DEVELOPING A BASELINE SURVEY FOR MONITORING BIOPHYSICAL AND SOCIO-ECONOMIC TRENDS IN DESERTIFICATION, LAND DEGRADATION AND DROUGHT

Consultancy report

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This consultancy report was prepared for the UNCCD secretariat to facilitate the discussion on impact indicators and baselines. The contents of this document are the sole responsibility of the author and can in no way be taken to reflect the views of the secretariat and or the Parties to the UNCCD

EXECUTIVE SUMMARY

i. Aims

This document presents proposals for the design and implementation of a Baseline Survey for the UN Convention to Combat Desertification (UNCCD). It has been prepared at the request of the Secretariat of the UNCCD. The Baseline Survey is to be initiated as part of the UNCCD's Ten Year Strategic Plan, and will form the starting point for monitoring long-term trends in desertification so that progress in implementing the UNCCD can be evaluated.

ii. Challenges

To monitor desertification effectively the Committee on Science and Technology (CST) of the UNCCD must tackle five major challenges. First, overcome technical difficulties in monitoring degradation of both vegetation and soil. Second, represent spatial variation in desertification. Third, adjust for temporal variation in vegetation cover linked to irregular variation in rainfall. Fourth, integrate social and economic aspects into the survey. Fifth, devise multi-scalar monitoring procedures, and institutions to implement these on a continuing basis.

iii. Key Concepts

A *baseline survey* is a starting point for monitoring that provides a comprehensive characterization of a phenomenon in a specific year so that later changes in its attributes can be measured. It identifies not a potential hazard, but the actual status of the extent and degree of desertification in a given *baseline year*. This provides a marker with which status in future years can be compared. Ideally, national baseline surveys would be undertaken in all affected countries in the same year, but this is not always possible. Another strategy is to project all national estimates from individual baseline years to a common international *reference year*, but this may incur considerable errors.

The *degree of degradation* of soil and vegetation is assessed in relation to some ideal, non-degraded, *benchmark* status. In both cases, the spectrum of degradation is normally divided into discrete bands, ranging from Low degradation at one end to Very Severe at the other.

To provide a comprehensive description of a phenomenon a set of *indicators* should be framed by a comprehensive *conceptual framework*. One possibility is to use the Driving Forces-Pressures-States-Impacts-Responses (DPSIR) framework. Previous attempts to devise sets of desertification indicators implicitly adopted a similar model. Structured using a DPSIR framework its components include:

1. Driving Forces: societal changes and indirect effects of climatic variation.
2. Pressures: land use, resource extraction and direct effects of climatic variation.
3. States: the quantity and quality of soil and vegetation resources.
4. Impacts: different types of changes in soil and vegetation; changes in economic welfare, as farmers receive income from cropping or pastoralism, which falls when degradation cuts yields: and changes in social welfare, as some social groups become absolutely or relatively poorer than others.
5. Responses: changes in national and international policies and in livelihood strategies.

In conformity with the Terms of Reference, this document provides an overview of desertification within a DPSIR framework. However, it also summarizes the numerous criticisms of this framework and then discusses how this conventional view has been challenged by recent research findings. Synthesized in the Drylands Development Paradigm, these findings reveal the importance of such features as: alternative ecosystem states, as opposed to equilibrium notions in the drylands; multiple interacting causes; coupled human-environment relationships; contextuality; cross-scalar spatial processes; and vulnerability. The implications of these features for indicator selection are discussed.

iv. Previous Surveys

The history of desertification surveys is critically reviewed. Most occurred during implementation of the UN Plan of Action to Combat Desertification (PACD). While they differ from each other, and each has its advantages and disadvantages, there is a certain consistency in their approach. This offers a foundation on which to design a Baseline Survey for the UNCCD. Two common and related drawbacks which must be overcome, however, are confusion between biophysical and economic indicators, and lack of integration of biophysical, economic and social indicators. All of the surveys also suffer from being implemented by subjective expert assessments, not scientific monitoring procedures. None of the small number of surveys undertaken independently by scientists constitutes a great advance over those produced to assess implementation of the PACD.

v. Surveying Biophysical Aspects of Desertification

A working set of biophysical indicators is proposed to illustrate the design of the Baseline Survey:

1. Vegetation Degradation:
a. Vegetation Cover
b. Vegetation Quality

2. Soil Degradation:
a. Wind Erosion
b. Water Erosion
c. Salinization
d. Waterlogging
e. Soil Health

3. Water Resources:
a. Surface Water Availability
b. Ground Water Availability
c. Water Quality

4. Climate: Annual Rainfall

Following a review of research into the use of remote-sensing techniques for monitoring desertification a set of data collection procedures is proposed for each indicator.This includes the use of remote-sensing methods, field measurements and acquisition of contextual knowledge:

1. Vegetation Degradation: combine aerial photography and high to very high resolution satellite images with ground measurements, accompanied by contextual knowledge.

2a. Water erosion: use high resolution satellite images (or aerial photography), supported by ground truth data collection, and accompanied by contextual knowledge on Soil Health.

2b. Wind erosion: employ ground measurements, accompanied by contextual knowledge on Soil Health, with the extent of sand dunes can be measured by medium to high resolution satellite images.

2c. Irrigated croplands: use high resolution satellite images, supported by ground measurements of salinity and alkalinity, and accompanied by contextual knowledge on Soil Health.

3. Surface water and groundwater availability and water quality: assess by satellite imagery, field measurements and contextual knowledge.

4. Annual Rainfall: measure by long-term monitoring stations.

vi. Overcoming Difficulties in Establishing a Baseline

Spatio-temporal variation in soil and vegetation degradation leads to major problems when trying to undertake a reliable Baseline Survey.

A map of vegetation cover that does not allow for the irregular fluctuation in vegetation growth with rainfall could give estimates of the baseline extent and degree of degradation that are misleadingly high or low. So when the next survey is undertaken the difference between the two findings will not give a reliable estimate of the trend in desertification in that period. One way to tackle this would be to ignore vegetation degradation and base estimates of the degree of desertification solely on indicators of the degree of soil degradation. Other options involve correcting for variation in vegetation cover using historical data.

Another challenge is to find how to estimate the degree of degradation in a reliable way. Universal 'natural benchmarks' for a fully non-degraded ecosystem in most dry areas are difficult, if not impossible, to identify, owing to the lack of long-term equilibrium states. One way to tackle this would be to ignore vegetation degradation. Other options involve the use of corrective methods.

As the intensity of degradation can vary greatly from place to place, a method must be devised to combine measurements at different spatial scales so they are fully representative of the broader picture and what is visible on the ground. To do this the Baseline Survey must take full account of both scientific measurements and the contextual knowledge of people living in each area. An algorithm is also proposed to allow for contextual variation within mapping units.

vii. An Integrated Survey

A three dimensional welfare model is proposed as a conceptual framework for a survey that integrates economic, social and environmental dimensions. This allows the three types of indicators to be integrated yet compared separately, without incurring problems associated with synthetic indices.

After reviewing the results of research on the merits of alternative indices of economic development, the following working set of economic and social indicators is proposed:

1. Economic:
a. Farm income/yields
b. Wood-based income/yields
c. Non-farm income
d. Remittances

2. Social:
a. Population

b. Poverty: life expectancy at birth
c. Vulnerability: susceptibility of livelihoods to drought

These indicators can be quantified by a combination of field surveys and official statistics. They can be combined with the biophysical indicators to form an integrated set of indicators.

viii. Results of the Integrated Baseline Survey

The Baseline Survey will provide the following pieces of information for a given country in the baseline year and for all affected countries in a common reference year:

1. The area of land affected by desertification, classified by degree of degradation.

2. The social impacts of desertification, comprising the number of people affected by different degrees of degradation and the distribution of vulnerability among each of these populations.

3. The magnitudes of agricultural productivity, production and income in affected areas, representing the economic benefits that offset the above environmental and social costs.

ix. Implementation

Before the Baseline Survey can be implemented its design will need refinement by the scientific conference of the CST and a series of scientific consultations. The choice of the most appropriate national baseline year and international reference year will depend on scientific and logistical factors. Much care also needs to be devoted to establishing appropriate national and international institutions to sustain regular monitoring after the Baseline Survey. Time must also be allowed for the preparation of manuals, training materials, data collection forms, and training workshops.

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Desertification is one of the most serious of all global environmental change problems. Like global climate change and the erosion of biological diversity it results from society's inability to develop sustainably, because decisions are taken to use natural resources in ways that ultimately impinge adversely on human environmental welfare (Grainger, 1990). Just as global climate change results from the degradation of the atmosphere resulting from the unmanaged accumulation of greenhouse gases, so desertification involves the accumulation of degraded land as human mismanagement leads to the removal of vegetation and the erosion of soil. As it often speeds up in times of drought it is likely to expand and intensify as global climate continues to change.

Desertification is also a critical social and economic problem, as it undermines global food security and efforts to alleviate poverty through sustainable development. So neglecting it is not an option if we are to meet the first of the Millennium Development Goals - eradicate extreme poverty and hunger - and improve the lives of the poorest people in the world, who are likely to come under even greater pressure as global climate change increases climate variability. According to the Millennium Ecosystem Assessment's special report on desertification (2005): "effectively dealing with desertification will lead to a reduction in global poverty. Addressing desertification is critical and essential for meeting the Millennium Development Goals successfully."

1.2 LACK OF RELIABLE ESTIMATES

Yet twenty one years after the world's governments first deliberated on the issue at the UN Conference on Desertification in 1977, we still lack scientifically credible estimates of the extent and rate of change of desertification, and of its social impacts. This handicaps all Parties to the UN Convention to Combat Desertification (UNCCD), and especially affected countries as they seek to make their agricultural sectors more productive and sustainable and to improve the welfare of their citizens. In the 1980s, the area of drylands at least moderately affected by desertification was estimated at between 600 million ha (Middleton and Thomas, 1992) and 2,000 million ha (Mabbutt, 1984). Whether the actual figure was closer to the bottom of this range or the top is impossible to say at the moment. But as the higher area exceeds that of all tropical forests combined the huge scale of the problem is easily apparent.

1.3 THE NEED FOR A GLOBAL MONITORING SYSTEM

An effective system for monitoring desertification at global scale is therefore needed if the Parties to the UNCCD are to have the reliable information they need to formulate collective and individual strategies for implementing the Convention and to monitor their effectiveness. It is also vital if the Committee on Science and Technology of the Convention (CST) is to become “a global authority on scientific and technical knowledge pertaining to desertification/land degradation and mitigation of the effects of drought”, as stated in the Ten Year Strategic Plan (TYSP) approved by the Eighth Conference of the Parties (COP 8) (COP, 2007a). The importance of taking action was signalled by "national monitoring and vulnerability assessment on biophysical and socio-economic trends in affected countries" being placed as the very first outcome of Operational Objective 3 of the TYSP.

Two fundamental decisions are required to make such a system operational:

1. A common set of indicators and monitoring procedures must be selected if national estimates are to be comparable and capable of aggregation to give regional and global estimates.

2. A comprehensive Baseline Survey must be undertaken in every affected country employing the same set of indicators and monitoring procedures. As Outcome 3.2 of the TYSP recognizes, without this initial assessment of status it will be impossible to reliably monitor the trend in desertification over time. An informal consultative meeting, held in Ottawa on 15-17 July 1997 shortly after the UNCCD came into force, defined a baseline as "a set of data that serves as the starting point for evaluating subsequent trends in an indicator or issue" (CST, 1997a).

The Baseline Survey implemented under the TYSP will be the first global survey of desertification ever undertaken through empirical measurement, as opposed to relying on subjective estimates by groups of experts. By establishing the true magnitude of the problem this should lead to greater consensus on how desertification is viewed by all Parties to the UNCCD. This was recommended by the UN Joint Inspection Unit report which prompted formulation of the TYSP (Ortiz and Tang, 2005). By establishing a marker in time it will also be the first step in providing concrete evidence for any causal links between desertification and global climate change. This will promote greater synergies between the UNCCD and the Framework Convention on Climate Change, something for which the Conference of the Parties to the UNCCD has worked tirelessly.

1.4 AIMS AND TERMS OF REFERENCE

The purpose of this document is to support the Parties in their efforts to launch a Baseline Survey by proposing a comprehensive framework for undertaking it. Using the best available scientific knowledge, it provides a basis for a structured discussion by the Parties about how to finalize the design and implementation of the survey. It also indicates where further scientific advice is required before deciding on particular details of the procedures to be employed.

The Terms of Reference for this document require it to "elaborate a framework for developing a baseline for country Parties on biophysical and socio-economic trends." The survey should lead to the "establishment of 'status' as the starting point...based on the most robust data available on biophysical and socio-economic" parameters. Consistent with this and another requirement, that the survey be "empirically grounded and analytically rigorous", the framework proposed here refers to indicators and procedures that relate to observable conditions on the ground, and utilizes the latest scientific insights into desertification and the technical feasibility of monitoring it.

1.5 EXPECTED RESULTS OF A BASELINE SURVEY

The Parties to the UNCCD may justifiably expect to obtain from a Baseline Survey the following pieces of information for a given country and for all affected countries in the same year:

1. The area of land affected by desertification, classified by degree of degradation.

2. The social impacts of desertification, comprising the number of people affected by different degrees of degradation, the impact on their welfare, and the distribution of vulnerability within each populations.

3. The magnitudes of agricultural productivity, production and income in affected areas, representing the economic benefits that offset the above environmental and social costs.

1.6. FIVE CHALLENGES FOR THE UNCCD

Before a Baseline Survey can be successfully undertaken, thereby laying the foundation for an effective ongoing monitoring system in future years, the Committee on Science and Technology of the UNCCD must work closely with the scientific community to tackle five major challenges.

1.6.1 Portraying the Complexity of the Phenomenon of Desertification

The first challenge is that desertification is a complex phenomenon and difficult to survey. Multiple indicators are needed to represent different forms of vegetation and soil degradation; each must relate present status to an ideal benchmark status to assess degradation; and it should be possible to combine all the indicators to give a succinct portrait of the extent and degree of desertification as a whole.

To put this challenge in perspective, the corresponding land use and land cover change problem in the humid tropics, deforestation, involves a fall in the quantity of a single land land resource, forest, by complete removal. Consequently, all that is needed to monitor deforestation in a particular country is to undertake a survey of its forest cover in one year and then repeat this survey in the following year.

Forest cover also declines in quality as a result of selective logging and other forms of exploitation. This process, called forest degradation, is more difficult to monitor because there is no change in forest area itself, only in some or all of of its many attributes. These include tree height, tree density, biomass density and species composition. So to monitor degradation it is necessary to survey multiple attributes of an area of forest every year, and not just one. While some of these attributes may, like forest area, be measured by remote sensing techniques, the resolution of the sensors used must be higher. Other attributes can only be measured by ground observations.

In contrast, desertification involves the degradation of not one but *two* land resources: vegetation and soil. To monitor it therefore requires a set of multiple indicators for each of these resources.

The current lack of a universal set of indicators for use by the Parties to the UNCCD is not for any want of effort by either the Parties or scientists. Choosing indicators to map desertification has been a high priority since the preparation of the UN Plan of Action to Combat Desertification (PACD), which launched the global desertification regime in 1977. A similar priority has been attached to them since the UNCCD entered into force in 1996. The need for such indicators was recognized in Article 16 of the UNCCD, which states that the Parties " shall, as appropriate... support and further develop bilateral and multilateral programmes and projects aimed at defining, conducting, assessing and financing the collection, analysis and exchange of data and information, including, inter alia, integrated sets of physical, biological, social and economic indicators" (UN, 1994). The Intergovernmental Negotiating Committee for Desertification, at its tenth session, later distinguished between (a) implementation indicators, which monitor the compliance of the Parties with their commitments under the terms of the Convention; and (b) impact indicators, which monitor desertification as an objective phenomenon, to provide information for decision making by the Parties (CST, 1997a). The indicators required for a Baseline Survey will come under this second group of impact indicators.

