. The smallest area that should be mapped is 1 x 1 cm (5625 km^2 at 1:7,500,000 scale). Only few exceptions are envisaged where compiled physiographic units at this scale are smaller than 1 x 1 cm. Most areas will be larger.

8.3.2 Evaluation of soil Degradation Status

Determine whether the delineated physiographic unit has human-induced soil degradation types or not. Evaluate their degree, recent past rate, and the extent of the land per physiographic unit being affected. The result of the evaluation process is a symbol for each of the relevant degradation processes, its degree, extent and recent past rate. These symbols must be inserted in the corresponding mapping units. Since it is possible that one polygon may consist of several soil degradation types, that type which affects the greatest area should be inserted in full; the other types should be listed in a separate matrix table per polygon (see example, section 8.6). Each polygon should therefore be given a unique number.

8.4 MAPPING SYMBOLS FOR POLYGONS AFFECTED BY SOIL DEGRADATION

8.4.1 Mapping symbols for soil degradation types

W : water erosion affected terrain
- **Wt** : loss of topsoil caused by water erosion
- **Wd** : terrain deformation caused by water erosion

E : wind erosion affected terrain
- **Et** : loss of topsoil caused by wind erosion
- **Ed** : terrain deformation caused by wind erosion

C : chemical deterioration of the soil
- **Cn** : loss of nutrients
- **Cp** : pollution and acidification from bio-industrial sources
- **Cs** : salinization
- **Cd** : discontinuation of flood-induced fertility
- **Co** : other chemical problems

P : physical deterioration of the soil
- **Pk** : crusting/sealing of topsoil
- **Pc** : compaction
- **Ps** : soil structure deterioration due to dispersing action of salts in the subsoil
- **Pw** : waterlogging
- **Pa** : aridification
- **Pl** : subsidence of organic soils

B : biological deterioration
- **Bb** : imbalance of (micro) biological activity

As indicated earlier human-induced terrain degradation, as a result of deforestation, or overgrazing, or intensive annual cropping will not be considered as a separate type of soil degradation, but specific symbols for these types should be added immediately after the symbol for the soil degradation type:

f : deforestation as causative factor
g : overgrazing as causative factor
i : over intensive annual cropping as causative factor
o : other forms
Example: **Wdf** : terrain deformation by water erosion caused by deforestation.

8.4.2 Mapping symbols for the degree of soil degradation:

<u>slight</u>:	**use of lower case letter of degradation type, w..., e..., c..., p..., b...**
<u>moderate</u>:	**use upper case letter of degradation type, W..., E..., C..., P..., B..**
<u>severe</u>:	**underline upper case letter of degradation type, <u>W</u>..., <u>E</u>..., <u>C</u>..., <u>P</u>..., <u>B</u>....**
<u>extreme</u>:	**encircle upper case letter of degradation type, Ⓦ.., Ⓔ., Ⓒ., Ⓟ., Ⓑ.**

8.4.3 Mapping symbols for the extent of the terrain affected:

1 : infrequent(1-5% of the terrain affected)
2 : common(6-10% of the terrain affected)
3 : frequent(11-25% of the terrain affected)
4 : very frequent(26-50% of the terrain affected)
5 : dominant(more than 50% of the terrain affected)

These numbers should be placed immediately after the degradation type symbol. e.g. Cs1 - severe salinization problem in 1-5% of the mapping unit.

8.4.4 Mapping symbol to indicate the recent past rate of human-induced degradation

1 : slow
2 : medium
3 : rapid

These numbers should be placed after the number indicating the land area percentage affected. e.g. Cs12 - this mapping unit has an infrequent (1-5%) frequency of occurrence of severe salinization taking place at a medium rate.

8.4.5 Mapping symbols to indicate human-induced soil degradation in the past

(a): early civilisation (more than 250 years ago).
(b): era of European expansion (50 to 250 years ago).

These symbols should be placed after the number, indicating the present rate of human-induced soil degradation, or after the mapping symbol for stable land (see section 8.4.7).

8.4.6 Mapping symbols for off-site effects

Evaluate off-site effects. Man induced wind and water erosion might cause off-site effects that have to be evaluated. Each of the off-site effects will be represented by "flagging", by means of an arrow or coloured lines:

Wr sedimentation of reservoir, lakes
Wf flooding
Wc coral reef destruction
Eo overblowing

8.4.7 Mapping symbols for stable terrain

We refer to mapping units with no present human-induced type of soil degradation. In these mapping units the degree of present soil degradation is none (see section 5), although there may have been soil degradation in the past (see section 8.4.5). We cannot recognize two types of stable terrain: stabilization naturally, or stabilization as a consequence of human intervention. The following symbols are to be used:

SN: terrain is stabilized naturally (e.g. tundra, extensive natural forest, ice).
SH: terrain is stabilized by human intervention.
SHp: stabilized as a consequence of paddy (wetland rice) field bunding
SHc: stabilized as a consequence of conservation practices for rainfed foodcrops or other forms of permanent conservation measures.
SHr: stabilized as a consequence of reforestation, permanent plantation crops, etc.
She: stabilized as a consequence of empoldering.

8.4.8 Mapping symbols for non-used wasteland.

Mapping units of terrain that has reached ultimate degradation under natural conditions, that has become non-vegetated and/or non-used wasteland.

D: active dunes
Z: salt flats
R: rock outcrops
A: deserts
I: ice caps.

8.5 REPORT

A document with a detailed description of man-induced soil degradation should be prepared per region. This document contains a precise explanation of the different types of degradation processes, its degree, rate and relative importance as represented on the accompanying map or in the matrix (see section 8.6). All the criteria used for defining degree and rate of the different processes have to be explained very precisely to facilitate correlation on a worldwide level afterwards. Moreover, all kinds of soil degradation processes (on-site or off-site) in the region that are not mentioned in the matrix or that cannot be represented on the map because of the scale used should be described as detailed as possible, for instance man caused landslides, solifluction, on-site pollution, mine spoils and others.

The report should contain a complete list of all the collaborating scientists and institutes on a regional level and a list of all the existing material, maps and documents used during the evaluation process.

GLASOD MATRIX TABLE

PHYSIOGRAPHY : .... MAP UNIT: ....
.... SYMBOL: ....
SOILS : .... COUNTRY: ....
.... REGION: ....
GEOLOGY : .... AREA (KM^2): .....
CLIMATE(an.mn.) :P(mm) ... PE(mm) ... T(°C) .. COMPILATOR: .....
POP.DENS.(I/km2) : ....
LAND USE : .... EXPERTS: ....
VEGETATION : ....

	TYPE	CAUS	DEGR	RATE	EXT.	RATE ON DEGRADATION TYPE
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

GENERAL REMARKS: ....
....
....
....
....
....

ADDENDA

I. section 4.2.1. sub. 5. **Other chemical problems.**

In this group gleysation as a result of waterlogging can be included.

II. section 4.2.2. **Physical Deterioration.**

In this type of soil degradation two other human-induced forms are suggested:

7) Cryoturbation and solifluction, caused by human-induced disturbance of the layer over the permafrost in the taiga/tundra areas.

8) Concrete or tarmac (asphalt) covered areas; of particular importance in densely populated and industrial areas.

III. section 4.3. **Causative factors of Soil Degradation.**
This section needs some more elaboration. It will read as follows:

4.3 Causative factors of Human-induced Soil Degradation. Soil degradation can be caused by exploitation of the original vegetative cover, either through deforestation or through over-exploitation for consumptive use (fuel source, fence materials etc.). Exploitation of the original vegetation cover results in a loss of biological diversity often leading to a secondary type of vegetation with predominantly obnoxious and unpalatable weeds and shrubs.

It can also be caused by over-intensive use of the agricultural land, either by overgrazing of pasture lands, or by using heavy machinery, by intensive (an) organic fertilizer practices, by irrigation etc. Finally soil degradation can be the result of (bio)-industrial waste. The causative factors of soil degradation are grouped in the following categories:

1) Deforestation, (burning for clearing land or logging: "slash and burn")

2) Over-exploitation of vegetative cover for human (e.g. for fuel use, as fence material).

3) Over-grazing of pasture lands; extensive areas of land have been completely cleared of its original vegetation.

4) Over-intensive use of agricultural land; e.g. heavy machinery; intensive fertilizer use (inorganic and organic); irrigation.

5) Bio-Industrial waste. (contamination of ground water; acid rain, etc.).

IV. Section 8.3.2 **Evaluation of Soil Degradation Status**. This section is rephrased to stress that often one mapping unit consists of several soil degradation types, which cannot be inserted on the base map because of lack of space.

8.3.2 Evaluation of Soil Degradation Status per mapping unit.

Give each mapping unit a unique number. Determine for each delineated mapping unit whether it includes one or more human-induced soil degradation types or not. Evaluate for each type the degree, recent past rate and the relative extent of the land per mapping unit being affected. The result of this evaluation process is a symbol for each of the relevant degradation processes as will be discussed in section 8.4. These symbols should be listed in the matrix table (section 8.6). The type which affects the largest area per mapping unit should be listed first, to be followed by other types that may also occur in the same mapping unit.

Insert on the base map in each mapping unit its unique number as well as the mapping symbol for the type which affects the largest area of that mapping unit.

If the mapping unit is not affected by any type of human-induced soil degradation, mapping symbols as discussed in section 8.4.7 or 8.4.8 should be used.