Unfortunately, the sets of indicators devised under the PACD and the maps produced with them did not enjoy wide respect in the scientific community, and efforts within the UNCCD have so far not led to a set acceptable to all its Parties. However, other regimes have difficulties too: the UN Convention on Biological Diversity is still finalizing its set of indicators (Balmford et al., 2005). Consequently, when planning their Baseline Survey the Parties to the UNCCD have the opportunity not only to improve their own information system but to set an example for other conventions too.

1.6.2 Properly Representing Spatial Variation in Desertification

Further difficulties arise from the great spatial complexity of desertification. Making generalizations about the degree of degradation of vegetation and soil over large areas is therefore difficult.

The currently dominant scientific model recognizes that desertification is contextual and ill-suited to simplistic regional or national generalizations. Studies by Andrew Warren (2002), of University College, London, one of the original group of experts who undertook research to support the drafting of the PACD in the 1970s, have made a major contribution to gaining acceptance for this view.

It has become ethically desirable to promote local participation in all aspects of development, including schemes to control and monitor desertification. Early feedback from the Parties to proposals for impact indicators also emphasized the need to select indicators that are meaningful at both national and local scales (CST, 1997b). Yet recent scientific insights on contextuality show that participation is not just ethically desirable, it is practically essential too. For if assessments made at national scale are not complemented by assessments at lower scales, and especially the local, then a true picture of the status of desertification will not emerge.

One temptation to avoid when trying to achieve legitimacy for a set of indicators is to merely combine all the indicators acceptable to every stakeholder. This will result in a huge number of indicators that will be costly to monitor, tax the institutional capacity of even the most highly developed countries, and undermine the operational feasibility of the monitoring system. For example, while the global forests regime still has no binding convention, nine regional criteria and indicator (C&I) schemes for monitoring forest sustainability at national scale have been established. Yet they have so far been little used in practice. One reason is that they have too many indicators: despite considerable refinement they still range in number from 47 to 65, and even the US government cannot supply data for all the indicators relating to its forests (Grainger, 2009a). So the informal consultative meeting held in Ottawa in 1997 was wise to stress the need for "a minimum set of indicators" (CST, 1997a).

1.6.3 Adjusting for Temporal Variation and the Role of Drought

The third challenge, and perhaps the most difficult of all, is to find how to cope with temporal variation in desertification. This makes it difficult to: (a) link the present status of vegetation determined in a Baseline Survey to benchmark values in order to assess the degree of degradation; (b) decide the correct year for a Baseline Survey; and (c) even identify the benchmarks themselves. Tackling this challenge cannot be postponed, because it is directly related to establishing the most suitable year for undertaking a Baseline Survey that will identify the extent and degree of desertification in each country with which all future measurements will be compared.

The problem arises because of the dual role played by extended periods of low rainfall, or droughts. On the one hand, in circumstances where human beings are unable to adapt to the change in circumstances, droughts can lead to a short-term rise in the rate of desertification compared with the long-term mean, while on the other, the associated reduction in vegetation growth can give a misleading impression of the extent and severity of desertification (Tucker and Choudhury, 1987).

1.6.4 Integrating Social and Economic Aspects into Survey Design

The fourth challenge is to devise an approach to survey design that integrates the economic, social and environmental dimensions of development so that the three outcomes listed in Section 1.5 can be determined clearly and in proper relation to each other.

An integrated approach is essential if, as stated in both Outcome 3.1 of the TYSP and the Terms of Reference for this document, the Parties are to engage in "national monitoring and vulnerability assessment on biophysical and socio-economic trends". Desertification is not just an environmental phenomenon, and improving the sustainability of development requires an approach that optimizes its economic, social and environmental dimensions. The choice of indicators must reflect this.

Selecting indicators to monitor the economic, social and biophysical dimensions of development without a conceptual framework to integrate them is likely to lead to ineffective monitoring and indicator inflation - as the regional forest C&I schemes have found (Grainger, 2009a).

1.6.5 Designing Multi-Scalar Monitoring Procedures and Institutions

The fifth and final challenge is to devise: (a) a set of procedures to collect the data needed to quantify the set of desertification indicators in the Baseline Survey; and (b) a set of institutions to ensure that these procedures can be applied uniformly on a continuing basis to monitor desertification over time. These institutions will, ideally, be established at the same time as the Baseline Survey.

Experiences in forest monitoring again provide a useful point of reference. Data collection procedures for deforestation are fairly straightforward. Only a single indicator, forest area, is required and forest can be distinguished easily from non-forest by satellite remote sensing technology that has been operating since 1972. In spite of this, and the incentives provided by the high economic and ecological values of tropical forests, neither governments nor scientists have yet devised the global institutions needed to fully employ this technology to monitor forests regularly. National surveys of forests in the humid tropics rarely take place more than once every ten years, and so estimates of forest areas and rates of change remain rather inaccurate (Grainger, 2008).

As desertification is several orders of magnitude more complex than deforestation a technically more complicated set of procedures is needed to monitor it. Frequent monitoring at global, national and local scales is also imperative to obtain an adequate knowledge of all its dimensions. Satellite and other forms of remote sensing can help survey the large areas involved, though the data they provide must be complemented by other data collected on the ground.

The institutional challenge is also much greater. As desertification is such a contextual phenomenon, adopting a participatory system for data collection is important to collect local data. Obtaining comprehensive knowledge, and using that knowledge to make management at multiple spatial scales more sustainable, requires that data are collected at all scales within a country and the resulting processed information is then channelled back to decision makers at each of these scales (Long-Martello, 2004).

The national, sub-regional and regional action programmes identified in Articles 10 and 11 of the UNCCD are consistent with this multi-scalar approach. But designing a set of institutions appropriate for each country is still a major challenge for every Party.

The description of procedures proposed in this document assume that the Baseline Survey and subsequent surveys will be carried out at national level by each of the Parties, and that they will adopt procedures and institutions compatible with those required to aggregate all resulting measurements to provide regional and global estimates to support decision-making by the Conference of the Parties.

1.7 AN OUTLINE OF THIS REPORT

This report has eight chapters. After this Introduction, Chapter 2 introduces and defines some concepts used in the text. Chapter 3 outlines a simple conceptual model of desertification which can be used to evaluate previous attempts to survey desertification. It also reviews criticisms of this modelling approach, and summarizes the principles of the latest scientific thinking on desertification. Chapter 4 critically reviews the historical development of desertification survey design and implementation. Chapter 5 builds on this experience to suggest how to design an integrated Baseline Survey. Chapter 6 suggests some key issues that the CST might wish to address when finalizing the design of the Baseline Survey and strategies for its implementation. Chapter 7 lists the main conclusions of this document and a set of recommendations for the CST.

CHAPTER TWO

CONCEPTS AND DEFINITIONS

2.1 INTRODUCTION

The purpose of this chapter is to introduce and define some of the key concepts used in this report.

2.2 DESERTIFICATION

Desertification is defined in the UNCCD as involving "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UN, 1994). This equates desertification with land degradation, and confines it geographically to dry areas. It also states that both human activities and climatic variation cause it but does not say how.

UNCOD's definition of desertification, as "the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions" (UN, 1977), implicitly referred to land degradation as something which reduced crucial features of soil, and in the process undermined its capacity to support the quality and quantity of natural vegetation and crops previously found in an area. Dryland degradation has always been understood to refer to two resources: soil and vegetation. Thus, the UNCOD definition also stated that desertification is not merely soil degradation, but is "an aspect of the widespread deterioration of ecosystems". The degradation of vegetation depends on the degradation of soil, but also contributes to it, since soil degradation is easier when the soil's protective vegetation cover has been reduced (Dregne, 1977).

The degree of degradation varies with time. UNCOD portrayed desertification as a long-term process of degradation caused by human activities, a process which often accelerates in degree and extent in the short-term when catalysed by droughts. UNCOD also distinguished desertified land from desert. While the degree of soil degradation in a given area may increase over time, this trend is reversible up to a certain threshold, but beyond this land can switch irreversibly to desert (Grainger, 1990).

2.3 DESERTIFICATION STATUS AND HAZARD

Since the very beginning of desertification assessment two main types of evaluation have been undertaken. Some have been restricted to desertification *hazard*, or the potential for desertification to occur at some unspecified time in the future. Others have attempted to estimate the current *status* of desertification, even though empirical data have been limited in scope.

2.4 BASELINE SURVEY

A *baseline survey* is a starting point for monitoring that provides a comprehensive characterization of a phenomenon in a specific year so that later changes in its attributes can be measured (CST, 1997a).

It identifies not a potential hazard, but the actual *status* of the extent and degree of desertification in a given *baseline year*, to provide a marker with which the status in future years can be compared.

2.5 INTERNATIONAL REFERENCE YEAR

For a phenomenon which is purely national in scope, a government agency has the discretion to undertake a baseline survey in any year that seems most appropriate. However, things become more complicated when the aim is to undertake a survey of a global phenomenon, such as desertification.

The normal procedure when conducting international surveys is to identify a common international *reference year*. This is usually at the end of a decade (e.g. 2010) or at its midpoint (e.g. 2015). If this approach were followed here then estimates of the extent and degree of desertification and its social impacts could be listed for all countries in the same year, and these could be aggregated to give estimates for each region and for the world as a whole. The Parties could then use subsequent surveys to monitor regional and global trends every five or ten years.

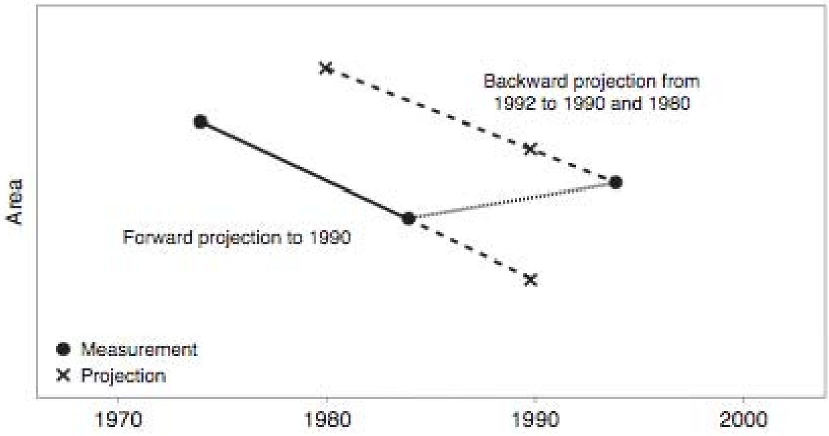
The simplest way to achieve this is to undertake all national baseline surveys in the same year, but this is not always possible. National forest surveys, for example, are routinely undertaken in different years. In this case each national survey finding has to be projected from its measurement years to the common reference year so that aggregated regional and global estimates can be produced (Fig. 2.1). However, projection can lead to errors, and the longer the projection period the higher the errors are likely to be. In the case of tropical forest statistics, projections often may have to be made 15 years or more into the future (Grainger, 2008).

An additional complication occurs when dealing with highly uncertain phenomena, such as deforestation and desertification. Since it is reasonable to expect that the accuracy of estimates will improve with continued measurements, statistical agencies may decide that since the latest survey is more accurate, it is important to correct the previous survey to be compatible with this latest finding. This requires back-projection, instead of the forward projection to the reference year.

This too can lead to problems because to make a back projection it is necessary to decide whether the likely direction of the historical trend was up or down. In the case of tropical forest change, the common assumption is to project deforestation, not reforestation, even if the latest survey reading is higher than the previous one. However, this ignores the possibility that the trajectory of the trend could have changed from deforestation to reforestation (Fig. 2.1).

The risks involved in projecting estimates of desertification are much greater than for forest change. For whereas national forest area tend to have either a consistently downward or upward trend for long periods of time, the extent and degree of desertification can fluctuate over much shorter periods.

Figure 2.1. Projecting National Forest Surveys to a Common Reference Year: (A) Forward projection to reference year of 1990 from 1983 survey with support from 1975 survey; (B) Backward projection to 1980 and 1990 from 1992 survey, with alternative interpretation.



2.6 DEGREE OF DEGRADATION

The *degree of degradation* of vegetation is assessed negatively in relation to some ideal, non-degraded, *benchmark* status. This is the ultimate vegetation cover in a particular area. Degradation involves a *decline* in the quality of vegetation cover relative to this benchmark (Fig. 2.2).

The degree of soil degradation is assessed positively relative to a *benchmark* status. The prevalence of gullies, sand, or salt deposits *increases* in comparison with the benchmark of non-degraded soil.

In both cases, the spectrum of degradation is normally divided into discrete bands, ranging from Low degradation at one end to Very Severe at the other.

2.7 INDICATORS

The degree of degradation is estimated using various measurable quantities, called indicators. An *indicator* is formally defined as a measurable variable representing an operational attribute of a given system (Gallopin, 1997). A feasible indicator is "representative, scientifically valid, simple and easy to interpret, shows trends over time, gives early warning about irreversible trends, is sensitive to changes, based on data that are readily available, adequately documented and of known quality, and capable of being updated at regular intervals" (DOE, 1996). Indicator systems may comprise sets of indicators or combine these to give composite indices (Booysen, 2002).

Jack Mabbutt, of the University of New South Wales, who made valuable contributions to UNEP's desertification assessments, stated in 1986 that desertification indicators should be: (a) as specific as possible to desertification, to avoid confusion with other phenomena; (b) sensitive enough to show the gradual development of desertification in an area; (c) easily quantified by ground observations or remote sensing techniques, or (especially for socio-economic indicators) available in published statistics; (d) comprehensive enough to be widely applicable to different types of areas; (e) suitable for repeated scanning by ground observation or remote sensing, or capable of periodic updating if obtained from published statistics; and (f) recognizable or usable without specialized training.

For any phenomenon a variety of indicator systems can be chosen. Differences between their taxonomies may be either semantic or structural. Semantic differences arise when alternative names are used for the same quantity. Structural differences are termed ontological (Hunter, 2002). Here an *ontology* is "an explicit, partial account of a conceptualization" (Guarino and Giaretta, 1995), not a philosophical "theory.. of what can be known" (Johnston, 1986). An indicator system's ontology is apparent in its multi-level classification system. A hierarchy of sustainability indicators is usually headed by key normative states or functions of a resource, e.g. vegetation and soil for desertification. Each is linked to indicators at lower levels which monitor progress in meeting it. These indicators may in turn by grouped for convenience, e.g. by land use in the case of desertification.

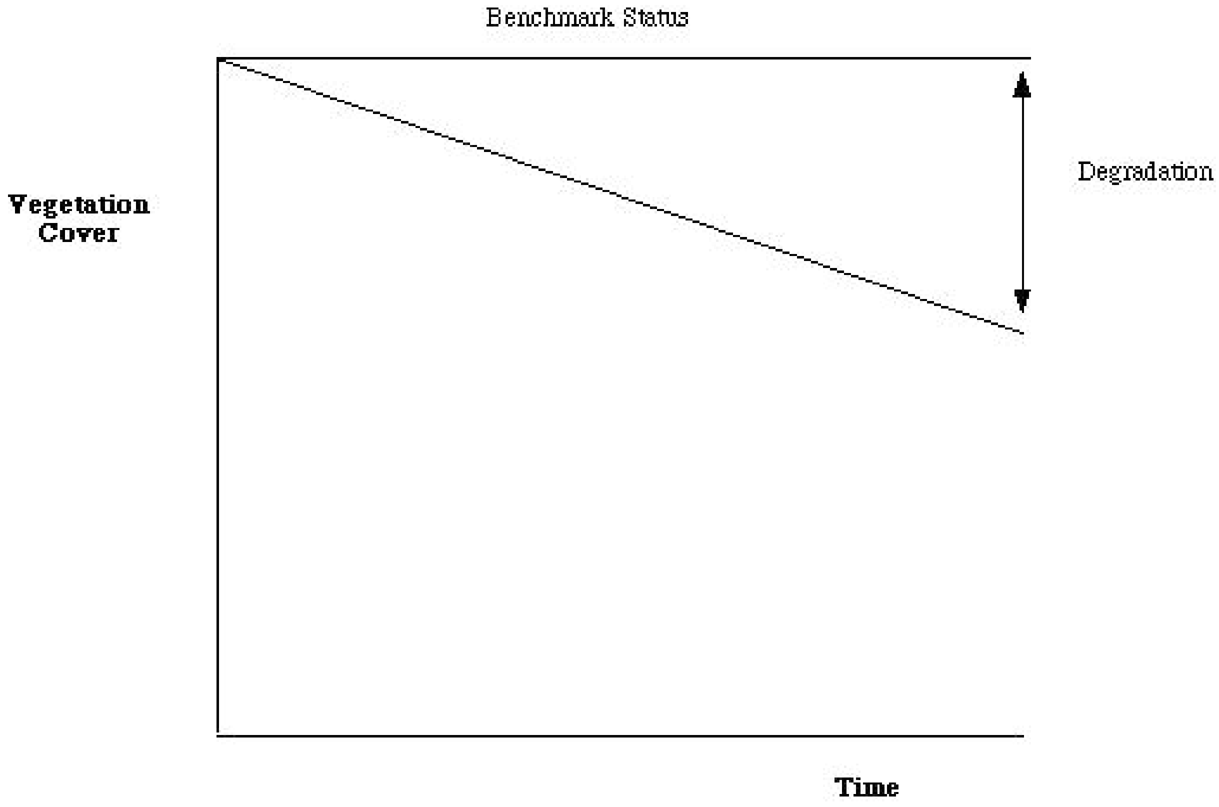
2.8 INDICATOR FRAMEWORKS

2.8.1 Conceptual Frameworks

If a set of indicators is to provide a comprehensive description of a given phenomenon in a Baseline Survey it should be framed within an equally comprehensive conceptual model of that phenomenon. Employing too simplistic a model will limit the scope of the set. A set of indicators framed by no model at all will lack coherence. Ideally, such a *conceptual framework* will:

1. Identify key variables.
2. Distinguish between (a) observable parameters that characterize the phenomenon, and which can be quantified using indicators; and (b) driving and controlling variables (Adamowicz, 2003).
3. Cluster similar indicators together under superior headings in the hierarchy.
4. Distinguish between indicators representing different types of variables (e.g. states and fluxes) and other items (e.g. plans and actions).
5. Reveal interconnections between variables and indicators.
6. Prevent duplication and inconsistencies.
7. Show how to synthesize information from indicators to give an integrated overall picture of a phenomenon (Reynolds et al., 2002).

Figure 2.2. The Role of Benchmark Status in Assessing Degree of Vegetation Degradation



2.8.2 Utilization Frameworks

Research by Henrik Gudmundsson (2003), of Denmark's National Environmental Research Institute, has distinguished between *conceptual frameworks* and *utilization frameworks* which portray the range of uses of indicator information. These are commonly divided into: *instrumental uses* that support decision-making; *conceptual uses* that allow actors to use the indicators to learn more about the phenomenon concerned in a general sense; and *symbolic uses* which confer legitimacy on actors using indicator information (Shulha and Cousins, 1997).

In view of the ambiguous nature of desertification in political fora (Ortiz and Tang, 2005) the Parties to the UNCCD will need to take care when selecting their set of indicators to ensure that they choose the set that best meets their intended requirements for utilization. Too large a set may well be politically legitimate and facilitate conceptual and symbolic uses, but it will lessen the feasibility of instrumental uses and producing scientifically credible information with the data collected.

2.9 DEVELOPMENT VARIABLES AND INDICATORS

As our understanding of development has evolved, increasingly integrated variables have been devised to portray it. However, indicator selection has not kept pace with this.

2.9.1 Economic Growth

Economic growth involves an increase in an economy's output of goods and services, a variable measured by the annual Gross Domestic Product (GDP) indicator.

2.9.2 Economic Development

Economic development involves a rise in the well-being of society as a whole. This requires that income generated by economic growth be distributed equitably throughout society (Thirwall, 1999).

GDP Per Capita has long been used as an indicator of development, even though it only measures average income per person and not its distribution. In 1990 the UN Development Programme began publishing a Human Development Index (HDI) which overcomes some of the limitations of GDP Per Capita by also incorporating social factors (UNDP, 1990). It varies between 0 and 1 and is estimated as the average of three indicators measuring:

1. Adjusted per capita income.
2. Educational attainment.
3. Life expectancy at birth.

The value of each of these indicators Xi (i = 1-3) is calculated using the formula: Xi = (actual value - minimum value)/(maximum value - minimum value). The HDI does not directly address inequality within a country (Hicks, 1997). Nor does it incorporate environmental welfare, even though some experts have suggested that this is a disadvantage (Sagar and Najam, 1998; Neumayer, 2001).

2.9.3 Sustainable Development

Sustainable development is a form of economic development which does not undermine the environmental basis of human livelihoods. Three definitions are widely used:

1. “Development which meets the needs of the present generation without jeopardizing the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). This is too unspecific to represent by a variable and measure by an indicator.

2. "Development which limits the human scale to a level which, if not optimal, is at least within carrying capacity" (Daly, 1990). This is based on an ecological economics model in which economic activities are increasingly constrained by biospheric laws as their scale gets closer to the planet's ultimate carrying capacity.

The relation between human scale and carrying capacity is measured by the Ecological Footprint index (Wackernagel and Rees, 1996) and the Environmental Space index

(Buitenkamp et al, 1992). Yet both have an environmental focus and neglect social and economic aspects (Moffatt, 1996).

3. "Development that leads to non-declining human welfare over time" (Pearce, 1991). This is based on an environmental economics model which compartmentalizes the economy from the environment and assumes that human welfare includes economic, social and environmental welfare.

The variable that most integrates these three forms of welfare is 'Total Capital', which is the sum of Natural Capital (environmental resources), Human Capital (human resources) and Man-Made Capital (productive resources). If all generations are to have equal access to Total Capital it should not decline. So annual investment in Human Capital and Man-Made Capital must at least equal the value of Natural Capital depleted to generate the income needed for this investment.

One national indicator that measures compliance with this condition is the *Genuine Savings Index* Z, which is the difference between Net Saving and Natural Capital depreciation, divided by annual income (Hamilton, 1994). Development is sustainable if Net Saving at least equals Natural Capital depreciation, i.e. Z is not less than zero. Thus the USA (Z=2) was sustainable in the 1980s but Mali (Z=-14) was not (Pearce and Atkinson, 1993). However, this indicator does not require a rise in intra-generational social welfare that is fundamental to economic development, as defined above.

2.10 ASSESSMENT PROCEDURES

2.10.1 Expert and Lay Assessments

Most previous estimates of the extent and degree of desertification have relied on subjective assessments by scientific 'experts' appointed by UN agencies. Experts are defined as "actors... possess[ing[... issue-related knowledge" by Corell (1999). According to this definition, the term 'experts' can also include people living in areas said to be affected by desertification. They possess considerable contextual knowledge and so have the ability to make lay assessments. This is the definition adopted by the UNCCD, which allows lay people to be on its Roster of Experts.

2.10.2 Measurements

The extent and degree of desertification may be measured empirically by instruments on the ground or in the air (remote sensing methods). Each of the latter methods has advantages and disadvantages.

Aerial photography from light aircraft is capable of high spatial resolution.However, surveys take a lot of time and produce a huge number of photographs, each of which must be interpreted separately by a trained operator. Consequently, aerial photography could be used for a detailed Baseline Survey of a country or part of a country, but it would not be suitable for subsequent annual monitoring, except of localized areas where problems are most acute.

Satellite images can survey large areas at relatively low cost, and strike a better balance between resolution and the volume of output data. The cost of interpreting an image is between a tenth and a third of that required to analyse an aerial photographic survey of the same area. Because the image is stored in digital format its interpretation can be automated, thus saving more time.

Until recently, the maximum resolution of satellite images has been lower than that of aerial photographs, though resolution still varied greatly. High resolution images are collected by Landsat satellites (30-80 m resolution) and SPOT satellites (10-20 m resolution). The latest satellites offer even higher resolution. In contrast, sensors on weather satellites have a coarser resolution, ranging from 1 km to 4 km. As each image covers a large area this reduces the amount of processing required, though the fine detail of soil erosion will not be shown.

2.11 INSTITUTIONS AND REGIMES

In order to follow the Baseline Survey with comparable surveys repeated at regular intervals of time it will be necessary to establish institutions to ensure this behaviour. *Institutions* are "enduring regularities of human action in situations structured by rules, norms and shared strategies, as well as by the physical world" (Crawford and Ostrom, 1995).

International environmental agreements, such as the UNCCD, are social institutions which are continually reproduced by the activities of their Parties (Vogler, 2003). The term *regime* is used to group all the agreements in a particular area, such as desertification (Krasner, 1983).

2.12 TYPES OF EVIDENCE FOR MONITORING IMPLEMENTATION

Three terms are used to evaluate the implementation of international environmental agreements:

Outputs refer to the reproduction of international or national institutions, e.g. by holding regular meetings of a Conference of the Parties, establishing national policies committed to implementing the international agreement concerned, or passing legislation to codify these policies.

Outcomes refer to the actual implementation of such policies and legislation in ways that change the behaviour of those who cause the problem tackled by the agreement.

Impacts refer to measurable changes in key features associated with the problem, e.g. in desertification the social, economic and biophysical dimensions of dryland livelihoods and environments (Young, 2001).

In the categorization of indicators by the Intergovernmental Negotiating Committee for Desertification (CST, 1997a), 'implementation indicators' correspond to outputs and outcomes, and 'impact indicators' to our definition here. The UNCCD Baseline Survey will use impact indicators.

CHAPTER THREE

MODELLING DESERTIFICATION

3.1 INTRODUCTION

In Chapter 2 it was argued that an appropriate conceptual framework is indispensable if a coherent and properly structured set of indicators is to be selected for a Baseline Survey and subsequent monitoring. Ideally this will be based on a scientific model of the phenomenon concerned. This chapter begins by showing, in conformity with the Terms of Reference for this document, how the DPSIR framework can be used to provide the template for a model to portray desertification. It then reviews the limitations of this approach, outlines the principles of the emerging consensus scientific model of desertification, and assesses the implications of this model for choosing a set of desertification indicators and procedures for measuring them.

3.2 THE DPSIR FRAMEWORK

A convenient generic stepping stone to a conceptual framework for organizing the indicator system in any survey is the Driving Forces-Pressures-States-Impacts-Responses (DPSIR) framework. It portrays any phenomenon as a circular system. State variables, which measure the quantitative or qualitative states of natural resources, undergo change as a result of direct Pressures. These are linked to underlying indirect Driving Forces. Changes in States lead to Impacts, measured by changes in physical or social states. Society reacts to the Impacts by Responses that ideally influence the Driving Forces (Fig. 3.1). Using this structure to classify indicators should, in principle, reduce confusion between different types of indicators when constructing indicator systems (Walmsley, 2002).

The DPSIR framework is not a scientific model. Instead, it was devised by development planning organizations to classify indicators to monitor sustainable development. It adopts a rational approach that does not draw on any academic conceptual framework of human-environment relationships, and this is symptomatic of the longstanding divide between the political process of sustainable development and the parallel academic process (Grainger, 2004). It evolved from the Pressure-State-Response framework devised by the Organization for Economic Cooperation and Development (1993), and the Driving Forces-State-Response framework used by the UN (UNEP/UNDPCSD, 1995). It attained its present form through work by the European Environment Agency (1995).

3.3 A SIMPLE MODEL OF DESERTIFICATION IN A DPSIR FRAMEWORK

Previous attempts to devise sets of desertification indicators implicitly adopted a conceptual model with linear unidirectional relationships. Structured using a DPSIR framework its components include:

1. Driving Forces: societal changes and the indirect effects of climatic variation.

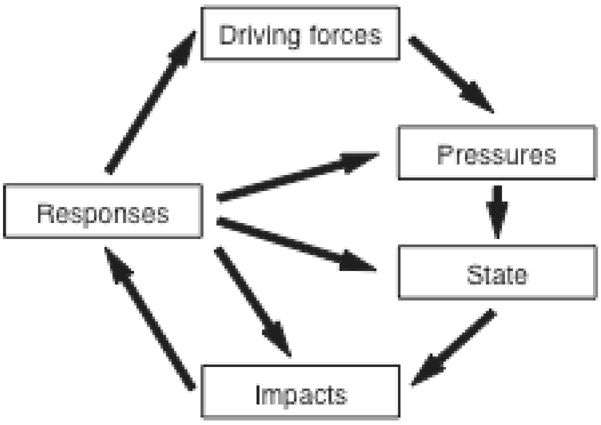
2. Pressures: land use, resource extraction and the direct effects of climatic variation.

3. States: the quantity and quality of soil and vegetation resources.

4. Impacts: different types of changes in soil and vegetation; changes in economic welfare, as farmers' income from cropping or pastoralism falls when degradation cuts yields: and changes in social welfare, as some social groups become absolutely or relatively poorer than others.

5. Responses: changes in national and international policies and in livelihood strategies.

Figure 3.1. The DPSIR Framework



Before proceeding, two differences between the DPSIR framework and reality must be acknowledged. First, some factors which act as Driving Forces for desertification can also control it. For example, economic development and technological innovation. Second, some factors fit into more than one category. For example, according to a recent article by Helmut Geist of the University of Aberdeen and Eric Lambin of the Catholic University of Louvain (2004), on which our analysis draws, climatic variation is both a Pressure which directly affects the quantity and quality of vegetation cover, and an underlying Driving Force which affects the type and intensity of land use. Government policies can also be Driving Forces as well as Responses, and hence are as much part of the problem as part of the solution.

3.4 TYPES OF LAND DEGRADATION

Desertification involves a diminution in the States of two land resources - vegetation and soil - in different ways. Within the DPSIR framework the latter can be understood as different Impacts.

3.4.1 Vegetation Degradation

There are two main forms of vegetation degradation:

1. A reduction in the proportion of land covered by vegetation, or in its biomass density (the amount of plant material per unit area). This occurs when rangelands are overgrazed; or when individual trees in open (savanna) woodlands are cleared for cropping and grazing, cut down or pruned for fuelwood or fodder, or overbrowsed by livestock. On rainfed croplands, the average density of vegetative cover can fall when crop yields and fallow periods decline.

2. A change to a less productive type of vegetative cover which consists of different species or even different general types of plants. On overgrazed rangelands, perennial grasses may be replaced by less palatable annual grasses and thorny, stunted shrubs, both of which are characteristic of the less productive ecosystems of drier climates. On irrigated croplands, more saline-tolerant crop species have to be grown when waterlogging and salinity problems develop.

Because the open woodlands characteristic of dry areas are multi-layer multiple-use resources comprising trees, shrubs and grasses, their degradation is difficult to monitor (Grainger, 1999). For convenience, the contribution to desertification of the degradation of natural woody vegetation is often assessed together with that of grasses in the context of 'rangeland degradation'.

3.4.2 Soil Degradation

Soil degradation occurs in four main ways:

1. Water erosion. Soil lacking the protection of vegetation cover is prone to being washed away by rain. In *splash erosion*, raindrops first disturb soil particles and then pack them together on the surface, sealing pores, decreasing infiltration and increasing runoff. A more serious form is *sheet erosion*, in which fine layers of topsoil are washed away, removing soil nutrients and reducing yields unless nutrients are replenished artificially.

   If erosion continues unhindered then water flows may concentrate in small channels or *rills*. These can develop into recognizable *gullies*. Small gullies often form along cattle tracks that create smooth channels for runoff. In some cases they grow into deep *canyons*.