V. section 8.4.1. **Mapping symbols for soil degradation types**

As a result of suggested changes mentioned above in remarks I and II, the following additional mapping symbols for soil degradation types are to be used:

Cg: gleyzation

Pt: cryoturbation and solifluction

Pu: concrete or tarmac (asphalt) covered areas.

As a result of suggested changes mentioned in remark III the following additional mapping symbols for causative factors are to be used:

i: over-intensive use of the agricultural land

e: over-exploitation of vegetative cover for consumptive use

w: (Bio)-industrial waste.

VI. section 8.4.7. **Mapping symbols for stable terrain.**

In this category terrain that is stable (either because of a permanent natural vegetation cover, or because of a permanent agricultural cover) is distinguished from terrain that is stabilized as a consequence of human interaction. In this category the degree of present soil degradation is none, although there may have been soil degradation in the past (see section 8.4.5). The following symbols are to be used:

SN: Terrain is naturally stable (e.g. tundra, extensive natural forest; marshes/swamps.

SA: terrain is stable as a consequence of a permanent agriculture type of land use (without conservation intended practices).

SH: terrain is stabilized by human intervention (conservation practices).

Shp: stabilized as a consequence of paddy (wetland rice) field terracing.

SHc: stabilized as a consequence of conservation practices for rainfed crops or other forms of permanent conservation measures.

SHr: stabilized as a consequence of reforestation, permanent plantation crops etc.

SHe: stabilized as a consequence of empoldering.

VII. section 8.4.8 **Mapping symbols for non-used wasteland**

The heading of this section is changed and another group is included: land that is being degraded at present under natural conditions, but that has not yet reached a state of ultimate degradation. The new version reads as follows:

8.4.8 **Miscellaneous terrain types**

In this category we recognize terrain that is being degraded at present or that has reached ultimate degradation under natural conditions and that is or has become non-vegetated and/or non-used wasteland.

Mapping symbols:

U: unstable land, undergoing present natural degradation

D: active dunes

Z: salt flats

R: rock outcrops

A: deserts

I: ice caps

VIII **8.6. Matrix table**

(This section is added to the original version to emphasize the importance of the matrix table).

The matrix table which accompanies the soil degradation status map, should be prepared for each mapping unit, which has been delineated. This table is a listing of all types of soil degradation, caused by human activity, their degree, relative extent, recent past rate and causative factor as recognized in that mapping unit. The table could be complemented with the relative extent of the mapping unit, which is stabilized, has reached ultimate degradation, or is undergoing natural degradation.

The lower part of the matrix table can be used for descriptive remarks by the correlator.

Annex 8.6.1 gives an example of the information for a mapping unit, that is required.

GLASOD GUIDELINES: CONDENSED SUMMARY

DEGRADATION TYPES

W : water erosion affected terrain
- **Wt** : loss of topsoil caused by water erosion
- **Wd** : terrain deformation caused by water erosion

E : wind erosion affected terrain
- **Et** : loss of topsoil caused by wind erosion
- **Ed** : terrain deformation caused by wind erosion

C : chemical deterioration of the soil
- **Cn** : loss of nutrients
- **Cp** : pollution and acidification from bio-industrial sources
- **Cs** : salinization
- **Cd** : discontinuation of flood-induced fertility
- **Cg** : gleysation as a result of waterlogging
- **Co** : other chemical problems

P : physical deterioration of the soil
- **Pk** : crusting/sealing of topsoil
- **Pc** : compaction
- **Ps** : soil structure deterioration due to dispersing action of salts in the subsoil
- **Pw** : waterlogging
- **Pa** : aridification
- **Pl** : subsidence of organic soils
- **Pt** : cryoturbation and solifluction caused by human induced disturbance of the permafrost layer
- **Pu** : concrete/tarmac/asphalt-covered areas

B : biological deterioration
- **Bb** : imbalance of (micro) biological activity

NON-DEGRADED LANDS

S: stable terrain
- **SN:** Terrain is stablilized naturally
- **SA:** stable by permanent form of agriculture
- **SH:** terrain is stabilized by human intervention
  - **SHp:** stabilized by paddy field bunding
  - **SHc:** stabilized by conservation practices
  - **SHr:** stabilized by reforestation, permanent plantation crops etc.
  - **SHe:** stabilized by empoldering.

U: unstable terrain

MISCELLANEOUS LAND TYPES

- **D** : active dunes
- **Z** : salt flats
- **R** : rock outcrops
- **A** : deserts
- **I** : ice caps

CAUSE

- **f** : deforestation
- **g** : overgrazing
- **i** : over-intensive annual cropping
- **e** : over-exploitation of vegetation for consumptive use
- **w** : industrial waste.
- **o** : other (to be specified)

RATE

- 1 : slow
- 2 : medium
- 3 : rapid

EXTENT

- **1** : infrequent (1-5% of the terrain affected)
- **2** : common (6-10% of the terrain affected)
- **3** : frequent (11-25% of the terrain affected)
- **4** : very frequent (26-50% of the terrain affected)
- **5** : dominant (> 50% of the terrain affected)

REMARKS ON DEGRADATION TYPE

Any description that specifies the nature and location of the distinguished degradation type within the mapping unit.

Descriptions may refer to landscape units (i.e. interfluves, floodplains, plateau edges), geographical location (i.e. north, south-east) or agricultural practices (i.e. state farms, cattle drinking places).

HISTORY (in general remarks, if specified)

- a : early civilization (more than 250 years ago)
- b : era of European expansion (50 to 250 years ago)

DEGREE - GENERAL

None: there is no sign of present degradation: all original biotic functions are intact. Such land is considered stable.

Slight: the terrain is suitable for use in local farming systems, but with somewhat reduced agricultural productivity. Restoration to full productivity is possible by modifications of the management system. Original biotic functions are still largely intact.

Moderate: the terrain is still suitable for use in local farming systems, but with greatly reduced agricultural productivity. Major structural alterations are required to restore productivity (e.g. draining for water logging or salinity; contour banks if the land is eroding). Original biotic functions partly destroyed.

Severe: the terrain is unreclaimable at the farm level. Major engineering works are required for terrain restoration. Original biotic functions largely destroyed.

Extreme: the terrain is unreclaimable and impossible to restore. Original biotic functions fully destroyed. The terrain has become non-vegetated and non-used wasteland.

DEGREE - WATER

1) **Slight:** In deep soils (rooting depth > 50 cm): part of the topsoil removed, or shallow rills 20-50 m apart. In shallow soils (rooting depth < 50 cm): some shallow rills at least 50 m apart. In pastoral country the groundcover of perennials of the original/optimal vegetation is > 70%*.
2) **Moderate:** In deep soils: all top soil removed, or shallow rills less than 20 m. apart or with moderately deep gullies 20-50 m. apart. In shallow soils: part of topsoil removed, or shallow rills 20-50 m apart; In pastoral country: groundcover of perennials of the original/optimal vegetation from 30% to 70%*.
3) **Severe:** In deep soils: all topsoil and part of subsoil removed, or with moderately deep gullies less than 20 m. apart. In shallow soils: all topsoil removed: lithic or leptic phases or with exposed hardpan. In pastoral country: groundcover of perennials of the original/optimal vegetation is <30%*.

DEGREE - WIND

1) **Slight:** In deep soils: topsoil partly removed or few (10-40% of the area) shallow (0-5 cm) hollows. In shallow soils: very few (<10%) shallow hollows. In pastoral country: groundcover of perennials of the original/optimal vegetation is > 70%*.
2) **Moderate:** In deep soils: all topsoil removed; or with common (40-70% of the area) shallow (0-5 cm) hollows or few (10-40%) moderately deep (5-15 cm) hollows; In shallow soils: topsoil partly removed or few (10-40%) shallow (0-5 cm) hollows. In pastoral country: groundcover of perennials of the original/optimal vegetation from 30%-70%*.
3) **Severe:** In deep soils: all topsoil and part of subsoil removed or with many (>70% of the area) shallow (0-5 cm) or common (40-70%) moderately deep (5-15 cm) or few (10-40%) deep (15 cm) hollows/blowouts. In shallow soils: all top soil removed: lithic or leptic phases or with exposed hardpan. In pastoral country: groundcover of perennials of the original/optimal vegetation is < 30%*.

DEGREE - SALINIZATION

Salinization should be considered as the relative change over the last 50 years in salinity status of the soil.

non-saline:	EC < 5 mS/cm; E.S.P. <15%; pH<8.5.
slightly saline:	EC 5-8 mS/cm; E.S.P. <15%; pH<8.5.
moderately saline:	EC 9-16 mS/cm; E.S.P. <15%; pH<8.5.
Severely saline:	EC >16 mS/cm;E.S.P. <15%; pH<8.5.

The present degree of human-induced salinization can now be identified from the change in salinity status.

1) **slight:** salinity increase 1 class
2) **Moderate:** salinity increase 2 classes
3) **severe:** salinity increase 3 classes

DEGREE - NUTRIENTS

1) **Slight:** Cleared and cultivated grassland or savannas on inherently poor soils in tropical regions. Cleared or cultivated formerly forestland in temperate regions on sandy soils, or in tropical (humid) regions on soils with rich parent materials.

2) **Moderate:** Cleared and cultivated grassland or savannas in temperate regions on soils high in inherent organic matter, when organic matter has declined markedly by mineralization (oxidation). Cleared and cultivated formerly forested land on soils with moderately rich parent materials in humid tropical regions, where subsequent annual cropping is not being sustained by adequate fertilization.