2. Wind erosion. Wind blows away the finer components of soil, such as silt, clay and organic matter (which contain most of the soil nutrients), leaving behind less fertile sand, gravel and other coarser particles. In some areas, sands drift and sand dunes are mobilized, sometimes overwhelming nearby cropland and communities. Strong winds can transport large numbers of detached soil particles as 'dust storms'. These damage and sometimes kill crops by shredding foliage, and finally deposit the soil as sediment in rivers, lakes and irrigation channels.

3. Soil compaction. Compaction makes soil harder and less permeable. Runoff increases, leading to erosion, less water entering the soil for use by plants, and a less pervious soil in which it is difficult for plants to germinate and establish roots. There are two main categories. *Surface crusting* arises when high speed mechanical cultivation or cultivation in the dry season turns crumbs of soil particles into a thin powder which, under the pressure of raindrops, is packed into a smooth hard surface crust. *Compaction* to a greater depth occurs

when soil with poor structure is compressed either by the wheels of heavy machinery or the hooves of animal herds.

4. Salinization and waterlogging of irrigated cropland. Paying insufficient attention to drainage when irrigating croplands, or using too much water, can *waterlog* the soil. This can lead to *salinization* as excess water evaporates from the surface and the salts of sodium and other metals dissolved in the water are left behind, either near to or on the surface. *Alkalinization*, which involves enrichment in sodium ions that bind to clay particles, may also occur. Both processes constrain plant growth and lead to a drop in yields. More saline tolerant crops may be grown, but without corrective action eventually the land becomes unproductive and white saline deserts may form.

3.5 PROXIMATE CAUSES OF LAND DEGRADATION

Direct Pressures come from *proximate causes* of desertification. These include expanding, over-intensive or otherwise poorly managed lands uses and climatic variation. Helmut Geist and Eric Lambin (2004) also include infrastructure extension in this list but we treat it as an underlying cause.

1. Overgrazing. Pastoralism should be the most sustainable use of the sparse vegetation of low rainfall areas because mobile herds of livestock can harvest heterogeneous distributions of vegetation periodically and at relatively low intensity. But if too many animals are concentrated in one area, either throughout the year (on pastures surrounding a village) or seasonally (around a borehole on a main trek route for nomadic herds), then valuable perennial grasses are depleted and replaced by less nutritious annual plants, vegetation density is reduced and soil compaction occurs because of trampling by livestock herds. All of these changes facilitate soil erosion.

2. Overcropping. Cropping has a more intense impact on the soil because it involves complete clearance of natural vegetation, cultivation of the soil, and often grazing of the stubble that remains after crops are harvested. The soil is therefore exposed to the elements for long periods each year. Overcropping reduces the fallow period or increases the number of crops planted each year. This reduces the potential for replenishing fertility and depletes soil organic matter, causing a decline in the soil's fertility, structure, permeability and water-

holding capacity and increasing its vulnerability to erosion. Organic matter also declines when crop residues are cut for animal feed instead of ploughing them into the soil, and when manure is burnt as fuel instead of spreading it on the fields.

3. Poor Management of Irrigated Cropping. The mechanisms involved were described above.

4. Deforestation and Woodland Degradation. Trees prevent soil from being blown away by wind, and their roots lend cohesion to the soil and protect it from erosion by water. Deforestation resulting from the expansion of cultivation reduces vegetation cover and makes soil more vulnerable to erosion by later overcultivation or overgrazing. Woodlands are also degraded as over-intensive harvesting of trees to produce fuelwood or charcoal, and either lopping for fodder or overbrowsing by animals, reduces the density of trees and the amount of biomass and carbon each tree contains. Overcutting of fuelwood featured prominently in the UNCOD deliberations (Eckholm, 1975, 1976).

5. Climatic variation has a direct impact on both the quantity of vegetation cover and its quality, with the possibility of a long-term change in species composition/biodiversity if drought is prolonged. UNCOD stressed that desertification is only partly caused by the mobilization of sand dunes, but a recent report from Oxford University has predicted that a loss of vegetation resulting from global climate change could remobilize large areas of dunes in southern Africa (Thomas et al., 2005).

3.6 UNDERLYING DRIVING AND CONTROLLING FORCES

Pressures from proximate causes of desertification can be linked to various underlying causes (Driving Forces) or controlling factors (Geist and Lambin, 2004):

1. Population Growth. When population rises so does demand for food. This can be supplied in two main ways. One route is to produce food more intensively, e.g. by reducing fallow periods or cultivating a particular patch of land for a longer time. This can raise yields, but without investment in fertilizers and more productive cropping systems it is not sustainable. Alternatively, the area of land under farming is increased. This is sustainable if

the land is fertile, but if marginal land unsuitable for farming is brought under cultivation this may lead to soil erosion.

The effects of national population growth may be felt throughout a country. Alternatively, population density may grow in certain areas. Overcrowding causes farmers to crop their lands more intensively, if they are unable to move elsewhere and are too poor to invest in more productive types of farming. Traditional cropping systems which have proved sustainable for hundreds of years because of long fallow periods therefore break down, yields decline and the land becomes degraded.

2. Economic Development. Economic development may either drive or control desertification. The income it generates helps to overcome poverty and increase the ability to invest in using more productive cropping techniques, improved seeds, fertilizers, pesticides and better crop storage etc. So agriculture can concentrate on the most fertile lands where it can be sustainable, and withdraw from less fertile lands which are most susceptible to degradation under unsustainable land use. If, instead, expanding cash crop cultivation displaces traditional land uses on to land too marginal for them then degradation may result. Poverty resulting from lack of economic development can drive desertification if poor communities cannot respond sustainably to drought. As Piers Blaikie of the University of East Anglia (1985) commented, "environmental degradation is seen as a result of underdevelopment (of poverty, inequality and exploitation), a symptom of underdevelopment, and a cause of underdevelopment (contributing to a failure to produce, invest and improve productivity)".

3. Extension of Modern Infrastructure. Establishing new roads, irrigation canals, boreholes and other forms of modern infrastructure can sometimes facilitate sustainable land use. But it often intensifies human impacts in particular areas, leading to overgrazing around boreholes or salinization resulting from poorly managed irrigated cropping.

4. Technological Innovation. While some new technologies can control desertification, others can drive it. For example, using heavy agricultural machinery may compact the soil. When new technology is installed but breaks down this can also have negative consequences. So when a water pump stops working because of lack of maintenance this can lead to waterlogging and salinization.

5. Policy and Institutional Factors. The spread of institutions of the market economy can undermine traditional institutions which ensure social control over land use. For example, the complex mechanisms which nomadic pastoralists have long used to control grazing on rangelands. Many traditional institutions also decay because they are regarded by governments as old-fashioned. Their importance may not be realized until they have largely been dismantled, by which time it is often too late to restore them. Many attempts to introduce more modern forms of rangeland management in Africa have failed. Adopting a 'geometric' approach to grazing management, for example, should in theory lead to sustainable land use. For by limiting the number of livestock allocated to each 'block' of rangeland it should ensure that the carrying capacity of each block is not exceeded. However, in practice, this can lead to overgrazing if each block does not receive equivalent rainfall (Grainger, 1990). Left alone, nomadic pastoralists avoid areas where rainfall is poor and vegetation sparse. In some countries, e.g. in southern Africa, colonial land tenure institutions confined many indigenous people to less fertile areas, and if these institutions continue today this too can drive desertification.

Similar changes in institutions occur unwittingly as a result of government policies. Too much focus on urban growth can reduce the agricultural labour force to a level where it is insufficient to maintain land use sustainably. When governments keep food prices low for the sake of urban dwellers commercial farmers may not be able to employ enough workers. Governments may also try to promote development through social change, e.g. by resettling nomadic pastoralists in villages. Although this may improve education and health care it may also lead to overgrazing in the vicinity.

Helmut Geist and Eric Lambin (2004) also list "cultural factors" as a driving force. But since cultural perceptions are inseparable from the repeated practices that reproduce institutions, in our view they belong in this larger category. Moreover, while Western perceptions of limitless growth can drive desertification, some traditional values are more environmentally attuned and can control it.

6. Climatic Variation. Drought is an underlying cause of desertification because the associated reduction in vegetation growth may influence decisions on the type and intensity of land use, leading to over-intensive practices that degrade soil and vegetation and exacerbate

the Pressures listed above. Overusing the land may be inevitable when the poorest social groups are relegated to marginal areas. It becomes most pronounced, and its effects most apparent, in times of drought. For farmers may overcrop or overuse an area of land to compensate for the limited growth of crops or pastures.

3.7 CRITICISMS OF THE DPSIR FRAMEWORK

Desertification can therefore be analysed using the DPSIR framework, subject to the limitations stated in Section 3.3. Some of its assumptions correspond to those made in UNCOD-related studies, e.g. the predominance of single Pressures linked to single Driving Forces, and a set of linear relationships which lead to a steady accumulation of degraded land over long periods that accelerates in droughts.

However, the DPSIR framework does not provide a perfect structure for desertification analysis, owing to numerous fundamental deficiencies which have been identified in scientific studies:

1. It is predominantly managerial in approach, not conceptual. So while it organizes all variables associated with a phenomenon it uses an over-simplistic ready-made structure (Beekman, 2005; Gobin et al., 2004) and does not explain why the phenomenon occurs (Pearce, 2006). The basic distinction between stocks of natural resources, the proximate causes of their degradation, and the underlying (largely social) causes that act as driving or controlling forces, were evident to scientists well before the DPSIR framework was first proposed (e.g. Grainger, 1990).

2. Despite its managerial approach it offers no insights into how to manage problems like desertification. Its rational approach ignores all the insights obtained through 60 years of study of the effectiveness of government responses to natural and human-made hazards. Right from the start this research challenged rational assumptions, and showed how behavioural mechanisms can undermine the effectiveness with which government strategies are implemented (Mitchell, 1989).

3. It is best suited to phenomena with human Driving Forces, which can be manipulated, not underlying environmental causes, such as drought, which cannot (Berger and Hodge, 1998).

4. Despite having a human focus, its portrait of how societies function is shallow (Svarstad et al., 2008). This is evident in its limited treatment of how societies are affected by Impacts, and how political Responses are devised to tackle a given phenomenon. That Responses are not in practice automatic is evident from problems in implementing both the PACD and the UNCCD. Academic analysis of Responses is diverse and well established (Kasperson, 1969; O'Riordan, 1971).

5. It assumes the presence of linear unidirectional relationships, which is especially 'heroic' for human-environment relations (Segnestam, 2002).

6. By fitting all phenomena into the same basic structure it does not generate neutral knowledge. As a result, claims a group led by Hanne Svarstad of the Norwegian Institute for Nature Research (2008), it "has shortcomings as a tool for establishing good communication between researchers,... stakeholders and policy makers."

7. Its category of 'Impacts' actually aggregates two different types of variables: (a) fluxes, such as the rate of soil loss from an area; and (b) states, such as the quality of water in a reservoir which is diminished if eroded soil is deposited in it.

8. It fails even in its most basic function of providing a generic framework for indicator classification that is easily understood by all users. A review by this author of a sample of studies which used the DPSIR framework found that variables associated with the same phenomenon were allocated in different ways between the five DPSIR categories. This even applies to soil degradation applications: one recent paper cited land cover, i.e. vegetation, as a Pressure, when it should be a State, and the rate of soil loss as a State, not an Impact. Such differences may, of course, reflect the difficulties experienced in fitting a phenomenon into the rather inflexible DPSIR framework.

9. It makes no explicit mention of monitoring. Implicit assumptions that this is located in the link between Impacts and Responses ignore the possibility of another feedback link

between States and Responses. Of course, the term 'Responses' glosses over the complex ways in which governments formulate and implement policies. A typical policy process can be divided into seven stages:

1. Problem recognition.
2. Pressures on policy makers to add a problem to the policy agenda.
3. Formulation of policy under pressures from competing interest groups.
4. Formal statement of policy.
5. Legislation: codification of policy into legally enforceable rule.
6. Implementation of policy by state institutions and other actors.
7. Evaluation of policy implementation and feedback to policy makers.

Feedback loops from the final evaluation stage to stages 3-6 result in this model being circular like the DPSIR framework. Indicators employed in the evaluation stage generate information that is used instrumentally to improve the process as a whole (Grainger and Malayang, 2006).

3.8 A STATE-OF-THE-ART SCIENTIFIC MODEL

3.8.1 Objections to the Simple Model

The basic distinctions made so far in this chapter between stocks of natural resources, proximate causes of their degradation and underlying driving or controlling forces still remain scientifically valid, and continue to provide a sound basis for classifying desertification indicators. However, we now know far more about the nature of the processes which connect them, and this affects how indicators should be measured in a Baseline Survey and then monitored on a continuing basis.

Early analysis of desertification was not structured using a DPSIR framework, but it did share the latter's default assumption of linear unidirectional relationships, and had it also had limited spatial coverage. Scientists have since questioned: (a) the relevance of such an approach, as it appears to conflict with empirical evidence; and (b) estimates of the global extent of desertification made using indicators framed by this simple model (Thomas and Middleton, 1995).

So to end this chapter we outline research findings achieved since 1990 and highlight the implications of these for Baseline Survey design. One key advance has been to highlight spatial mechanisms of desertification, and this greatly enhances our ability to understand its spatio-temporal patterns.

3.8.2 Spatial Dynamics in Climate

The cyclical nature of rainfall in dry areas and its relationship with desertification was recognized at UNCOD (Grainger, 1990), but insufficient attention was paid to the existence of spatial cycles linked to these temporal cycles. Considerable emphasis was placed by UNEP, for example, on a comparison of recent aerial reconnaissance observations with an 18-year old map of the Sahara Desert's southern border, which implied that the desert was moving south at over 5 km per annum (Lamprey, 1975). This was ironic given that UNCOD was adamant that deserts did not expand of their own volition.

One factor that made scientists in the 1990s sceptical about the existence of desertification was a study carried out at NASA's Goddard Space Flight Centre. This showed, based on an analysis of low-resolution satellite images, that the boundary between the Sahara desert and the Sahelian region shifted south in 1981 but in 1985 moved north when rainfall returned (Tucker and Choudhury, 1987). In 1984 alone, the area of the Sahara Desert expanded by 15% compared with its value in 1980. Subsequently it contracted, but then continued to fluctuate (Tucker et al., 1991, 1994).

One implication of this research for Baseline Survey design is that identifying negative trends and their use as evidence for desertification crucially depends on the choice of start- and end-dates. Referring to the particular example above, a survey using 1981 as the baseline year could be interpreted to provide evidence for desertification, but one with 1985 as the baseline year would not. Another implication is that it can be misleading to use vegetation cover as a sole indicator of desertification, and to use it as one of two indicators unless the measurement in one year can be placed in a long-term context.

3.8.3 Uncertainty about Ecosystem Benchmarks

The degree of vegetation degradation is normally estimated in relation to the optimum vegetation cover that would be found in an area had it not been subjected to human influence (Fig. 2.2). Yet research has shown that this type of ecosystem *benchmark* is particularly difficult to identify in the drylands.

The original idea of desertification assumed that degradation occurred from a long-term *equilibrium* state, based on the traditional climax theory of ecosystem succession. Climatic climax vegetation should be the end-point of change when the vegetation in each area is free to develop to reach its ideal state, subject only to climatic and other natural constraints. Monitoring forest degradation in the humid tropics, for example, usually involves comparing the structure and species composition of the climax vegetation of tropical rain forest with that of the ecosystem that replaces it after human exploitation.

It has long been known that such a simple comparison is not possible in the dry tropics. Of those areas which are not under crop cultivation, most have changed greatly during thousands of years of human intervention, and so it is not possible to know what the original vegetation was. The annual burning of grasslands to improve pasture growth has prevented tree regeneration, and led to an artificially adapted vegetative cover of savanna grasslands with only a sparse tree cover. Full development to mature ecosystems is prevented (Monnier, 1981; Eyre, 1968).

Yet further studies of savanna ecosystems suggested that they are in a state of continual change and that no equilibrium ecosystem can be identified. Instead, the view that became prominent was best described as *non-equilibrium* dynamics (Abel and Blaikie, 1989; Behnke and Scoones, 1993).

More recent studies have shown that the situation even far more complicated. Currently, the dominant view is that equilibrium and non-equilibrium dynamics are just "extremes at either end of a continuum" (Skarpe, 2000). Both are simple models that should be approached with caution. The majority of more complex situations are best described by an *alternative states* theory, in which overgrazing can lead to a switch from one ecosystem state to another (Rietkerk and Van de Koppel, 1997). If the switch is to states of low vegetation cover then the degradation assumed in simple models of desertification can be seen, but the latter still do not typify all trends in dryland ecosystems.

This research has implications for how vegetation degradation is assessed in the Baseline Survey. It suggests that identifying a maximum vegetation cover benchmark for evaluation may be impossible, at least without further research. One option to cope with this would be to simply ignore vegetation degradation in desertification assessments. Another would be to propose either an 'optimum' type and percentage of vegetation cover, or a 'minimum safe' type and percentage of vegetation cover needed for environmental sustainability in each area.

In the longer term, continuous large-scale monitoring of changes in dryland ecosystems worldwide is needed so that scientists can use the resulting empirical evidence to construct a more science-based approach to assessing vegetation degradation in a way that takes full account of the complex spatio-temporal cycles of rainfall, plant growth and human exploitation of the latter.

3.8.4 Multiple Interacting Causes

As shown above, it has been thought convenient until now to explain desertification using various proximate causes, or Pressures, each of which can be linked to underlying causes, or Driving Forces. However, research by Helmut Geist and Eric Lambin (2004) suggests that single factor causation is rare, and that multiple factor causation is common. But it also finds that the complexity of human-environment relationships does have its limits: "in most cases, three to five underlying causes drive two to three proximate causes...[and] our results do not reflect irreducible complexity."

This has implications for the selection of indicators for use in the Baseline Survey since, as the discussion in Chapter 4 will show, previous sets of indicators have been linked to particular land uses. If monitoring environmental change in dry areas is not to become too complicated, one pragmatic response might be to continue with previous practice and then to qualify the results of desertification assessments by referring to the multiplicity of proximate causes.

3.8.5 Coupled Human-Environment Relationships

Early desertification studies assumed, as in the DPSIR framework, that human-environment relationships are fundamentally linear and unidirectional. Thus, farmers and pastoralists respond to reduced crop and pasture yields by intensifying cropping and grazing, which can degrade the land. As yields fall they intensify land use even more, to maintain overall yields.

Recent studies have shown that such 'vicious circles' are not as common as originally thought, since human beings often adapt to environmental constraints in ways that can prevent the occurrence of such extreme scenarios. So human-environment relationships are now treated as interactive or "coupled" (Liu et al., 2007), with people responding to environmental changes and vice versa.

It has long been recognized that ecosystems exhibit resilience, which is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still retain the same relationships between populations or state variables" (Holling, 1973). *Ecological resilience* is apparent when vegetation in the Sahel regrows as rains return, shown in the satellite studies reported above. But there is mounting evidence that it is accompanied by *social resilience*, in which people adapt to climatic and resource constraints in ways that do not degrade the environment, and help them to return smoothly to their former livelihood strategies when conditions improve.

For instance, Senegal's silvopastoral zone was, according to some reports, severely affected by desertification in the 1980s. But when Daniel Bradley, of the University of Leeds, visited the area in the 1990s he found little evidence for this. When he studied its two main social groups, the Wolof (mainly croppers) and the Peul (mainly pastoralists), he discovered that the Peul cope better with drought, as their mobile livelihoods have built-in adaptability resulting from long experience. When drought becomes very severe they switch seamlessly into a 'survival mode' which ensures an easy return to their long-term livelihoods when conditions improve. In contrast, the Wolof are much less able to cope with drought, and need to resort to quite radical responses, for example, migration and reliance on external support, when conditions deteriorate (Bradley and Grainger, 2004).

So human-environment relationships in dry areas are not uniform, linear and predictable, but variable, non-linear and unpredictable. Particular Driving Forces do not always lead to the same Pressures and Impacts, and the same Driving Forces can result in different Pressures and Impacts in different areas.

The implication for Baseline Survey design is that it is misleading to infer desertification when coarse resolution satellite images show that vegetation growth is restricted by limited rainfall.

3.8.6 Contextuality

These findings also help to explain why empirical studies have found that areas reported to have suffered from desertification actually experienced nothing of the kind. Even if land degradation occurs in some parts of an area it may be absent from others (Rasmussen et al., 2001; Tiffen and Mortimore, 2002). So land degradation is best portrayed as a *contextual* phenomenon (Warren, 2002).

The heterogeneity of human impacts on drylands contrasts with the relatively more homogeneous patterns seen in the humid tropics. These include frontier expansion of agriculture into large blocks of forests, and spatial concentrations of deforestation which are linked to the presence of roads or other underlying factors. Analysis of land use and land cover change in the humid tropics is facilitated by the assumption that uniform areas of forest and agriculture can be distinguished. This is not valid in the drylands. Consequently, mapping desertification, and changes in it, is far more challenging.

The implication for Baseline Survey design is that the large-area generalization about the extent and degree of desertification found in many early assessments may not be scientifically justified. Instead, credible assessments of the true spatial distribution of land degradation will only be obtained by empirical measurements that draw on a mixture of field measurements, contextual knowledge of people living in each area, high resolution aerial photos and satellite images.

3.8.7 Cross-Scalar Spatial Processes

Desertification has spatial dynamics as well as temporal dynamics. An early attempt by this author to describe these proposed four main spatial desertification mechanisms (Grainger, 1992):

1. Expansion. Meeting a rise in demand for food through extensification is a recognized strategy in agricultural change. But expansion on marginal land which is unsuited to it can lead to degradation.

2. Confinement. Degradation is also apparent when humans and their animals are confined to particular areas, by either proximity to boreholes and other water supplies, or land tenure restrictions.

3. Displacement. The expansion of export cash crop cultivation in humid areas can displace smallholder cultivation and pastoralism to more marginal areas, where they lead to degradation. In such cases the original underlying cause of degradation is exerted a long way from where its biophysical effects are actually observed.

4. Institutional Disintegration. Desertification was initially considered in some quarters to exemplify the so-called "tragedy of the commons" (Hardin, 1968), with open access rangelands being overgrazed by many herds operating without regulation. In retrospect, however, deficiencies in regulation resulted from a collapse of traditional forms of "social control" over grazing rights by nomadic tribes, driven by the encroachment of the market economy and disintegration of traditional societies. Introducing modern range management institutions also led to desertification, by imposing rational spatial restrictions that took no account of contextual variation in rainfall.

Displacement is now widely recognized as an important and distinctive feature of land use and land cover change in the drylands. The associated remote links between distant places are commonly referred to as "cross-scalar interactions" (Reynolds et al., 2007). The disintegration of nomadic institutions by the spread of market institutions from metropolitan cores is a similar phenomenon. Using DPSIR terminology, for instance, Pressures and Impacts in one area may be responses to Driving Forces originally exerted in another area entirely.

The implication for Baseline Survey design is that although empirical measurement remains vital, underlying causes of degradation may be far away from where it is observed. So adopting an integrated approach to indicator selection is important, but it is not valid to draw conclusions about causal factors by attempting to correlate the values of biophysical indicators in an area with the values of social and economic indicators in the *same* area. Similarly, development planners should take a holistic systems approach and evaluate impacts on the national scale when they evaluate proposed land use changes, or design programmes to control desertification. If they do this they will not be tempted to base their decisions on the results of 'same-area correlations' (Grainger, 1997).

3.8.8 Environmental Justice and Vulnerability

Simple circular models with linear unidirectional relationships imply that all social groups suffer equally from the same Impacts, regardless of socio-economic status, a phenomenon known as *environmental justice* (Cutter, 1996). Yet research shows that impacts of environmental hazards actually vary from one social group to another and from place to place (Mitchell and Dorling, 2003).

Such research builds on a long tradition of work by development economists, human-environment geographers and political ecologists.The Nobel prize-winning economist Amartya Sen argued that a link between drought and famine is not inevitable. Some groups are affected more than others because they have insufficient *entitlements* to cope with social, economic or environmental hazards that arise.

Entitlements are "the set of alternative commodity bundles that a person can command in a society using the totality of rights and obligations that he or she faces", and are affected by the institutions which frame the livelihoods of different groups (Sen, 1983, 1984). Human-environment geographers have also shown that different social groups are affected in different ways by hazards, depending on where their live, the nature of their livelihoods, and the institutions which frame the latter (Burton et al., 1993). According to political ecologists, poorer groups suffer the most from hazards since economic marginalization forces them to live in areas where risks are greatest (Watts, 1983).

Differentiation of social impacts is also a key theme in studies of *vulnerability*. This is "a function of the exposure and sensitivity of a system to hazardous conditions" and its ability "to cope, adapt, or recover from the effects of these conditions" (Smit et al., 2006). This research also builds on earlier work on entitlements and natural hazards, and is providing new insights into phenomena such as desertification. An influential paper by a group led by Billie Lee Turner, of Arizona State University, has proposed that vulnerability be interpreted on the assumption that interactions between human and environmental systems are reciprocal or "coupled", not unidirectional as the DPSIR framework assumes. Consequently, as Daniel Bradley found in Senegal (see above), different human-environment systems vary in their vulnerabilities to external stresses, as they differ in (a) entitlements; (b) coping capacities - how they respond to or avert harm from stresses; and (c) resilience - their ability to return to their former mode when stresses end (Turner et al., 2003).

It is generally agreed that that an index of vulnerability would help to compare the vulnerabilities of different groups and areas (Cutter, 2003; Bogardi, 2004). Unfortunately, no consensus index has yet been developed. This in part is a consequence of the range of scientific disciplines now undertaking research in this area. While the intensity and range of effort is encouraging, each adopts its own theoretical approach and this inhibits the development of a common explanation (Adger, 2006).

These findings have similar implications for Baseline Survey design to those described in Section 3.8.6, as they stress that social Impacts are just as contextualized as environmental Impacts. This suggests that it would be desirable to include an indicator of the distribution of vulnerability in the list of social indicators. It also strengthens the case for an integrated approach to selecting sets of economic, social and environmental indicators of desertification.

Table 3.1. Summary of the Drylands Development Paradigm

A. Five Key Features of the Drylands Syndrome

1. Variability
2. Low fertility and productivity
3. Sparse population
4. Remoteness
5. Distant voice

B. Five General Lessons from Research and Development Practice

1. Environmental and human dimensions are interwoven and need an integrated approach by natural science and social science researchers and practitioners

2. Many conditions are slowly evolving. There needs to be a heightened awareness of this, as short-term measures do not judge resolve persistent, chronic problems nor deal with continual change

3. Non-linear processes are common and should be recognized. Dryland ecosystems are not in equilibrium, have multiple thresholds and thus often exhibit multiple ecological and social states

4. Cross-scale interactions must be anticipated. Problems and solutions at one scale influence, and are influenced by, those at other scales

5. A much greater value must be placed on local environmental knowledge

C. Five Principles of the Drylands Development Paradigm

1. Human-environment systems are coupled, dynamic, and co-adapting, with no single target equilibrium point, so their structure, function and interrelationships change over time

2. The critical dynamics of dryland systems are determined by a limited suite of both biophysical and socio-economic "slow variables", such as soil fertility and household capital. These are influenced by "fast variables", such as crop yields linked to strongly fluctuating precipitation, which may lead to confusing conclusions about human-environment relationships

3. Slow variables possess thresholds which, if crossed, cause the human-environment system to move into a new state. Different states often have different controlling processes, and thresholds may change over time

4. Coupled human-environment systems are hierarchical, nested and networked across multiple scales. They involve multiple stakeholders, with highly differing objectives

5. Retaining coadaptation of human-environment systems depends on maintaining a body of up-to-date hybrid environmental knowledge that combines local and science-based knowledge. So maintaining and drawing on local environmental knowledge is crucial.

Source: Based on Reynolds et al. (2007), and paraphrased as appropriate

3.8.9 Drylands Development Paradigm

Science is not unitary, and at any time various explanations are being debated (Thomas, 1997). Yet many of the findings reported in this section were included in a recent synthesis of dryland knowledge made by a group led by James Reynolds of Duke University (Table 3.1). Many scientists working in the field would agree with what it says. Presented as an initial set of building blocks for a new "science of dryland development" (Reynolds et al., 2007), it outlines the principles of a Drylands Development Paradigm (DDP), which is itself a development of the earlier Dahlem Desertification Paradigm (Reynolds and Stafford-Smith, 2002). The article lists five main "fields of activity" in the drylands: desertification and rangelands ecology, vulnerability studies, poverty alleviation and community-driven development. The authors are correct to refer to the preliminary nature of this analysis, which is an uneasy mix between an ecological framework and the current participatory development paradigm, and thereby limited in its social science conceptualization. So our present scientific understanding is still embryonic and greatly in need of improvement and elaboration. Notwithstanding these limitations, the DDP is a fair reflection of the current state of the art.

CHAPTER FOUR

A HISTORY OF DESERTIFICATION SURVEY DESIGN AND IMPLEMENTATION

4.1 INTRODUCTION

A great deal of useful experience has been gained over the last thirty years in designing and implementing desertification surveys. This chapter critically evaluates these surveys, focusing on their design and implementation rather than on the estimates produced, and identifies the lessons that can be learned for the design of the forthcoming UNCCD Baseline Survey.

4.2 UN PLAN OF ACTION TO COMBAT DESERTIFICATION SURVEYS

The UN Plan of Action to Combat Desertification (PACD) was approved by the UN Conference on Desertification (UNCOD), held in Nairobi from 29 August to 9 September 1977 (UN, 1977a). UNCOD was preceded by two years of scientific research by UN agencies and a small group of expert consultants appointed by the UN Environment Programme (UNEP) (Lonergan, 2005).

4.2.1 The World Map of Desertification Hazard (1977)

One result of this research was a World Map of Desertification, prepared by the UN Food and Agriculture Organization (FAO), the UN Educational, Scientific and Cultural Organization, and the World Meteorological Organization (FAO/UNESCO/WMO, 1977). Although it became the most widely publicized of the four maps commissioned for UNCOD, it only showed the degree of desertification *hazard*, not the *status* of desertification (Fig. 4.1).

Table 4.1. Previous Sets of Desertification Indicators and Criteria for Allocating Areas to Severity Grades

Severity of Desertification	Vegetation Degradation	Wind Erosion	Water Erosion	Crop Yields
Dregne (1977)				
1. None				
2. Moderate				
a. Rangelands	Significant rise in undesired shrubs	-	-	-
b. Rainfed croplands	-	Significant rise in small dunes	Or significant rise in gullies	-
c. Irrigated croplands	-	-		≤50% fall due to salinity
3. Severe				
a. Rangelands	Undesirable shrubs dominate flora	-	-	-
b. Rainfed croplands	-	Vegetation cover largely absent	Or large gullies present	-
c. Irrigated croplands	-	-	-	> 50% fall due to salinity
4. Very severe				
a. Rangeland	-	Large, shifting barren sand dunes	Or many large, deep gullies	-
b. Rainfed cropland	-	Large, shifting barren sand dunes	Or many large, deep gullies	-
c. Irrigated cropland	-	-	-	Salt crusts form, soils almost impermeable
Dregne (1983)				
1. Slight				
a. Rangeland	Little/no vegetation degradation	-	-	-
b. Rainfed cropland	-	Little/no soil degradation	-	-
c. Irrigated cropland	-	-	-	Little/no soil degradation
2. Moderate				
a. Rangeland	climax species: 26-50% of total plant community	-	-	-
b. Rainfed cropland	-	25-75% of original topsoil lost	25-75% of original topsoil lost	-
c. Irrigated cropland	-	-	-	Fall 10-50% due to salinity
3. Severe				
a. Rangeland	climax species: 10-25% of total	-	-	-
b. Rainfed cropland	-	All/practically all topsoil lost	All/practically all topsoil lost	-
c. Irrigated cropland	-	-	-	Fall > 50% due to salinity
4. Very severe				
a. Rangeland	climax species: <10% of total	-	-	-
b. Rainfed cropland	-	Many sand dunes	Or many deep gullies	-
c. Irrigated cropland	-	-	-	Salt crusts present

Table 4.1 (Cont....)