3) **Severe:** Cleared and cultivated formerly forestland in humid tropical regions on soils with inherently poor parent materials (soils with low CEC), where all above-ground biomass is removed during clearing and where subsequent crop growth is poor or non-existent and cannot be improved by N fertilizer alone.

4) **Extreme:** Cleared formerly forested land with all above ground biomass removed during clearing, on soils with inherently poor parent materials, where no crop growth occurs and forest regeneration is not possible.

Appendix 2

DESERTIFICATION AND ITS CONTROL IN ISLAMIC REPUBLIC OF IRAN

M.R. Ganji and Ali Farzaneh
Bureau of Sand dune Fixation and Combating Desertification
Forestry and Range Organization
Ministry of Agriculture
Islamic Republic of Iran

Presented to the Ad-Hoc Consultation Meeting "Assessment of Global Desertification: Status and Methodologies"

February 1990, UNEP, Nairobi-Kenya

INTRODUCTION

With a total land area of about 165 million hectares, Iran is the second largest country in the Middle East. It is one of the most ancient countries with a history of man's presence dating back about 6,000 years. The country now consists of 24 provinces, which extend from latitude 26° to 38° north and from longitude 44° to 63° east.

Because of this wide range in latitude and longitude, Iran is also one of the most variable from the standpoint of physiography, climate, vegetation, and biological productivity. While the whole of the Caspian Coastal plain is below sea level, the majestic Mt. Damavand (5, 766 meters) is the highest peak between the Alps and Himalaya. Although Iran's climate is characterized by aridity, with more than 30% of the country receiving less than 100 millimeters of precipitation annually, much of Gilan Province (in the Caspian Area) receives from 1000 to 2000 millimeters annually. The perpetual snows of a number of the mountain summits contrast strongly with the intense summer heat of the low lying desert areas. Plant cover varies from the sparse sand dune and salt desert vegetation to the lush Caspian Flora and the forests of oak, beech and other species, on the slopes of the Elburz Mountains.

Four main physiographic provinces can be distinguished in Iran:

(1) The Elburz and Zagros Mountain ranges and their extension,

(2) The Caspian Sea Coast,

(3) The Khuzistan and Southern Coastal Plains and

(4) The Central Plateau (Dewan and Famouri 1964). Although aridity is extending into adjacent zones, the major arid and semi-arid rangelands are found in the two last provinces.

LAND USE IN IRAN

The traditional land use in Iran has been divided between crop production and livestock grazing. Due to the steady increase in village population which has resulted in demand for more arable land, the area of range and forest has been decreased drastically. Here is the last estimation of the different land use types in Iran

Land use Classification

Type	Area (ha)	percent
Rangeland	90,700,000	55
Deserts, Desertified & degraded lands	34,600,000	21
Forests	12,200,000	7.4
Agricultural land	23,800,000	14.4
Cities, lakes, etc.	3,700,000	2.2
	165,000,000	100

DESERTIFICATION IN IRAN

Most parts of the country is covered by arid and semi arid lands in which the average annual rain fall is less than 300 mm, and potential evapotranspiration is many times more than precipitation. For instance the average annual rainfall in the central part of Iran and the Dasht-e-lut is less than 50 mm and the evapotranspiration is more than 4000 mm. In such a condition the soil and vegetation do not have any opportunity to develop.

There is no need to mention that in such a situation the biological equilibrium is totally fragile and sensitive and it can be degraded easily, and the result of such degradation is a decrease in the biological productivity of agricultural lands and even of the areas covered by natural vegetation.

The historical evidence and statistics show that vast areas of Iran's central land mass now suffering aridity and desert like conditions had once been covered by the native hardy plants, forming valuable rangelands and even forests with the theoretically arid land. However the role of the environmental factor and climatological change in desertification is undoubtable. Much of the desertification can be attributed to human activities.

Undoubtedly, land degradation and soil erosion in the interior plateau of Iran has been closely associated with man's settlement and his activities. There are many evidences to prove this occurence during the past several centuries. But the land degradation and desertification has accelerated during last century, and especially during the last 25 years.

Out of many of the desertification causes, the following are the most important:

1. DEMOGRAPHIC EXPLOSION

The population of the country has doubled during last 20 years. The need for more agricultural and animal products has forced the people to increase their livestock and to use the lands more extensively or to increase the agricultural land by converting and ploughing forested areas and rangelands or farming on

marginal lands, without any consideration of their real potentials. These activities in many cases have ended into desertification.

2. INCREASE IN HERDS AND OVER-GRAZING

Increasing demand for dairy products during recent years has caused the increase in the number of livestock. In addition to over-grazing due to excessive livestock numbers most ranges are grazed too early in the spring or are grazed too long and at the wrong season.

3. CONVERSION OF RANGELANDS INTO CROPLANDS AND INCREASE OF DRY FARMING

In recent years, ploughing of rangelands which are located on the mountainous areas and slopes has increased as the demand for cereals has increased. Because the condition of these lands is not suitable for agricultural practices they are eventually abandoned with greatly reduced value for grazing, and vulnerable to the desertification process.

4. UNCONTROLLED USE OF FARM MACHINERY

Villagers and farmers can now obtain farm machinery easily. Most of these imported equipment is not suited for use in arid and semi arid areas of Iran. This machinery not only permits much more extensive operations than the traditional equipments, but are used to plough more rangelands and to transport more cut trees and bushes from the range and forest areas.

5. FUEL GATHERING

Despite the fact that the Islamic Republic of Iran is a rich oil country, only a few percent of villagers have been able to use petroleum fuel, before the Islamic revolution.

In addition to the demand for fuel for household cooking and heating needs, some factories use native woody fuels. Fuel gatherers harvest any woody plant, with no regard to its forage value, and so this practice is even more destructive than grazing.

6. IRREGULAR EXPLOITATION OF WATER RESOURCE AND THE MISMANAGEMENT OF IRRIGATION

Disregarding the aridity of region and lack of sufficient rainfall, to recharge the ground water basin, deep wells are dug and powerful water - pumps are used to exploit water. Overuse of water has led to the deterioration of the water quality and quantity in many areas of Iran, and excessive irrigation and inefficient drainage have converted many farm lands into saline and alkaline lands.

In the recent 50 years and before the Islamic revolution our economy used to be dependent capitalist. Abundant income from oil motivated capital formation in sectors other than productive sectors. Agriculture and natural resources as the back bone of the economic development and the true national treasures were neglected. For instance the over-all forest area of Iran which was 18 million hectares 30 years ago decreased to 12 million hectares.

Many villages were abandoned and villagers migrated to the cities, depleting rural areas of existing potential labour force necessary for development.

It is obvious that such exploitation and improper treatment of natural resources ends in the deterioration of land capability and decline in biological productivity, hence producing a clear evidence of desertification.

The scale at which desertification and land degradation is occuring in Iran might be estimated to be about 1% of total land.

Despite harmful effects of pre-revolution destruction on its socio-economic structure, and despite 6 years of imposed war by imperialism and hegemonism, the Islamic Republic of Iran considers its renewable natural resource as the life blood of agriculture and a basis for its political and economical independence. Forest and Range Organization as an independent section of Ministry of Agriculture has recently approved and executed the policies and programmes to revive and develop the renewable resources with special attention to biological productivity and desertification matters as follows:

1. Recognition and evaluation of existing renewable natural resources including area, boundary, location, situation, potential, present use, classification;
2. Clarification of land ownership;
3. Better protection of forests and rangeland against unmanaged use;
4. Resettlement of forest inhabitants in suitable locations;
5. Allocation of northern forest belt for industrial and commercial production;
6. Recognition and identification of areas potentially suitable for afforestation and wood and timber production;
7. Public involvement in range and forest activities through rural cooperation - Islamic societies, rural Islamic councils and private companies;
8. Utilization of volunteer forces such as students, army personnel, revolutionary corps, etc. for tree plantings;
9. Development and expansion of public parks and green belts around the cities and residential areas;
10. Promotion of small wood and timber industries;
11. Substitution of petroleum fuel to fuelwood in areas where ecological conditions necessitates vegetation protection;
12. Protection of rare and extinct species and introducing exotic species and varieties of plants;
13. Exchange of scientific and technical information and expertise with other countries and international agencies;
14. More active participation in international scientific organizations, particularly those affiliated with the United Nations;
15. Determination of all rangeland grazing capacity and issuing of grazing permits according to their capacities;

16. Rehabilitation of degraded rangeland through preparation of comprehensive improvement plans;
17. Development and mobilization of nurseries and seed propagation stations for range and forest seed and seedlings;
18. Conversion of less productive rainfed lands to hand planted ranges and pastures;
19. Extension of sand dune fixation activities in vulnerable areas, and conversion of barren sandy areas into productive vegetated lands;
20. Improvement of techniques and modes of application of petroleum by-produce for temporary shifting sand dune fixation, and in agriculture and range improvement;
21. Afforestation near rural areas to provide fuel wood;
22. Utilization of stabilized areas for parks, grazing lands and fuel wood cutting;
23. Increasing the numbers and capacity of natural resources educational and training centers and improving their qualities;
24. Taking advantages of mass media and public places such as mosques, schools, to increase the awareness of the public about the importance of renewable natural resources and the dangers of desertification;
25. Addition of new chapters in students textbooks about natural resources, land degradation and desertification;
26. Collection, centralization and distribution of scientific books, papers, documents and other publications relating to natural resources in centers accessible to scientists, experts, technicians and interested persons.