Severity of Desertification	Vegetation Degradation	Wind Erosion	Water Erosion	Farm Yields
Mabbutt (1984)				
1. None				
2. Moderate				
a. Rangeland	Significant fall in cover/composition	Significant level	Significant level	carrying capacity down by ≤25%
b. Rainfed cropland	-	Widespread	Widespread	≤25% fall
c. Irrigated cropland	-	-	-	≤25% fall due to salinity
3. Severe				
a. Rangeland	-	-	-	carrying capacity down by 25-50%
b. Rainfed cropland	-	-	-	25-50% fall
c. Irrigated cropland	-	-	-	26-50% fall due to salinity
4. Very severe				
a. Rangeland	Economic reclamation impossible	-	-	carrying capacity down by >50%
b. Rainfed cropland	-	-	-	>50% fall
c. Irrigated cropland	-	-	-	>50% fall due to salinity

UNEP World Atlas of Desertification (1992)

	Biotic Functions	Erosion	Terrain Suitability to Local Farming Systems	Farm Yields	Ease of Restoring Yields	Ease of Restoring Terrain
1. None	All intact	None	-	-	-	-
2. Light	Largely intact	-	Suitable	Reduced	By Changing Management	-
3. Moderate	Partially destroyed	-	Suitable	Greatly reduced	With major improvements	-
4. Strong	Largely destroyed	-	-	-	Cannot restore	Major engineering works
5. Extreme	Completely destroyed	-	-	-	Cannot restore	Cannot reclaim

Table 4.2. Critical Indicators of Desertification

A. Physical
1. Soil
a. Soil depth
b. Amount of soil organic matter content
c. Degree of soil crusting
d. Dust, dust storms and sandstorms
2. Water
a. Groundwater depth and quality
b. Extent and persistence of surface water
c. General status of rivers and streams
d. Stream turbidity and rate of discharge

B. Biological and Agricultural
3. Vegetation
a. Extent of vegetation cover
b. Species composition of vegetation cover
c. Annual amount of biomass produced by plants
d. Distribution and frequency of key plant species
4. Fauna
a. Species distribution of domestic livestock herds
b. Size of domestic livestock herds
5. Land and Water Use
a. Irrigation
b. Dryland agriculture
c. Pastoralism
d. Mining
e. Firewood
f. Water

C. Social
6. Settlement Patterns
a. New settlement
b. Expansion of settlement and sedentarization
c. Diversification of settlement
d. Settlement abandonment
7. Human Biological Parameters
a. Population structure and rates
b. Measures of nutrition status
c. Public health indices
8. Social Process Parameters
a. Conflict
b. Migration
c. Redistribution patterns
d. Marginalization
e. Cash versus subsistence livelihoods

Source: Reining (1978)

Figure 4.1. The World Map of Desertification Hazard (FAO/UNESCO/WMO, 1977)

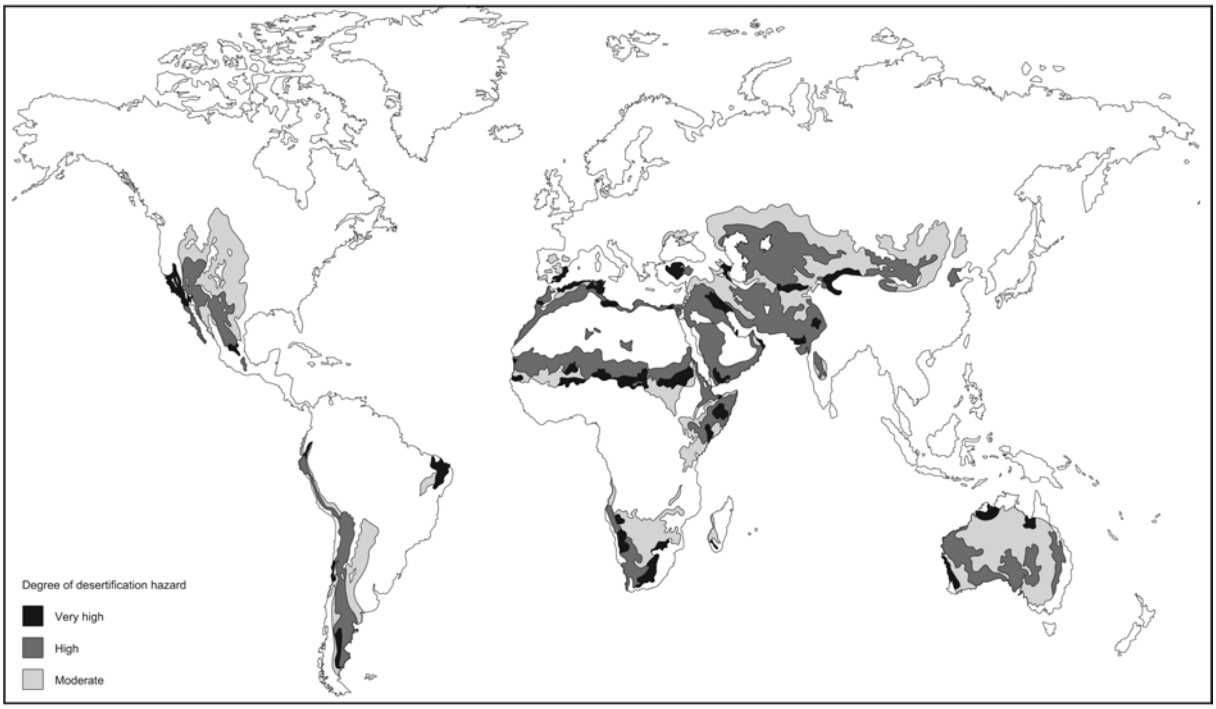


Figure 4.2. The World Map of Desertification Status (Dregne, 1977)

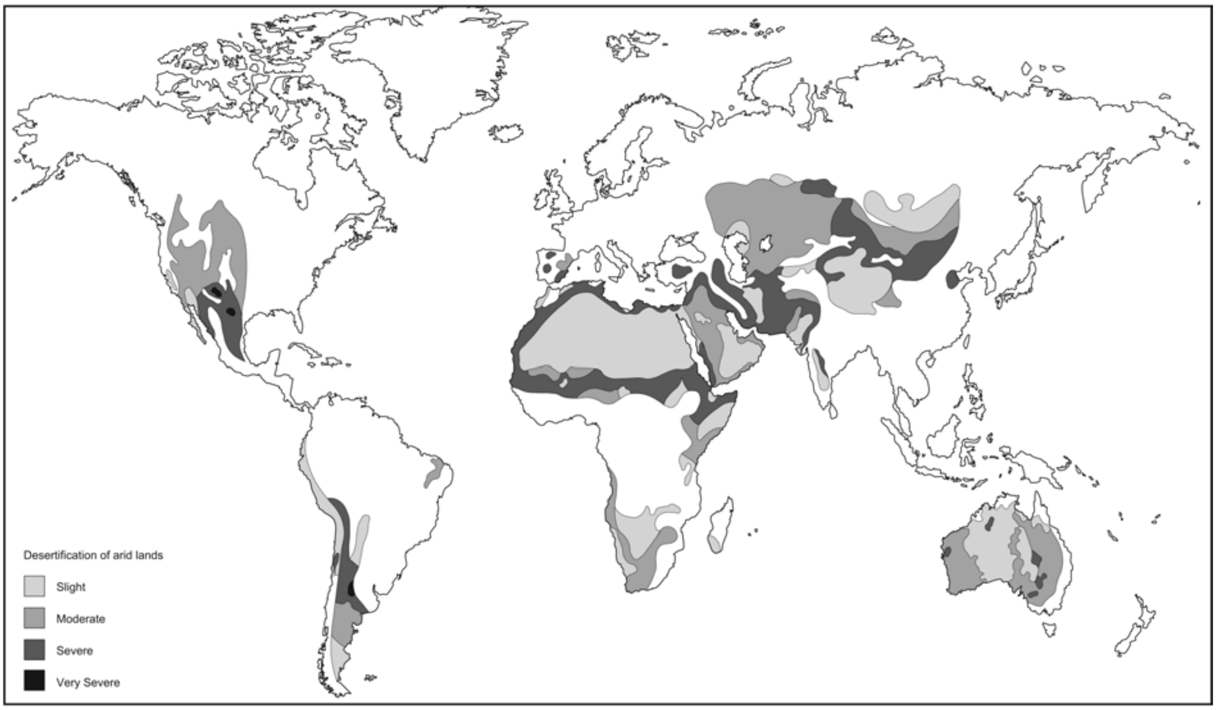


Table 4.3. Continental Areas Suffering At Least Moderate Desertification (million ha)

	Dregne (1983)	Mabbutt (1984)	UNEP Atlas (1992)
Africa	490	741	201
Asia	769	748	213
Australia	403	112	4
North America	399	208	66
South America	174	162	37
Europe	20	30	86
Total	2,255	2,001	607

Table 4.4. Areas by Land Use Suffering At Least Moderate Desertification 1984 (million ha)

Rainfed cropland	346
Irrigated cropland	40
Rangeland	1,615
Total	2,001

Source: Mabbutt (1984)

A desertification hazard indicator was estimated for each area through a subjective evaluation of climatic conditions, the inherent susceptibility of the land, and human or animal pressure. A four point severity scale was employed:

1. No hazard
2. Moderate hazard
3. High hazard
4. Very high hazard

An estimated 37.6 million sq km of drylands, two thirds of which were in Asia and Africa, were said to be subject to at least moderate risk from desertification.

4.2.2 The World Map of Desertification Status (1977)

Another output, given much less publicity, was a map of desertification status prepared by one of UNEP's experts, Harold Dregne (1977) of Texas Tech University (Fig. 4.2). His indicators were:

1. Vegetation composition
2. Wind erosion
3. Water erosion
4. Crop yield

As in many later assessments, each indicator was applied selectively to three major land use types:

1. Rangeland
2. Rainfed cropland
3. Irrigated cropland

Indicator values were estimated using separate criteria for each indicator, listed in Table 4.1 and with a four point severity scale:

1. No desertification
2. Moderate desertification
3. Severe desertification
4. Very severe desertification

This set included three biophysical indicators and one economic indicator, agricultural yield, though only for irrigated cropland. The equivalent biophysical indicator would be the degree of salinity. Dregne (1983) later proposed a partial scale for measuring this, based on electrical conductivity:

1. Slight: < 4 milliSiemens
2. Moderate: 4-8 milliSiemens
3. Severe: 8-15 milliSiemens
4. Very Severe: thick salt crust

The criteria for the two other land uses required comparison with features of some ideal type of non-degraded land. Each indicator was used consistently in the Moderate and Severe grades, but in the Very Severe grade no vegetation indicator was used and agricultural yield was replaced by a biophysical indicator. No estimates of the areas in each severity class were published with this map.

4.2.3 American Association for the Advancement of Science Indicators (1977)

Another early indicator system was developed independently of the UN system, though it contributed to its work. This was constructed at an American Association for the Advancement of Science seminar held in Nairobi directly before UNCOD in 1977 (Reining, 1978). This set of indicators was notable for its wide scope, covering biophysical, agricultural and social factors (Table 4.2). On the other hand, it could be criticized for being too general and too academic in tone. Quantifying many of the indicators would also require extensive field work. Animal indicators are not that useful since they are indirect and could be confusing, e.g. large herd numbers could either indicate plentiful pastures or overgrazing and the potential for future desertification.

4.2.4 Dregne's (1983) Assessment of Desertification Status

For his second survey, in which he produced desertification maps for each continent as well as the whole world, Dregne used the same three land use types but only three indicators, since Water Erosion and Wind Erosion were now effectively combined. His criteria were now more specific, though there was some lack of consistency. For example, the Soil Erosion indicator switched from soil depth to erosive features in the Very Severe grade, and the indicator for irrigated cropland again switched from agricultural yield to a biophysical variable in the Very Severe grade (Table 4.1). Vegetation Composition was now applied consistently in all severity grades, though the rangeland criteria made specific references to the concept of climax ecosystems central to equilibrium theory (see Section 3.8.2), which raises questions about its present scientific credibility.

Of a total dryland area of 4,706 million ha, almost half, 2,255 million ha, was said to be affected by moderate, severe or very severe desertification (Table 4.3). The annual rate of desertification was estimated at 20 million ha per annum. But since the overall scale of desertification was not known very accurately, this last figure should be treated with caution.

4.2.5 General Assessment of Progress of the Plan of Action (Mabbutt, 1984)

In 1984 UNEP undertook a General Assessment of Progress of the Plan of Action. It began by circulating questionnaires to 91 governments, but as this produced very little meaningful information an expert consultant, Jack Mabbutt, was asked to undertake his own survey.

Like Dregne, he used a four point severity scale and divided his set of indicators by the three main agricultural land uses, though he aggregated all croplands. He employed some environmental indicators but economic indicators measuring agricultural production were predominant.

Some 2,000 million ha of drylands were estimated to suffer from at least moderate desertification, of which 1,615 million ha were rangelands, 346 million ha rainfed croplands, and 40 million ha irrigated croplands (Table 4.4). Although these estimates were prepared for UNEP they were not officially released by it, mainly because of the poor quality and quantity of the data on which they were based.

Table 4.5. FAO/UNEP Provisional Methodology: Criteria for Assessing Water Erosion Status, Rate and Inherent Risk

Desertification Aspect	Assessment Factor	Slight	Moderate	Severe	Very severe
Status	1. Surface status (%) <10	Gravel & stones 10-25	Stones & boulders 25-50	Boulders & rocks >50	Boulders, exposures of rocks
	2. Type of erosion	In sheet & rill	In sheet & rill	In sheet, rill & gully	In sheet, rill & deep gully
	3. Subsoil exposed (% of area)	<10	10-25	25-50	>50
	4. Gully area (% of total area)	<10	10-25	25-50	>50
	5. Soil thickness (cm) (%)	>90	90-50	50-10	<10
	6. Loss of soil depth over root-inhibiting layer (%)				
	a. Original soil depth < 1m (%)	<25	25-50	50-75	>75
	b. Original soil depth > 1m (%)	<30	30-60	60-90	>90
	7. Present productivity as % of potential productivity	85-100	65-85	25-65	<25
Rate	1. Increase in eroded area (%/yr)	<1	1-2	2-5	>5
	2. Soil loss (t/ha/yr)	<2.0	2.0-3.5	3.5-5.0	>5.0
	3. Decrease in annual biomass production (%/yr)	<1.5	1.5-3.5	3.5-7.5	>7.5
	4. Sediment deposition in reservoirs, watershed 500 sq km (cubic m/sq km/yr)	<60	60-200	200-500	>500
	5. Annual loss of storage (%)	<0.2	0.2-0.4	0.4-1.0	>1.0
Inherent risk	1. Rating of climatic aggressivity	0.03	0.03-0.06	0.07-0.10	>0.1
	2. Rating of pedo-topographical conditions	<1	1-2	2-3	>3
	3. Rating of potential soil loss (t/ha/yr)	<5	5-15	15-25	>25

Source: FAO/UNEP (1984)

This study was distinctive for also covering social impacts, estimating that at least moderate desertification affected 280 million rural people and 190 urban residents. Most affected rural people were in rainfed cropland areas in the Sudano-Sahelian region, Africa south of this region, the Andean region of South America, and parts of South Asia. Fewer people were affected by desertification of irrigated lands, though this caused the greatest production and investment losses.