A new Forestry and Range Organization has been created consisting of Bureaus of Range Management, Sand Dune Fixation and Combating Desertification, Forest Management, Afforestation and Parks. Wood and timber plants and factories, observing the above mentioned goals and policies execute different long, medium and short term programmes.

Since the shifting sand dunes an a result of desertification has had a long history of damage to former agricultural lands, and great impact all over the country, the sand dune fixation activities as a measure to combat desertification has been at the center of consideration and will be discussed briefly.

THE SAND DUNE STABILIZATION PROJECT

Until 25 years ago damage to land and to property associated with sand movement and dune encroachment was increasing annually. Villages by the hundreds were being abandoned because they were actually being buried by sand. Fields were not planted because they would be buried beneath sand before the crop was ready to harvest. Newspapers frequently carried stories of trains being derailed, about airports being closed and mosques being buried. Air pollution was accepted as a natural characteristic of the affected regions. Life was generally miserable.

Awareness of the increasing severity of sand encroachment developed in about 1958. At this time 2 small demonstration areas to test mechanical methods of controlling sand drift were established about 30 km north of Ahwaz. Although these demonstrations were successful, no further activity was initiated until late 1965 and 1966, when Iranian experts returned from study tours in Russia and Pakistan.

The first truly serious effort to check the encroachment of dune fields was initiated in 1965 on 100 ha adjacent to the village of Haresabad near the city of Sabsevar and on two 10 ha plots near Ahwaz.

The work at Sabsevar demonstrated that dune stabilization was a feasible operation. Consequently, support for this project was increased. Today the project is operating 72 stations and sub stations in 12 provinces.

In 1968 the first trials with bitumen mulch were initiated at Fathabad near the vicinity of Eshtehardt. In 1969 the experimental mulching was applied to 500 ha. In 1970 1000 ha near Ahwaz were treated with mulch.

PROCEDURES AND METHODS

Because the project was initially conceived as an emergency measure with a primary objective of saving and protecting villages, mosques, communication systems, etc, project activities were concentrated on the most critical areas. Woody species are planted in plastic bags or in beds. Grasses are planted in beds. The planting schedule is such that woody species are three to six months old and 20 - 30 cm tall at the time when field planting should be done. Woody species are transplanted in plastic bags or as barefoot seedling. Grass species are planted as springs that are produced in the nursery or are obtained from plants already established in the project area. Table 1 shows the names of species used more frequently in dune stabilization in I. R. Iran.

Preparations for field planting vary with site conditions. If wind action is severe, palisades are constructed to lift the wind off the sand surface.

Use of bitumen mulch is another way to obtain immediate control of shifting dune fields.

The mulch project has developed from a rather humble beginning when a bituminous mixture was applied from hand sprayers and back packs to a highly sophisticated operation in which giant tanks mounted on sledges are pulled over the sand by track laying vehicles. The mulch is sprayed from nozzles mounted on long booms and from "jet" guns, so that a swath about 15 - 25 m wide is treated with each pass of the equipment.

Depending upon the site conditions, the transplants may be hand irrigated. Water may be supplied once, twice or thrice during the first field growing season and again in subsequent years. Water is supplied from tanks mounted on trucks or trailers.

Direct broadcast seeding of both woody and grass species has been done. Hand broadcasting and broadcasting from aircraft has been tried. Generally broadcasting has been less effective than transplanting.

All areas included in the stabilization projects are placed under protection. No cultivation or livestock grazing is permitted. As a result in most areas there has been, a good recovery of native vegetation in the inter-spaces between the planted species and in areas that were not treated. This recovery of native vegetation has been so substantial in the older project areas that some areas are open to controlled grazing and fuel wood gathering.

Table 1 Species used in dune stabilization in i. R. Iran

1.	*Aeaela farnesiana*	14.	*Olea* spp.
2.	*Albagi camelorum*	15.	*Panicum antidotale*
3.	*Aristida pinnata*	16.	*Pennisetum* spp.
4.	*Atriplex halimus*	17.	*Prosopis duliflora*
5.	*Atriplex canescens*	18.	*Prosopis spicigera*
6.	*Atriplex nemularia*	19.	*Prosopis stephaniana*
7.	*Calligonum polygonoides*	20.	*Sedlitsia* spp.
8.	*Eucalyptus camaldulensis*	21.	*Smirnovia Iranica*
9.	*Haloxylan aphylla*	22.	*Sueada Rosemarina*
10.	*Haloxylan persicum*	23.	*Tamarix Pallisei*
11.	*Imperata cylindrica*	24.	*Tamarix Stricta*
12.	*Leucaena leucocephala*	25.	*Ziziphus Spinachristi*
13.	*Nitraria schobeiri*	26.	*Zygophyllum Fabago*

The following are the achievements of the sand dune fixation programme up to the present time:

Activities	Quantity
Transplantation	898,526 ha
Broad cast seeding	2,027,675 ha
Palisade construction	9,556 km
Petroleum mulching	177,330 ha

These stabilized and afforested dunes naturally provide a much wider protection for surrounding areas, as it is estimated that more than 3 million hectares of sandy hills and desertified areas are rehabilitated.

Regarding widespread measures taken by Iranian experts in this field, especially by using oil by-product, the islamic Republic of Iran is capable to cooperate in combating desertification and sand dune fixation in other countries. In this connection we invite experts and interested peoples to Iran for close observation of our success.

RESEARCH AND STUDY PROGRAMMES FOR ARID AND SEMI-ARID LAND MANAGEMENT, DESERTIFICATION CONTROL, AND SAND DUNE FIXATION IN I. R. IRAN

Of Iran's total land area of 1,650,000 square kilometers arid and semi-arid lands occupies about 80%, therefore the importance of research and study programmes for management of arid lands and desertification control is evident. At the present time several institutes and organizations are working in various fields of desertification process, environmental degradation, economic and social impact of desertification, ways and means to solve the problems, and other related areas.

Here is a list of involved institutes and organizations:

1. Bureau of Sand Dune Fixation and Combating Desertification, Forestry and Range Organization, Ministry of Agriculture;

2. Department of Environment, Office of the Prime Minister;

3. Research Institutes of Forests and Rangelands, Research Organization of Agriculture and Natural Resources. Ministry of Agriculture;

4. Research Center for Arid Zone, Tehran University;

5. Center for Coordination of Environmental Studies, Tehran University;

6. Institute of Geography, Tehran University;

7. Center for Technical and Scientifical Research, Office of the President;

8. Different consulting engineers, private sectors;

9. Most of the Higher Educational Centres and Universities. The activities of these organizations and institutes are limited to very special subjects and case studies, and there is a need for establishment of a centre for coordination of all the activities and direction of the activities toward desertification control in the country and in the region.

In this connection we are willingly ready for more cooperation in the establishment of the research and training centres on desertification control in the ESCAP region.

We recommend to establish a centre in I. R. Iran and undoubtedly this centre could be able to cooperate with the present institutes and centres in the country and also use the physical and personnel facilities already available in these institutes and organizations.

Appendix 3

Desertification Control Activities in Japan

Soil and Agricultural Chemicals Division
Water Quality Bureau
Japan Environment Agency

February 1990

CONTENTS

1. INTRODUCTION

1.1 GLOBAL ENVIRONMENTAL PROBLEMS AND JAPAN

The environmental problems of today are not simply domestic matters of one country but cross border ones extending to encompass the entire earth.

After United Nations Conference on Human Environment in 1972, the environmental problems are realized prevalently as the common issues of mankind which must be addressed through the cooperation of all countries in the world. The counter-measures have been discussed under the initiative of the United Nations agencies led by the UNEP. However, the rapid growth of world population in recent years and expansion of socio-economic activities and the evolution of interdependent relationship between development and environment have caused the environmental problems to extend worldwide which may lead to its measures on a global scale. The recent report by the "World Commission on Environment and Development (WCED)" also recommends that the world should urgently take concrete action towards the sustainable development in order to preserve the hopeful future of the earth. At the summit of the 7 developed countries held in Paris in last July, leaders agreed that the necessity of the conservation of the global environment for the future generations as well as the importance of the continuation of the well balanced sustainable development of economics and facilitating of the developing countries in the economic declaration.

Japanese economic activity, which has become gigantic is heavily involved with the global environment, so we have a large responsibility to give our descendants a hopeful future on the earth. On the other hand, our country has abundant economic and technological powers but also much experience and accumulation of expertise in the area of environmental conservation, whereby we are having the potential of being able to contribute to the conservation of global environment. Treading the path of "a country contributing to the world", Japan, in view of the circumstances facing it which regard to the global environment and its position in the international society today, is being called upon and asked what contribution it can make to the conservation of future global environment.

Under these circumstances, the Japanese Government held "Tokyo Conference of the Global Environment and Human Response toward Sustainable Development" ("Tokyo conference") under the cooperation with U.N. in September 1989. The conference stressed the new concept "environmental ethics" which expressed that the individual person was responsible for the conservation of the global environment and should not waste resources.

Regarding the organization of the government, a Director General of the Environment Agency has been appointed the minister responsible for global environment problems. In addition to that the Japanese Government has established the Council of Ministers for Global Environmental Conservation consisting of 18 ministers to cooperate with each other much more since May 1989.