4.2.6 FAO/UNEP Provisional Methodology (1984)

In the same year FAO, working with UNEP, devised a Provisional Methodology for assessing and mapping desertification. This divided indicators into six main groups:

1. Vegetation Degradation
2. Water Erosion
3. Wind Erosion
4. Salinization
5. Soil Crusting and Compaction
6. Organic Matter Reduction

After each indicator was quantified, desertification status was to be assessed on a four point severity scale as Slight, Moderate, Severe or Very Severe.

This set of indicators was comprehensive in biophysical scope but largely ignored social and economic aspects. It was more complex and precise than other sets, as shown by its water erosion indicators and criteria (Table 4.5). Mabbutt (1986) felt that heavy reliance on ground measurements requiring "considerable technical skill" might limit its feasibility for operational surveys of large areas.

4.2.7 UNEP World Atlas of Desertification (1992)

Eight years later UNEP undertook a new survey of desertification status in collaboration with the International Soil Reference and Information Centre (ISRC) in the Netherlands. This was based on ISRC's Global Assessment of Human-Induced Soil Degradation (GLASOD) database. A full global assessment and mapping exercise was carried out by 250 experts. It

Table 4.6. Areas by Degradation Type Suffering At Least Moderate Desertification 1992 (million ha)

Water erosion	292
Wind erosion	235
Chemical deterioration	56
Physical deterioration	24
Total	607

Source: Middleton and Thomas (1992)

Table 4.7. Criteria for Assessing Four Categories of Soil Degradation in the UNEP World Atlas of Desertification (Middleton and Thomas, 1992)

A. Water Erosion

1. None.
2. Light
   a. Rangelands: the original/optimal vegetation covers at least 70 % of the surface
   b. Rainfed croplands: part of the topsoil has been removed from deep soils, and shallow rills spaced 20-50 m part may be present. Thin soils have rills at least 50 m apart
3. Moderate
   a. Rangelands: the original or optimal vegetation cover is reduced to 30-70 %
   b. Rainfed croplands: deep soils have lost all topsoil; there may be rills, less than 20 m apart, and gullies 20-50 m apart. Thin soils have lost part of the topsoil and are likely to have rills 20-50 m apart
4. Strong
   a. Rangelands: the original/optimal vegetation cover is less than 30 per cent.
   b. Rainfed croplands: deep soils have lost all topsoil and some subsoil,with moderately deep gullies under 20 m apart. Thin soils have lost all topsoil, exposing bedrock, weathered bedrock or a hard pan
5. Extreme: the land is unreclaimable and impossible to restore

B. Wind Erosion

1. None
2. Light
   a. Rangelands: the original/optimal vegetation covers more than 70 % of the surface
   b. Rainfed croplands: part of the topsoil has been removed from deep soils, and there may be a few (10-40% of area) shallow (0-5 cm) hollows.Thin soils have very few (under 10%) shallow hollows
3. Moderate
   a. Rangelands: the original/optimal vegetation cover is 30-70%
   b. Rainfed croplands:
      i. In deep soils, all topsoil is removed, or with common (40-70 per cent of area) shallow (0-5 cm) hollows, or few(10-40% of area) moderately deep (5-15 cm) hollows
      ii. In thin soils, topsoil is partly removed or with few (10-40% of area) shallow (0-5 cm) hollows
4. Severe
   a. Rangelands: the original/optimal vegetation cover is less than 30%
   b. Rainfed croplands: deep soils have lost all topsoil and part of the subsoil. There are many (>70% of area) shallow (0-5 cm) hollows, common (40-70 % of area) moderately deep (5-15 cm) hollows, or a few (10-40% of area) deep (15 cm) hollows/blow-outs. Thin soils have lost all topsoil, exposing bedrock or a hard pan

C. Chemical Deterioration

This category includes nutrient depletion in all soils and salinization of irrigated soils. Salinization was assessed by a five point scale - None, Light, Moderate, Strong and Extreme - based on a change in status over the last 50 years, not current status. No methodologies were included for assessing the 1940 baseline or nutrient depletion.

D. Physical Deterioration

The category of physical deterioration referred to compaction sealing and crusting; sodification (a physical consequence of salinization); waterlogging: a lowering of local ground water levels; and subsidence of organic soils. A five point scale was used (None, Light, Moderate, Strong and Extreme), but no assessment methodology was described.

was then refined to focus on susceptible drylands, divided into dry sub-humid, semi-arid and arid zones. The results were presented to the UN Conference on Environment and Development in 1992 and later published in UNEP's World Atlas of Desertification (Middleton and Thomas, 1992).

The focus was on assessing the severity of soil degradation using rather general indicators:

1. Intactness of biotic functions
2. Suitability of terrain to local farming systems
3. Agricultural yields
4. Ease of restoring full productivity
5. Ease of restoring terrainThese were assessed using less precise criteria than in earlier studies (Table 4.1) and on a five point severity scale:

1. None
2. Light
3. Moderate
4. Strong
5. Extreme

The total area affected by desertification was estimated as 1,035 million ha, of which 427 million ha was in the Light category, 470 million ha Moderate, 130 million ha Strong, and 7 million ha Extreme. The 607 million ha suffering from at least Moderate desertification was less than a third of the corresponding estimates by Dregne and Mabbutt (Table 4.3).

To map desertification the area affected in each mapping unit was ranked with another five point scale:

1. Infrequent: up to 5% of the area is affected
2. Common: 6-10% of the area is affected
3. Frequent: 11-25% of the area is affected
4. Very frequent: 26-50% of the area is affected
5. Dominant: over 50% of the area is affected

The two scores were then combined to give a map showing land suffering from No, Low, Medium, High and Very High degradation. These latter areas were not tabulated. The allocation algorithm was:

1. Low: Light 0-10%, Moderate <5%
2. Medium: Light 10-50%, Moderate 5-10%, Strong 0-5%, Extreme 0-5%
3. High: Light 50-100%, Moderate 10-50%, Strong 5-25%, Extreme 5-25%
4. Very High: Moderate 50-100%, Strong 25-100%, Extreme 10-100%

Separate assessments and maps were also produced for water erosion, wind erosion, chemical deterioration and physical deterioration. Water and wind erosion each accounted for over 40% of all degradation (Table 4.6). These surveys were made using more specific criteria (Table 4.7) and were divided by the three main agricultural land uses, as in earlier surveys. Although the focus was still on soil degradation, vegetation condition was included in assessing water and wind erosion.

Africa was surveyed separately using these four degradation types. Its 'vegetation degradation' was mapped too, but as this was based on a low (16 km) resolution Normalized Difference Vegetation Index (NDVI) product derived from weather satellite images its relevance is debatable.

Compared with previous surveys, the only significant advance made in indicator selection and estimation was in the use of two-stage ranking.

4.2.8 UNEP World Atlas of Desertification Revised Edition (1997)

In a revised edition of the Atlas, published in 1997, UNEP acknowledged that its earlier surveys had been criticized, partly because the data base was so subjective. The original global and Africa maps were retained and a new assessment for Asia (ASSOD) was included (Middleton and Thomas, 1997).

Although UNEP claimed that the ASSOD database was more refined, changes to the methodology were fairly minor. There was no change to wind erosion assessment and no significant change to that for water erosion. Chemical deterioration now also included eutrophication, and "pollution having no impact on productivity". Physical deterioration also included land taken out of productive use due to urban growth and mining, and a distinction was made between compaction, and crusting and sealing.

The overall impact of degradation on agriculture was determined by combining the magnitude of the change in agricultural productivity and the level of agricultural management. In principle, a large drop in productivity in a highly managed area should affect production more than in a poorly managed area, but as some terms in its taxonomy seemed to be inconsistent it is not described further here.

ASSOD indicators did not greatly improve on those of GLASOD. But indicator estimation was more decentralized, relying on national scientific bodies, instead of a group of UNEP experts.

4.2.9 Discussion

None of the estimates of the extent of desertification made during implementation of the PACD was very accurate, because they all largely relied on expert assessment rather than empirical measurement. Both Mabbutt and Dregne only gave very approximate estimates of the scale and degree of desertification. Desertification categories were only loosely defined, very few actual measurements were made to obtain basic data, and subjective expert judgement was much to the fore. Mabbutt's ontology is notable for including both biophysical indicators and economic (agricultural productivity) indicators. Dregne (1983) only used productivity indicators for irrigated croplands. Nevertheless, the huge effort put into developing indicators in the PACD era provides a foundation on which to build. Mabbutt's definitive 1986 analysis of desertification indicators also still has many lessons for us.

4.3 SURVEYING INITIATIVES OF THE UN CONVENTION TO COMBAT DESERTIFICATION

The need for a feasible universal set of benchmarks and indicators that can be used to survey desertification has been recognized by the Parties to the UN Convention to Combat Desertification (UNCCD) since it came into force in 1996. However, little progress has been made in meeting this need so far, which explains why the UNCCD still lacks a Baseline Survey.

This review is in two parts. The first relates to the period up to 2001, when the Committee on Science and Technology (CST) was advised by ad hoc panels of experts. The second deals with the period since 2001, when these panels were replaced by a Group of Experts (GOE) to provide advice with greater continuity and scientific depth (COP, 2001b, 2001d).

4.3.1 Actions up to 2001

Following discussions about national reporting commitments at the seventh and eighth sessions of the Intergovernmental Negotiating Committee on Desertification, a matrix of *implementation indicators* was presented for comment to the ninth session. This was reviewed and revised by an informal group of scientists and officials from governments and international organizations which met in Geneva on 13-14 November, 1996. The group also made suggestions about the role of *impact indicators* and recommended that matters be taken further by an ad hoc panel (INCD, 1996).

An informal consultative meeting, held in Ottawa on 15-17 July, 1997, further revised the set of implementation indicators and made suggestions about how to devise impact indicators (CST, 1997a). The first session of the Conference of the Parties (COP) convened an ad hoc panel of scientists. Its two meetings in Beijing from 20-22 May 1998 and Geneva from 1-3 September 1998 led to a series of recommendations about (a) the content of a set of indicators and (b) the consultative process required for its construction. It did not lead to a draft set of impact indicators (CST, 1998).

In the light of the continuing absence of a universal set of indicators agreeable to all Parties, in 2001 the COP urged Parties to develop their own sets of indicators to monitor progress, "better integrate the activities of the scientific and technical community into the implementation of the Convention", and include more scientific information when making their reports to the COP (COP, 2001b). The resulting diversity of indicator systems (CST, 2007b) has not facilitated coherent evaluation by the COP of the effectiveness of implementation of the UNCCD.

4.3.2 Actions Since 2001

Consequently, in 2005 the COP asked the CST "to advance progress in standardization of systems and data and information for the monitoring and assessment of land degradation and desertification, and to assist in establishing a standardized format for bio-physical and socio-economic indicators to be used in the formulation of country profiles" (COP, 2005).

The CST adopted a dual strategy in response to this request. First, in 2001 it established links with the Land Degradation Assessment in Drylands (LADA) Project which was due to begin in the following year (CST, 2001). Implemented by the UN Food and Agriculture Organization (FAO) and UNEP, this aims to integrate biophysical and socio-economic aspects of land degradation and produce a new global map to replace the Global Assessment of Soil Degradation (GLASOD) map used in the UNEP World Atlas of Desertification. The COP received progress reports from LADA in 2005 and 2007 (CST, 2005b, 2007a). The most recent output of LADA is reviewed below.

Second, it asked the new Group of Experts to produce proposals. A method to assess desertification at global, regional and local levels using benchmarks and indicators was one of three projects that formed the Programme of Work of the Group of Experts agreed in 2005 (CST, 2005c, 2005d). Another was the development of an integrated assessment method for poverty and land degradation.

Two years later, the Group of Experts published three reports on its work (CST, 2007b, 2007c, 2007d). Unfortunately, these are more like frameworks for future action than detailed proposals based on scientific research, and their tone is administrative, not scientific.

4.3.3 Land Degradation Assessment in Drylands Biophysical Indicators

The Land Degradation Assessment in Drylands (LADA) project initially proposed separate sets of indicators for Driving Forces, Pressures, States, Impacts and Responses at global, national/regional, watershed/village, and farm scales. A large number of demographic, socio-economic and institutional indicators were also included (FAO, 2004). However, the size of this set made its practical feasibility for operational monitoring questionable.

Figure 4.3. LADA/ISRIC Preliminary Map of Land Degradation

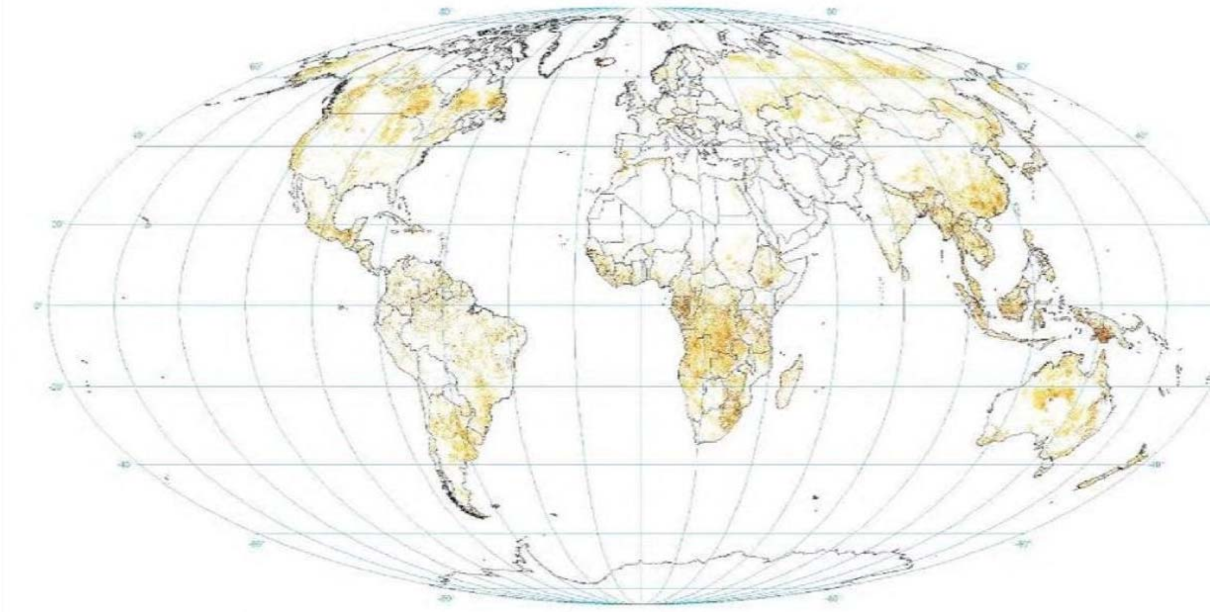
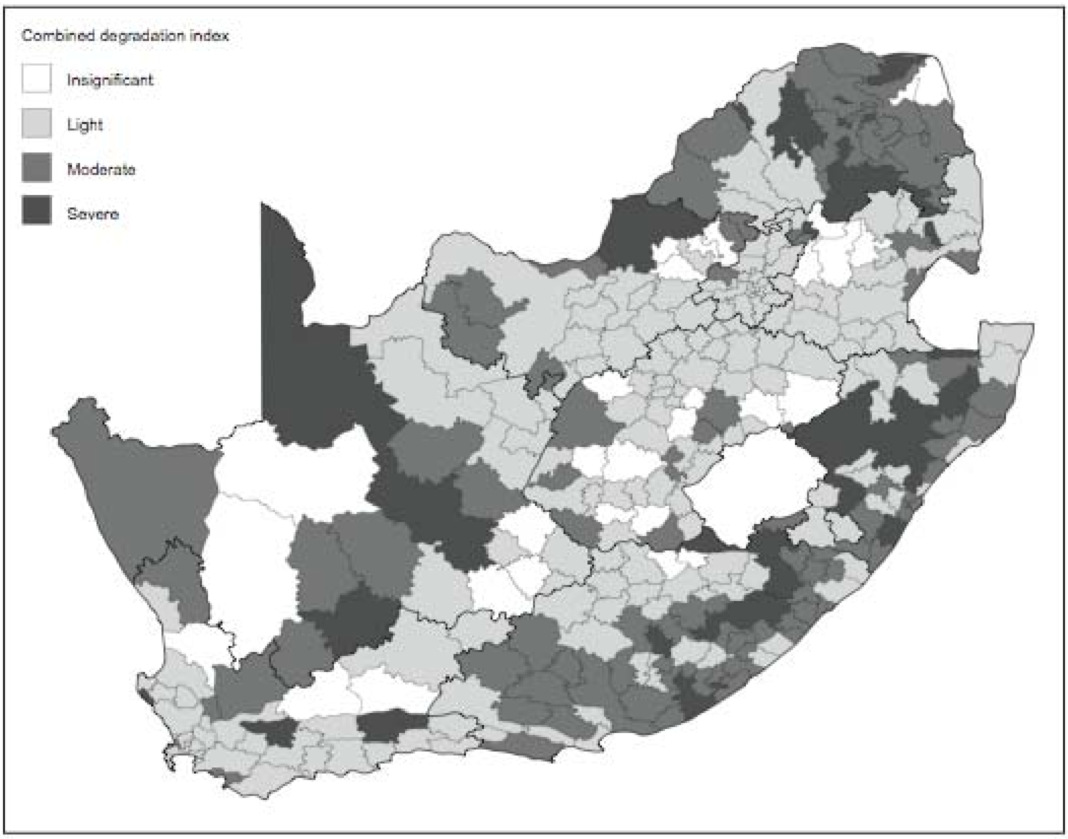