The Environment Agency set up the Ad Hoc Group on Global Environmental Problems to seek Japan's concrete approach to those problems responding to the WCED report. The Ad Hoc Group submitted the report to the Director General of the Environment Agency in June 1988. That report mentioned the various activities of the government and private sectors, and included the objectives in the medium to long term.

As for the administrative system in the Environment Agency, the Global Environment Protection Board was set up tentatively in May 1989 and the Office for the Conservation of the Global Environment was also established in the Planning and Coordination Bureau in October 1989.

The Office for the Conservation of the Global Environment was planned to be reorganized as a department to facilitate the measures in 1990.

In respect to the research, the Global Environmental Research Center (tentative translation) will be established within the National Institute for Environmental Studies (NIES) in October 1990, and 1.200 million yen expenditure for the Promotion of Global Environmental Research has been requested in fiscal year 1990.

1.2 DESERTIFICATION PROBLEMS AND JAPAN

Desertification is one of the severest global environmental problems. According to the UNEP, desertification is defined as the decline of land productivity in arid and semi-arid land areas which occupy approximately one third of all land areas, excluding the Antarctic continent. Approximately 6 million hectares of land, equivalent to the total area of Kyushu and Shikoku in Japan is becoming "desert" annually following the research of the UNEP carried out in 1977. Over 230 million people were seriously affected by desertification in 1983.

Japan consists of many islands located in the north western part of Pacific Ocean, and does not have any arid and semi-arid areas because annual average precipitation is about 1800 mm.

As mentioned above, Japan has shown a strong intention to support countries financially as well as technologically which are suffering from the desertification. For example, Japan proposed the "Green Innovation Plan in Africa", which included strengthening of agricultural research and promotion of afforestation at the Summit held in Bonn in 1985. Furthermore Japan has declared to expand the Official Development Aids (ODA) to 300 billion yen in coming three years at the Summit held in France in 1989.

As for the Environment Agency, the Ad Hoc Group on Global Environmental Problems pointed out that desertification was one of the severest global wide environmental problems, and counter-measures should be taken by Japan (see ANNEX I). The interim report of the Global Environment Protection Board suggested that Japan should always help countries solve desertification problems and also support the UNEP's desertification control activities.

2. PRESENT STATUS OF THE DESERTIFICATION CONTROL ACTIVITIES

2.1 ACTIVITIES OF THE GOVERNMENT

In Japan, seven ministries and agencies have been engaged in the desertification problems or the related problems.

The Environment Agency conducts the planning and cooperation regarding global environmental problems within the government as well as carries the environmental studies. Other ministries and agencies are implementing researches and measures according to their assignments. As for relations and cooperation with foreign countries, Ministry of Foreign Affairs manages them usually.

The sum of the expenditures relating to the desertification fully or partly in 1990 draft budget is about 3 billion yen.

A. The Environment Agency

The Environment Agency organized the Expert Committee on the Desertification Problems chaired by Prof. K. Kyuma of Kyoto University in January 1990 in order to collect information on the problems and discuss how to contribute to resolutions of the problems. The report of the committee will be published in May.

The Environment Agency will also establish the Department of Global Environment and the Global Environment Research Center in fiscal year 1990. The department will play a leading role in the government by coordinating the activities among the ministries and agencies.

[1990 Draft Budget]

(1) Global Environment Research Center (228 million yen)

The above mentioned center will be established in order to promote global environmental research.

(2) The expenditure for Promotion of Global Environment (1.2 billion yen).

The Expenditure allocated to institutions etc. in order to promote global environmental research in cooperation with national research institutes and universities.

B. The Science and Technology Agency

To facilitate the scientific studies on desertification, the Science and Technology Agency implemented preparatory study on desertification problems last year, and stated the five year study on the mechanism of desertification under the cooperation with China this year. NIES takes part in this project and plans to study the vegetation of deserts.

[1990 Draft Budget]

(1) The Research on the mechanisms etc. of the desertification.

The research of the present state of desertification, and its mechanisms etc. under cooperation with China (about 200 million yen (annual average, about 1 billion yen for five years).

C. The Ministry of Education

The Ministry of Education has prepared the budget for universitites to implement special study on desertification under cooperation with China since last year.

[1990 Draft Budget]

Japan-China cooperating study on interaction between ground and atmosphere in Kokuga area (84 million yen). The five year project to study on modelling of climatic change in Chinese arid area.

D. The Meteorological Agency

The Institute of Meteorology is developing the models to investigate the influence of the human activities on the world climate.

E. The Ministry of Agriculture, Forestry and Fisheries

The Ministry of Agriculture, Forestry and Fisheries has been conducting basic surveys on the measures relating to agriculture and forestry to prevent desertification, such as the research at the Niger river basin in West Africa.

[1990 Draft Budget]

(1) The basic survey on measures for environmental conservation relating to desertification (131 million yen).

The five year survey to prevent desertification at Niger river basin by developing the agricultural technology suitable for that area etc.

(2) The research on irrigation and soil characteristics in arid areas (28 million yen).

The Tropical Agriculture Research Center is carrying the research on the suitable way to irrigate the field etc.

(3) The research on pasture and its conservation technology in the African arid and semi-arid area (34 million yen).

The research on the present state of pasture and developing the technologies to increase the productivity and to conserve the pasture.

(4) The research on developing technological guidelines for reforestation in deserted area (29 million yen).

The research on suitable conditions of forestry in arid area and applicability of forestation developed in Japan to arid area through field experiments in order to make technical manual for reforestation.

(5) The basic survey on planning the agricultural resources management for global environment (41 million yen).

The research on the management of agricultural resources in order to support sustainable agricultural development harmonized with the conservation of the environment, and developing the guidelines for management.

F. The Ministry of International Trade and Industry

The Ministry of International Trade and Industry has been trying to increase agricultural productivity in arid areas by using water retentive materials such as asphalt (fiscal 1975-1981) and polymers (fiscal 1988-1992).

[1990 Draft Budget]

Cooperation on developing retentive polymers in arid areas (about 200 million yen).

G. The Ministry of Foreign Affairs

The Ministry of Foreign Affairs is engaged in managing ODA and has various activities through using it.

At Bonn Summit in 1985, Japan proposed the "Green Innovation Plan in Africa", which includes strengthening of agricultural research and promotion of afforestation. As a part of this Plan, Ministry of

Table 1 The Surveys and Studies on Desertification Problems which are carried by Universities in Japan in 1988

Title	University and person in charge	Area	Summary
The study on formative process of savanna in Africa	Department of Geography, Faculty of Science, Tokyo Metroporitan University, Dr. Hiroshi KADOMURA	Tropical countries in Africa	The integrated study on savanisation formed by the natural process and the human activity.
The basic study on planting trees in Huangdo highlands of China	Faculty of Agriculture, Tokyo University, Dr. Satoshi MATSUMOTO	China	The basic study on prevention of soil erosion.
The study to probe mechanism and analysis of desertification on dry land in China	Faculty of Agriculture, Tottori University, Dr. Akimi MATSUDA	China	The aim is to indicate the ways of preventing desertification and agricultural development based on investigation and experiment in China.
The survey and study on protection method and productivity of ecosystem in arid arable land accompanied by agricultural development	Faculty of Agriculture, Tottori University, Dr. Yoshinori TAKEUCHI	Guerreroneglo of Baji, California, Mexico	The aim is to develop sustainable agriculture and to improve productivity in desert.
The survey and study on management of irrigation water at sand desert in China	Faculty of Agriculture, Tottori University, Dr. Tomohisa YANO	China	The survey on natural environment and desertification control methods.
The study on desertification control at Kokuga basin in China	Faculty of global science, Tsukuba University, Dr. Masatoshi YOSHINO	China	The survey of meteorological, hydrological and thermodynamic condition.
The study on natural environment, land use for agriculture and disease in the tropical area of north-western Brazil	Faculty of global science, Tsukuba University, Dr. Masaki ICHIKAWA	Brazil	The study on influence of agricultural land use to natural environment and study on disease in the tropical area.

Table 1 The Surveys and Studies on Desertification Problems which are carried by Universities in Japan in 1988 (continued)

Title	University and person in charge	Area	Summary
The study of comparison of water supply systems through Kanooat	Faculty of Political Science and economics, Meiji University, Dr. Iwao KOBORI	China, Iran, North America, Arabian Peninsula	The study to solve problems of using ground-water in dry land.
The survey on the environment in Hisinchian Area in China	Faculty of Agriculture, Shizuoka University, Dr. Takuo TONDA	Hisinchian in China	The geographical and folklore survey on vegetation, people and desert.
The study of plantation of trees in desert	Faculty of Agriculture, Shizuoka University, Dr. Keiichirou MATSUDA	United Arab Emirates	The survey on planting trees, available irrigation and favourable growing crops for sand control.
The historical study on development of configulation of ground in dry land	Faculty of Science, Tokyo University, Dr. Yutaka SAKAGUCHI	Syria, Palmyra Basin	The study on configulation of ground and analysis of pollen etc.
The study on configulation of ground and meteorology on desertification	Faculty of Science, Tokyo University, Dr. Hiroo Oomori	Australia, China	The study on configulation of ground and formulation of dune, etc.
The ecological study of plant in dry land	Faculty of Agriculture, Tokyo University, Dr. Kazuhiko TAKEUCHI	Australia	The study on ecology of plant, planting trees and soil erosion.
The study on formation of sand-dunes	Faculty of Humanities and Sciences, Nihon University, Dr. Kunihiko ENDOU	Australia, USA, Syria, China	
The study on natural environment and residence in arid land	Faculty of Humilities, Rikkyo University, Dr. Hiroki TAKAMURA	Takla Makan Shamo in China	The study to probe cause of desertification and to develop measures against it.
The study on agricultural and regional change in land usually influenced by drought in India	Geographical Study Center, Hiroshima University, Dr. Kenzou HUJIWARA	Central and Western India	The study on change of natural environment by human activities.

Foreign Affairs has implemented the "Green Crops Plan" which carries out afforestation through sending the Japan Overseas Cooperation Volunteers organized by JICA.

Financial contribution to the UNEP will be 1020 million yen in fiscal 1990.

2.2. ACTIVITIES OF THE UNIVERSITITES

Besides governmental activities, universities in Japan are carrying out various researches and studies (see Table 1).

2.3 ACTIVITIES OF PRIVATE SECTOR

Regarding the activities of the private sector, the "Japan Afforestation Center" has been studying the systematization of afforestation technology since 1982, which focuses on the ecological afforestation of desert regions by utilizing the power of natural ecology. During fiscal 1986-1987, the center dispatched technology transfer teams to China as a part of support projects organized by Ministry of Agriculture, Forestry and Fisheries for the "Japan-China Economy Association". The "Japan Desert Development Association" carries a research on utilizing water retentive materials as consignment work.

In addition, many civilian groups, such as the "Association Sahel", have been carrying out cooperation on afforestation and agriculture.

Recently, some companies are carrying out the developing projects relating to desertification. For example, four companies have started "Sahelian Green Belt Project" jointly, which consist of construction of underground dam and irrigation by pumps moved by solar energy.

3. FUTURE DEVELOPMENT OF ACTIVITIES ON DESERTIFICATION PROBLEMS

Japan will make more effort not only financially but also technologically to combat the desertification problems.

As mentioned above, the Ad Hoc Group on Global Environmental Problems pointed out that Japan should proceed with various model projects at the countries concerned. For example, speaking of afforestation, proper afforested areas should be made as part of national or international "Plan to Combat Desertification".

The interim report of the Global Environment Protection board suggested that Japan should take entergrated measures to help countries solve desertification and also support the UNEP's desertification control activities.

According to these suggestions, Japan will take various activities such as enlargement of ODA budget making researces on the desertification problems.

Regarding technological cooperation, the Environment Agency has much concern about monitoring and predication of desertification by remote sensing using satellites, because it is one of the fields which Japan has much experience. The basic studies, such as to understand the physical mechanism of desertification, to develop dry-proof plants using bio-technology, to examine the activity of plants in deserts using an infrared camera and so on, are also important.

ANNEX 2 shows examples of remote sensing studies and others mainly by the NIES, which are applicable to desertification problems. Insufficient information is one of the main reasons to lose successful results of desertification control, it is very important to make up of desertification monitoring network under cooperation with countries and internatioal agencies. In this point, Japan Environment Agency considers it is possible to cooperate with the UNEP and, in Asian-Pacific region, the ESCAP.

The efforts taken by individual countries are important, however the international cooperation including both bilateral and multilateral base are much more important to take measures against desertification. So the Japan Environment Agency has been very much interested in the French "Sahara and Sahel Observatory" project which was supported politically at the Summit in 1989.

One of the main reasons why Japan has not been involved in the desertification control activities seriously is that the government and people lack the information of desertification. Few Japanese have been to the desert and almost all people have only very romantic images on the deserts. Japan Environment Agency is looking forward to contacting many countries and international agencies to get proper sufficient information. Based on that, the agency will be able to cooperate much closer with countries and agencies and contribute to the desertification control activities. We are sure Japanese people support our policy.

ANNEX 1:

JAPAN'S ACTIVITIES TO COPE WITH GLOBAL ENVIRONMENTAL PROBLEMS. THE AD HOC GROUP ON GLOBAL ENVIRONMENTAL PROBLEMS, JUNE 1988

CHAPTER 2: PRESENT STATUS OF GLOBAL ENVIRONMENTAL PROBLEMS AND COUNTERMEASURES TAKEN.

SECTION 3. GLOBAL ENVIRONMENTAL PROBLEMS MAINLY OCCURING IN DEVELOPING COUNTRIES.

(2) Desertification

1. Present Status and Problems

According to UNEP, desertification is defined as the decline of land to productivity in arid and semi-arid areas which occupy approximately two thirds of all land areas, excluding the Antarctic continent. The UNEP's survey (1977) indicated that approximately 6 million ha of land, equivalent to the total area of Kyushu and Shikoku in Japan, is wasted every year almost to the point at which land capability cannot be recovered. Another survey (1980) by UNEP mentioned that land areas with zero or minus productivity, including not fully desertified areas, incrfeases at a rate of 2.1 million ha per year. Reviewing the status of desertification by land-use categories, deterioration is significant in grazing land while it is slight in irrigated land.

The numbe of people affectec by serious desertification problems was estimated at 230 million in 1983. This figure increase dramatically from 70 million people in 1977, indicating that the process of deserertification has been intensified.

Desertification serisously affects the living standards of inhabitants. At first, as the food production is affected, famine and malnutrition will increase. The survey by FAO and UNEP show that African countries with severe food shortages overlap with the areas severely affected by desertification. Secondly shrotage of fuelwoods also threatens the livelihood of inhabitants. The shortage of fuelwoods is serious in arid and semi-arid areas. FAO reported that approximately 29.3 million people were severely affected by such a shortage in 1980. FAO also noted a possible vicious cycle in which further desertification would cause a change in climate, which in turn would trigger desertification.

2. Background

The causes of desertification can be divided into two categories, climatic and aritificial causes. Climatic causes include the movement of arid areas due to changes in atmospheric circulation on a global scale. Artificial causes include the impact of human activities (collection of fuelwoods, over-grazing) beyond the sustainable capacity of vulnerable ecosystems in arid and semi-arid areas.

Climatic causes are considered to be related to green-house effect induced by the increase of the concentration of carbon dioxide in the atmosphere (see 2 (l), depletion of tropical forest, and fluctuations of sea surface temperature, but the concrete relations between causes and effects are not yet identified. Artificial causes such as over-grazing, over-farming, and excessive collection of fuelwoods are related to the socio-economic background of the area, such as poverty and rapid population growth. At this point, the nature of the problem is the same as that of the tropical forests. The salinization of irrigated land is a

secondary artificial problem. When the irrigation is implemented to deal with the previously described socio-economic problems, excessive irrigation or leakage from the water path which leads to a rise in ground water levels, or utilization of ground water containing a large amount of salt, results in the accumulation of salt after the water evaporates.

Soil erosion is also closely relted to desertification. As a result of rapid population growth, agricultural land development in steep slope areas unfit for farming has led to soil erosion, which accelerates desertification. In arid areas easily lose fertile topsoil through erosion by the force of wind. This pehonomenon also accelerates desertification. The surveys by FAO and UNEP highlight the close overlap between easily eroded areas by the force of wind and areas of desertification process.

3. Activities to deal with the problems

UNEP has been playing a central role in this problem. In 1974, the United Nations General Assembly adopted a resolution on "International Cooperation for the Prevention of Desertification" which was formulated in response to a drought from 1968-1973 in the Sudano-Sahelian region, 200-500 km wide buffer zone between desert and forest crossing African continent along the southern edge of Sahara Desert. Based on this resolution, UNEP held the "United Nations Conference on Desertification" in 1977, in which the "Plan of Action to Combat Desertification" was adopted. The plan proposed 26 recommendations for governments and international organizations to take action in the field of impact reserach and assessment of desertification, planning of rational land-use policies for environmental conservation.

In 1984, the 12th Session of Governing Council of UNEP reviewed the implementation of the programmes based on the Plan of Action to Combat Desertification. The Governing Council concluded that the development of desert areas, prevention of desertification, and recovery of desertified land were retarded by the lack of financial resources and the inability of social and political initiation to decide and carry out the plan as well as the physical restrictions of water, soil and biological resources. And the Governing Council also concluded that the rate of desertification has not yet slowed down since the adoption of the Plan of Action. For the prevention of desertification, the Governing Council estimated that the financial resource of $90 billion would be necessary from 1980 to 2000, at an annual rate of $4.5 billion, of which $2.4 billion would be necessary to developing countries as financial support and cooperation. However, it is estimated that available resource is only $0.6 billion per year as of 1980, which means that there is $1.8 billion shortage every year.

Another international activity involves an independent regional cooperation organization, the "Committee of Intergovernmental League of Sudano Sahel (CILSS)", which was established in 1973 in response to the drought in the Sahelian region. The committee aims at cooperation between intra-Sahelian countries to discover solutions to the problems concerning food production, the environment, and climate. The Committee organized the "Sahel Club" in 1976 with the cooperation of OECD, and it has been carrying out negotiations and coordination via this Club with supporting countries regarding technical and financial support, as well as carrying out information exchange and "think-tank" activities. Japan has been implementing such activities as focusing on afforestation and agriculture development in arid areas.

Regarding governmental activities, in relation to support for Africa, one of the main agenda of the Bonn Summit in 1985, Japan proposed the "Green Innovation Plan in Africa", which includes strengthening of agricultural research and promotion of afforestation. As a part of this plan, the govenment has implemented the "Green Corps Plan" which carries out afforestation through sending the Japan Overseas Cooperation Volunteers. Also, as a part of FAO projects, the government has promoted afforestation in the Jai area of Tanzania since fiscal 1986 in cooperation with the local inhabitants. In the field of agriculture in arid areas, the Ministry of International Trade and Industry has been trying to increase agricultural productivity in arid areas by using water retentive materials such as asphalt (fiscal 1975 - 1981) and polymers (fiscal 1988-1992). The Ministry of Agriculture, Forestry and Fisheries has been carrying out basic survey on measures to prevent desertification of the Niger river basin in West Africa. The Ministy utilizes the remote sensing technology using the Landsat satellite to collect fundamental data. The Tropical Agriculture Research Center of the Ministry of Agriculture, Forestry and Fisheries has been carrying out research on the "Analysis and Utilization of Stress Resistance Mechanisms of Plants in Africa" in Senegal from fiscal 1988. This center also started study projects titled "Research on Irrigation and Soil Characteristics in Arid Areas" in China and Egypt. The Meteorological Agency has been carrying out studies using a general circulation model of the atmosphere. The Science and Technology Agency plans to start the "Survey on the Mechanism of Desertification" in fiscal 1988. In addition to these activities, universities in Japan are also carrying out various researches and studies.

Regarding the activities of the private sector, the "Japan Desert Development Association" dispatches survey teams to problem areas as well as implementing consignement work on agriculture of arid areas by using the above described water retentive materials. The "Japan Afforestation Center" has been studying the systematization of afforestation technology since 1982, which focuses on the ecological afforestation of desert regions by utilizing the power of natural ecology. During fiscal 1986-1987, the Center dispatched technology transfer teams to China as a part of support projects organized by the Ministry of Agriculture, Forestry and Fisheries for the "Japan-China Economy Association". In addition, many civilian groups, such as the "Association Sahel", have been carrying out cooperation on afforestation and agriculture.

4. Shortcomings in the past activities :

With respect to this topic, no accurate data on desertified area exist. In addition, complex socio-economic factors, such as poverty and population growth, underline this problem as in the case of tropical forest. It is very difficult to elaborate countermeasures to solve this problem under these circumstances. As stated in the review of the United Nations Plan of Action to Combat Desertification, the low priority of desertifiction prevention project in developing countries hinders the request for action of supporting countries. A similar situation also exists in the case of depletion of tropical forest. It should be noted that some preventive measures for desertification backfire. In one case, irrigation of an arid area led to salinization and resulted in the acceleration of desertification.

There are various problems in the aspect of research and studies. Although dat indicating the process of desertification are insufficient, areas subject to desertification can be observed much easier than tropical forest areas. The observation in arid areas is facilitated by a good meteorological conditions such as little cloud cover. Therefore, the positive utilization of remote sensing monitoring is desirable. Unfortunately the method has only been applied to a limited range of activities. Research on desertification prevention methods, such as afforestation and appropriate agriculture techniques has not yet identified their key factors, and the study on socio-economic factors is still insufficient.

Although definite data have not yet been obtained, the present rapid rate of desertification makes it necessary to strengthen countermeasures both in quality and quantity. As estimated by UNEP, absolute financial resource is below the necessary level, and insufficient preliminary assessments often lead to adverse impacts on the environment, as in the case of salinization. Unless there is enough collaboration with surveys on techniques for desertification prevention, the effective result will not be produced. Long range programs which go beyond symptomatic treatment, such as the development of a new alternative energy source for fuelwood are necessary, however it is still far from the good result induced by such programmes.

CHAPTER 3 JAPAN'S FUTURE ACTIVITIES ON GLOBAL ENVIRONMENTAL PROBLEMS

SECTION 2. PROPOSALS FOR SPECIFIC ACTIVITIES

2. Promotion of model projects for desertification control

The "Action Plan to Combat Desertification" of UNEP provided for the international framework of actions for the prevention of desertification. However, actual achievements are little at present because of the financial limitations and also because the problems are directly related to the life-style of the local inhabitants.

Japan should proceed with various model projects at the countries concerned. For example, at the area where the recovery of production capacity is expected in views of natural, technical, and social conditions, the prevention of desertification and ther recovery of soil fertility should be done through afforestation, proper management of aforested areas, and the prevention of salt accumulation. Also, considering the weak ecological system, the stable food production in arid area should be perforemed through the development and diffusion of agriculutre and forestry technology such as irrigation and drainage, raising crops, breeding livestock, etc.

In addition, Japan should give practical support for the development of new energy sources which substitute fuelwoods because, if this effort is successful, it will have a considerable effect on the demand for fuelwoods and the prevention of desertification.

ANNEX 2

SUMMARY OF SOME REPORTS RELATING TO DESERTIFICATION

(1) A Stochastic Model for Describing Revegetation Following Forest Cutting : An A application of Remote Sensing, Y. Yasuoka et.al., Ecological Modelling Vol.32 (1988) pp. 105-117.

(2) Detection of Land-Cover Change from Remotely Sensed Images Using Spectral Signature Similarity, Y. Yasuoka et. al., Proceedings of the Ninth Asian Conference on Remote Sensing (1988) pp.G-3, 1-5.

(3) Present Situation of Desertification and Its Explication Using Landsat Data: The Northern China Experiences, Masayuki Nemoto et.al., Bulletin of the National Institute of Agro-Environmental Science No. 6 (1989) pp. 75-97.

(4) Phytotorons in the National Institute for Environmental Studies, Ichiro Aiga, et.al., Res. Rep. Natl. Inst. Environ. Stud. Jpn. No. 66, (1984) pp. 133.

(5) Image Analysis of Chlorophyll Fluorescence Transients for Diagnosing the Photosynthetic Systems of Attached leaves, Kenji Omasa et. al. Plant Physiol. Vol. 84, (1987) pp. 748-752.

(6) SO_2 Tolerance of Tobacco Plants Regenrated from Paraquet-Tolerant Callus, Kiyoshi Tanaka et.al. Plant Cell Physiol., Vol. 29 (1988) pp. 743-746.

(7) Image Instrumentation Methods of Plant Analysis, K. Omasa, Modern Methods of Plant Analysis, Vol. ll, Springer-Verlog.

(8) Considerable Difference between the Velocity of Water Percolation and that of Soil Moisture Profile in a Lysimeter, K. Otsubo, Journal of Hydroscience and Hydraulic Engineering, Vol. 7, (1989), pp. 13-32.

(1) A STOCHASTIC MODEL FOR DESCRIBING REVEGETATION FOLLOWING FOREST CUTTING: AN APPLICATION OF REMOTE SENSING

N. Kachi[1], Y. Yasuoka[2] T. Totsuka[1] and K. Suzuki[3]

[1] Environmental Biology Division, National Institute for Environmental Studies, Tsukuba, Ibaraki 305 (Japan). [2] Systems Analysis and Planning Division, National Institute for Environmental Studies, Tsukuba, Ibaraki 305 (Japan). [3] Department of Economics, Asia University, 24-10, Sakai 5 Chome, Musashino-shi, Tokyo 180 (Japan).

Abstract

Kachi, N., Yasuoka, Y., Totsuka, T. and Suzuki K., 19886. A stochasitc model for describing revegetation following forest cutting; an application of remote sensing. Ecol. Modelling, 32: 105-117.

A regeneration process of plant communities following disturbances of a pine forest in Tsukuba region in Japan has been studied. Bare ground was established by clear-cutting a red pine plantation and after that natural regeneration of plant communities staring from bare soil was observed by taking multi-spectral aerial photographs. Based on the photographic data, year-to year changes in patterns of regenerating plant communities were described and the process was anlyzed by a Markovian model. The model represents a point-to-point replacement process from one year to the next among different plant communities. We found that following clear-cutting of a red pine plantation, bare soil was rapidly revegetated by plant communities. We have also found that the point-to-point replacement process was a non-stationary Markovian process. This result suggests that patterns and processes of invasion of pioneer plants into the bare soil at the intial stage would primarily affect the following revegetation process.

(2) DETECTION OF LAND-COVER CHANGE FROM REMOTELY SENSED IMAGES USING SPECTRAL SIGNATURE SIMILARITY

Y. Yasuoka, T. Miyazaki, Y. Likura and S. Otoma

The National Institute for Environmental Studies 16-2 Onogawa, Tsukuba-shi Ibaraki 305 Japan

Abstract

Remote sensing provides an efficient tool for monitoring environmental changes in a large area. However, change detection using remote sensing is complex because remotely sensed data is affected by the atmospheric conditions as well as by the suface condition. This paper describes a method to detect land-cover changes using remote sensing data based on the similarity of spectral signatures. Multi-spectral images from two dates are registered and spectral signatures of each points are compared. Correlation analysis is used to evaluate the similarity of two spectral signatures. It is shown that the method is robust to various effects due to the difference in the atmospheric conditions or in sun elevation angle. The method is applied to the detection of vegetation change in Thailand using LANDSAT MSS images.

(3) PRESENT SITUATION OF DESERTIFICATION AND ITS EXPLICATION USING LANDSAT DATA : THE NORTHERN CHINA EXPERIENCES

Masayuki NEMOTO, Michikazu FUKUHARA, Cheng ZUOZHONG, Cheng ZINJUN

Summary

Desertification is defined as the diminution or destruction of the biological potential of land which may lead ultimately to desert-like conditions (United Nations' definition, 1980). In the recent fifty years areas undergoing a desertification process have been rapidly expanding mainly in the steppe zone in Northern China. On the basis of previous data, the distribution of lands undergoing desertification, factors responsible for desertification and the process of retrogressive succession in vegetation in such lands have been analysed. Furthermore the possibility of diagnosing the degree of desertification using the Landsat image was examined. The results obtained through the data analysis are summarized as follows:

1. The amount of annual rainfall in lands undergoing desertification varies markedly the location. Within the steppe zone the floristic composition changes with the amount of precipitation and can be divided into three types, i.e. Desert steppe. Typical steppe and Meadow steppe. It is difficult for the vegetation in areas with low precipitation to recover. Land undergoing desertification in northern China were classified into three major zones according to the precipitation, and the degree of desertification was also classified into four ranks (Zhu, 1981).

2. Excessive human interference and abiotic pressures readily promote desertification in the arid and semi-arid zones of northern China. The major factors involved in desertification are (1) over-development of farmlands. (2) overgrazing by domestic animals and (3) over-felling of bushes for fuel caused by the increase in human population. Variable annual precipitation, strong winds, loose sandy surface and recent abnormal weather accelerate the desertification process.

3. A close relationship beteeen the degree of desertification and vegetation dynamics is recognized in lands undergoing desertification. In a typical steppe where *Stipa spp.* dominate, the biomass decreases with

the progress of desertification. While that of the unpalatable *Artemisia spp.* and poisonous species increase. When the desertification progresses further, the percentage of vegetational cover decrease and the thorny shrub *Caragana sp.* becomes a predominant species. Ulitmately the vegetation disappears completely.

4. The reflectivity ratio of red band to near infrared band varies with the amount of biomass and vegetation cover in the area surveyed. The degree of desertification can be estimated by the vegetational conditions in a given area, and diagnosed by the data on red and near infrared bands obtained from Landsat TM. Using the Landsat image the land undergoing desertification in Inner Mongolia can be automatically classified by applying the maximum likelihood method.

(4) PHYTOTRONS IN THE NATIONAL INSTITUTE FOR ENVIRONMENTAL STUDIES

Ichiro AIGA[1], Kenji OMASA[1] and Shigeru MATSUMOTO[1]

[1] Division of Engineering, the National Institute for Environmental Studies, Yatabemachi, Ibaraki 305, Japan.

Phytotrons in the National Institute for Environmental Studies (NIES) were introduced. The feature of these facilities was described from the standpoint of engineering. Furthermore, an experiment for analysing the sorption of air pollutants by plant community was shown.

Key words: Phytotron - Controlled Greenhouse - Growth Cabinet - Environment Simulator - Plant Community - Environmental Study.

The first-period Phytotron (Phytotron I) in the National Institute for Environmental Studies (NIES) was built in December, 1975, and the second-period Phytotron (Pytotron II) was completed in August, 1981 in order to obtain basic data for planning the environmental policy. These facilities belong to the great and new Phytotron in the world. The Pytotron I has controlled greenhouses and growth cabinets for the air pollutant exposure, and the Phytotron II includes simulators to analyse the plant-environment system. Outlines of these facilities and their technical features are described in this paper.

(5) IMAGE ANALYSIS OF CHLOROPHYLL FLUORESCENCE TRANSIENTS FOR DIAGNOSING THE PHOTOSYNTHETIC SYSTEMS OF ATTACHED LEAVES

Kenji OMASA et. al.

Abstract

A new image instrumentation system for quantitative analysis of the rapid change in intensity of chlorophyll fluorescence during dark-light transition (CFI, chlorophyll fluorescence induction), which is a sensitive indicator of the various reactions of photsynthesis, was developed and its performance was evaluated. This system made it possible to resolve cfi at any small leaf area (about 1 square millimeter) of a whole leaf when the plant was illuminated by blue-green light at more than 50 micromoles photons per square meter per second. In order to test the usefulness of this system, we applied it to analyze the effect of SO_2 on photosynthetic apparatus in attached sunflower leaves. Dynamic CFI imaging over the whole single leaf, where there was no visible injury, indicated not only the local changes in photosynthetic activity but also the site of inhibition in photsynthetic electron transport system in chloroplasts. The new instrumentation system will be useful for the analytical diagnosis of various stress-actions on plants in situ.

(6) SO_2 TOLERANCE OF TOBACCO PLANTS REGENERATED FROM PARAQUAT-TOLERANT CALLUS

Kiyoshi TANAKA[1], Iwao FURUSAWA[2], Noriaki Kondo[1] and Kunisuke TANAKA[3]

[1] Division of Environmental Biology, the National Institute for Environmental Studies, Tsukuba, Ibaraki 305, Japan. [2] Laboratory of Plant Pathology, Faculty of Agriculture, Kyoto University, Kyoto 606, Japan. [3] Department of Biochemistry, College of Agriculture, Kyoto Prefectural University, Kyoto 606, Japan.

To establish whether SO_2 tolerance of plants is related to their ability to defend themselves against the toxicity of active oxygen, this study examined the SO_2 tolerance of paraquat-tolerant tobacco plants (Nicotiana tabacum L. cv. Samsun), which had been regenerated from paraquat-tolerant callus. When the test plants, which had higher superoxide dismutase activity than the control ones, were fumigated with 2 ppm SO_2, they showed tolerance, while the control ones suffered severe damages. These results indicate that SO_2 toxicity in plants is caused by active oxygen and that superoxide dismutase participates in counteracting SO_2 toxicity.

(7) IMAGE INSTRUMENTATION METHODS OF PLANT ANALYSIS

K. OMASA

1. Introduction

Knowledge and understanding of the biological world result from information about orgnisms and their interactions with their surroundings. Although information can come from any sources, tremendous advances inscience have occured with advances in instrumentation and technology, e.g. microscopes. THe recent advances in electronics have greatly increased the amount of information that can be obtained. The development of image instrumentation technologies, which gather two or three-dimensional information about the organism in a non-destructive manner, has been particularly remarkable. In the field of medicine, instrumentation technologies for surface, microscopic, C-ray, RI (radio isotope) and ultrasonic images have been put to practical use for patient diagnoses. In conjunction with advances in computed tomography (CT), tomographic images that give not only morphological information but also functional and physiological information have also been obtained (Herman 1979; Onoe 1982; Mansfield and Morris 1982).

In the field of plant research, a variety of image instrumentation technologies, similar to those in the field of medical science, have been developed for cells, individual plants, and small-scale plant communities (Omasa and Aiga 1987; Omasa et al. 1989). THese technologies are used to elucidate the reaction mechanisms of living plants in fields such as physiological ecology Based on the information obtained from these fundamental studies, diagnosis of plant growing conditions, injury by disease and pests, nutrition disorders, and environmental pollution injury, etc., have become possible. In addition, in the field of biotechnolgy these technologies can also be used for screening plants obtained by such methods as breeding, cell fusion, and gene recombination.

Development of wide-area remote sensing for plant communities by artificial satellites or airplanes has also been quite remarkable (Colwell 1983). The sensing is used to survey cropping acreage of field crops, to estimate yields, and also to investigate changes in vegetation and ecosystems. Since a TM (Thematic Mapper) with many spectral bands and about 30 m resolution has been mounted in Landsat, the expansion in applications of remote sensing to agriculture or vegetation investigation are expected. However, wide-area remote sensing for large-scale plant communities are limited in terms of the pysiological information obtained from living plants. Therefore, in order to extend the application fields, image instrumentation technologies for individual plants and small-scale plant communities, which will combine physiology at the cell level with information obtained from the wide-area remote sensing are important.

The application fields for image instrumentation of living plants include those of the future, listed in Table 1. The instrumentations are expected to be used in a great many fields, ranging from the fundamental to the applied, such as botany, agriculture, environmental science, space science, and pedagogy.

(8) CONSIDERABLE DIFFERENCE BETWEEN THE VELOCITY OF WATER PERCOLATION AND THAT OF SOIL MOISTURE PROFILE IN A LYSIMETER

Kuninori OTSUBO

National Institute for Environmental Studies, Tsukuba, Tbaraki, Japan

Synopsis

The main purpose of this study is to obtain experimental data as to the actual water moving velocity in a lysimeter and the shifitng velocity of soil moisture content there as well. The former was determined fromt he behavior of the peak concentration of heavy water (D_2O) injected artificially, while the latter was determined from the data of suction and resistance in soil. The actual movement of water due to a rainfall was only 0.06 cm/h (10cm/week) in the topsoil layer and from 0.018 to 0.023 cm/h (3 to 4 cm/week) in the subsoil layer. This velocity at the subsoil layer showed a good coincidence with the estimated value based on the data of the amount of percolation at the bottom and the soil conditional parameters, such as void ratio and the degree of saturation of pore-water. The shifting velocity of the high moisture peak was found to be from 8 to 12 cm/h in the topsoil layer and from 0.8 to 2cm/h in the subsoil layer, either of which was nearly one hundred times greater than that of actual water movement. This fast phenomenon is basically explained by diffusion wave and kinematic wave characteristics of water in unsaturated soils.

DESERTIFICATION CONTROL PROGRAMME ACTIVITY CENTRE
UNITED NATIONS ENVIRONMENT PROGRAMME
P.O. Box 30522, NAIROBI,KENYA
Tel: (254 2) 333930,520380,520600
Cable: UNITERRA NAIROBI
Telex: 22068 UNEP KE
Telefax: (254 2) 520711

Cover illustration:
The Desertification Map of the World
prepared for UNCOD by UNEP/FAO/UNESCO/WMO
This World Map of Desertification was published by UNEP in 1977