Figure 4.4. Map of Land Degradation in South Africa (Hoffman and Ashwell, 2001)



After extensive consultation, LADA (2005) proposed a more limited set of 14 biophysical indicators covering soil, vegetation and water quality as well as climate:

1. Climate
a. Aridity Index
b. Rainfall Variability
c. Soil Moisture

2. Soil Degradation
a. Soil Health
b. Soil Loss
c. Soil Salinity

d. Soil Fertility
e. Soil Contamination

3. Vegetation
a. Vegetation Activity

4. Water
a. Water Availability
b. Groundwater Level
c. Water Salinity
d. Water Contamination

This set of indicators has two advantages. First, it is sufficiently compact to be practically feasible. Second, the Soil Health indicator is a useful combination of various soil features, including depth, structure, tillage, crusting etc., that can be assessed by farmers themselves, as can Soil Fertility. It has two limitations. First, the Aridity Index and Rainfall Variability indicators are used to characterize an area in the long term. They would be useful for stratifying a region or country in a Baseline Survey, but would not be very sensitive to changes. Soil Moisture would be the most sensitive indicator of climatic variation, but it is conceived solely in terms of a quantity that must be measured with a specialized satellite containing a radar, not optical or infra-red, sensor. Second, 'Vegetation Activity' is defined solely in terms of a signal from a low-resolution remote-sensing satellite - the Normalized Difference Vegetation Index (NDVI) - and not features measurable on the ground.

In mid-2008 LADA and ISRIC released a Preliminary Map of Land Degradation, based solely on 20 years of satellite data on vegetation and rainfall, not soil measurements (Fig. 4.3). The NDVI signal from these images has been used to estimate trends in biomass productivity, or more strictly Net Primary Productivity (NPP). A full report by ISRIC on its methods has been released separately (Bai et al., 2008). It is fully transparent on the study's limitations, stating that "Land degradation means a loss of NPP but a decrease in NPP is not necessarily land degradation. Long-term trends in NDVI derivatives are unsophisticated indicators of land degradation and improvement."

4.4 OTHER DESERTIFICATION SURVEYS

Little attention has been paid to surveying desertification status outside the UN system. A World Bank review has referred to the "embryonic nature" of land quality monitoring generally, and to the lack of systematic national data on land degradation (Dumanski and Pieri, 2000).

4.4.1 Desertification Status Mapping in South Africa

A search of the scientific literature only revealed one study that has constructed a set of indicators and made a comprehensive survey of land degradation status at national scale. Carried out by Tim Hoffman of the University of Cape Town and Ally Ashwell of the National Botanical Institute (2001), this ranked soil and vegetation degradation using the following indicators:

1. Soil Degradation
a. Water erosion
b. Wind erosion
c. Salinization
d. Acidification and soil pollution

2. Vegetation Degradation
a. Loss of herbaceous cover
b. Changes in species composition
c. Bush encroachment
d. Alien plant invasions
e. Deforestation
f. Miscellaneous, including transfer of rangeland to cropland

Each indicator was ranked as Insignificant, Light, Moderate or Severe for each of the 367 magisterial districts in South Africa. This enabled the calculation of an Index of Soil Degradation and an Index of Vegetation Degradation. The two were then combined to give an overall Index of Land Degradation. National maps were produced for each indicator, the Index of Soil Degradation, the Index of Vegetation Degradation, and the Index of Land Degradation (Fig. 4.4). This was an impressive achievement, though rankings were made by consultative workshops, not measurements, and too many vegetation degradation indicators were used to assess changes in species composition.

4.4.2 Other Desertification Status Surveys

Other desertification status surveys have only had partial coverage.

A huge amount of research into desertification monitoring has taken place in China but its main focus has been on studying the expansion of sandy areas. This is reflected in a set of four indicators proposed by staff of the Chinese Academy of Sciences: (a) vegetation cover; (b) drifting sand coverage; (c) annual desertification rate; and (d) population pressure (Liu et al., 2003). The use of both rate and state indicators for desertification was unusual, and not properly justified.

Similarly, research by the Central Arid Zone Research Institute in India (Sharma, 1998) has classified hydrological indicators into two main categories:

1. Ground Water
a. Depth of water table
b. Water quality

2. Surface Water

a. Runoff: (i) area and turbidity of surface water; (ii) changes in water flow; (iii) sediment load

b. Infiltration

c. Evapotranspiration

A European project to devise a comprehensive set of desertification indicators, DESERTLINKS, has proposed no fewer than 148 indicators. As this undermines its operational feasibility the indicators will not be listed here. They were divided into (a) ecological, (b) economic, (c) social and (d) institutional categories but lacked an appropriate conceptual framework. This, and trying to be relevant to many contextual case studies, helps to explain why there were so many indicators (Brandt et al., 2005). Other European indicator initiatives were synthesized by Enne and Zucca (2000).

4.4.3 Contextual Indicators

Various attempts have been made to undertake participatory surveys of desertification that draw on local contextual knowledge. Research at the International Development Research Centre in Canada has shown how local people respond to questions about indicators on: (a) vegetation; (b) soil; (c) climate; (d) land use; and (e) economic conditions (Krugmann, 2000).

However, bottom-up surveys that rely only on contextual knowledge can be just as partial as top-down surveys. A recent University of Leeds study proposed that national and local indicators should therefore not be selected separately but in an integrated way. This should lead to a common methodology and a relatively homogeneous overall assessment (Reed et al., 2006).

4.4.4 Desertification Hazard Surveys

There have been numerous scientific surveys of desertification hazard, not status (e.g. Greco et al., 2005; Kirkby et al., 2000; Klintenberg and Seely, 2004; Mouat et al., 1997; Salvati and Zitti, 2008). Rubio and Bochet (1998) proposed some procedures for selecting indicators for hazard assessment, and even proposed a set of indicators of their own, but did not justify their selection.

Yet such studies do not take us much further than the 1977 World Map of Desertification Hazard (FAO/UNESCO/WMO, 1977). They are justified scientifically by including increasingly complex mathematical models. But their practical utility is questionable if their results do not inform residents of threatened areas about the hazards they face, or are not fed directly into a planning system.

The Government of Kenya undertook a pioneering national assessment of desertification in 1997. This only assessed desertification hazard but it did structure information within a format provided by indicators for: climate (annual rainfall, rainfall reliability, and probability of extreme events); water erosion; wind erosion; vegetation; fuelwood deficit; water resource availability; and socio-economic conditions (population growth, distribution and density; poverty; food consumption per capita; fertilizer inputs; percentage of arable land irrigated; land tenure and range utilization). Owing to lack of data, detailed socio-economic assessments were only made for two of the country's districts.

4.5 DISCUSSION

The various attempts made within the UN system to survey desertification on the global scale differ in their approach, and each has its advantages and disadvantages. Yet they are fairly consistent, and this offers a foundation on which to build when designing a UNCCD Baseline Survey.

However, three common drawbacks must be overcome: (a) confusion between biophysical and economic indicators; (b) lack of integration of biophysical, economic and social indicators; and (c) being implemented by subjective expert assessments rather than scientific monitoring procedures.

CHAPTER FIVE

DESIGNING THE BASELINE SURVEY

5.1 INTRODUCTION

This chapter builds on past experience, reviewed in previous chapters, to present a set of proposals for designing a Baseline Survey to be implemented by the Parties to the UNCCD.

The proposals are presented in two stages. The design for a solely biophysical survey is outlined first, since certain challenges must be overcome before implementation, and they merit detailed discussion. This is followed by a description of an integrated survey that also encompasses economic and social dimensions. The proposed approach is also justified in relation to alternative strategies.

The design of the Baseline Survey must satisfy three main stakeholder groups. First, the Parties must regard it as legitimate, for the results of the survey will set a marker against which future UNCCD surveys are compared, in order to evaluate progress in implementing the Convention. Second, it must satisfy stakeholders within each affected country, since the results of each national survey will probably be used for domestic planning purposes. Third, scientists must be convinced that the design will yield credible findings, since the Baseline Survey will be the first global survey of desertification to be undertaken on the basis of empirical measurements rather than expert assessments.

The chapter is in six main parts. The first proposes a working set of biophysical indicators. While other proposals for indicators are being considered a working set is needed here so a comprehensive design for a Baseline Survey can be evaluated. Part two reviews experience in measuring the main elements of vegetation and soil degradation over large areas using remote sensing, and then proposes how to measure each candidate indicator. Part three suggests how to adjust initial empirical measurements for temporal and spatial variation to make the Baseline Survey meaningful. Part four critically reviews alternative conceptual frameworks for structuring an integrated survey and selects the most appropriate one. Part five proposes a list of economic and social indicators and how to quantify them. Part six presents the final complete list of indicators and suggests how to combine them in practice, for both reporting and planning purposes.

5.2 CHOOSING A SET OF BIOPHYSICAL INDICATORS

5.2.1 Selection Criteria

When selecting a set of desertification indicators, the following general criteria are desirable:

1. Keep the number of indicators to a minimum.
2. Avoid duplication and redundancy.
3. Select indicators that are easy to estimate and interpret.
4. Include both scientific indicators and indicators that make use of contextual knowledge.
5. Select indicators within an appropriate conceptual framework.

5.2.2 Conceptual Framework

In the light of the last criterion we adopt a conceptual framework that follows the simple model in Chapter 4 as amended by the Dryland Development Paradigm:

1. Desertification involves the degradation of vegetation and soil by human impact, catalysed by drought.
2. Desertification assumes different appearances in different land uses.
3. The biophysical features of desertification are distinct from its economic proximate causes and social and economic underlying causes, and relations between these are not deterministic.

4. Long-term vegetation degradation is distinct from short-term variation in vegetation growth due to lack of rainfall.
5. Estimating the degree of vegetation degradation relative to a benchmark is made difficult by the existence of alternative ecosystem states.
6. Since desertification reflects the operation of cross-scalar processes the distribution of biophysical degradation in an area is not necessarily correlated with its social and economic features.
7. The extent and degree of desertification are both distributed in a spatially heterogeneous way.
8. The social and economic impacts of desertification in an area are not uniform either, but vary with social group.

5.2.3 A Summary Assessment of the Merits of Previous Sets of Indicators

The Dregne, Mabbutt and GLASOD indicator sets each have their merits for providing a basis for a set of biophysical indicators for the Parties to the UNCCD. All reflect the vast experience of the scientists who designed them, and so are salient to dryland contexts. The Dregne and Mabbutt sets have the advantage of brevity, while the GLASOD set takes into account later scientific insights and does not confuse economic indicators of productivity with biophysical indicators. Of the Dregne and Mabbutt sets, Mabbutt's has the disadvantage of relying heavily on economic indicators. The GLASOD set emphasizes biophysical indicators, especially for salinization, but is overelaborate.

5.2.4 A Working Set of Indicators Based on Dregne (1983)

We therefore use Dregne's 1983 set as a starting point for selecting a working set of indicators, but modify it to compensate for the above limitations and take account of subsequent research findings.

Dregne's ontology, which divides indicators by land uses and typology of land degradation, is retained, as is the four point severity scale. Including land use in the classification scheme will make it easy to quantify indicators using maps stratified by land use.

However, we suggest the following modifications:

1. Emphasize empirically verifiable indicators of soil degradation, such as gullies and dunes, to balance subjective estimates of total soil loss. This restores Dregne's earlier (1977) approach.

2. Replace Dregne's economic indicators of salinization with biophysical indicators.

3. Replace references to climax vegetation by GLASOD's idea of original/optimal vegetation cover.

4. Include both Vegetation Cover and Vegetation Quality. They may be initially combined in practice, to reflect how an overall reduction in vegetation cover is often accompanied by the encroachment of species from more hostile environments. However, retaining a separate Vegetation Quality indicator, or a pair of indicators of carbon density and biodiversity, will promote synergies with the implementation of the two other 'Rio conventions', on climate change and biodiversity.

5. Employ GLASOD's two stage severity classification to take account of the Dryland Development Paradigm and the proportions of each area covered by different degrees of degradation. This will describe the spatial heterogeneity of degradation on which so many scientists now agree.

6. Follow LADA by including:

a. A Soil Health indicator to reduce the subjectivity of expert assessments of Soil Loss by making use of contextual knowledge.

b. Indicators of Water Availability and Water Quality.

7. Include an information indicator from the LADA set: Annual Rainfall in the measurement year. This provides a point of reference for evaluating cyclical variation in vegetation cover.

Our proposed working set of biophysical indicators therefore consists of:

1. Vegetation Degradation
   a. Vegetation Cover
   b. Vegetation Quality

2. Soil Degradation
   a. Wind Erosion
   b. Water Erosion
   c. Salinization
   d. Waterlogging
   e. Soil Health

3. Water Resources
   a. Surface Water Availability
   b. Ground Water Availability
   c. Water Quality

4. Climate: Annual Rainfall

5.2.5 Making the Working Set of Indicators Operational

Once a set of indicators has been approved by the CST a group of experts should be appointed to recommend a set of criteria for using them to rank the severity of degradation, as shown for previous sets of indicators in Table 4.1. It is understood that proposals for a set of indicators are being presented to the CST in another document. The above working set is for illustration only.

For each of the indicators a set of threshold values denoting severity of degradation is needed. This demands careful consideration by a group of experts who can make reference to field conditions and available scientific evidence. The threshold beyond which soil erosion is classed as Moderate must not include acceptable background rates of erosion, while the threshold beyond which it is classed as Very Severe should be sufficiently high that it does not encompass reversible change.

5.3 REMOTE SENSING MEASUREMENTS OF LAND DEGRADATION

5.3.1 Introduction

Once a set of indicators has been finalized further decisions are needed on how to quantify them. One possibility would be to rely on subjective evaluations by a small number of experts, drawing on their long experience of the areas concerned and ability to interpret available documentary evidence. This method has often been used in the past, because of the high cost and complexity of measurement by remote sensing and detailed field observations. On the other hand, the subjectivity of this approach has brought into question the reality of desertification (Thomas and Middleton, 1995).

Consequently, the CST may decide instead to recommend the use of more scientifically credible methods to ensure a "empirically grounded and analytically rigorous" assessment, as stated in the Terms of Reference for this assignment. The alternative to expert assessment is a multi-scalar and multi-source measurement approach that combines remote sensing data, ground observations, official statistics and contextual knowledge obtained by participatory stakeholder interviews.

A well designed remote sensing survey, supported by ground truth data collection, can reduce the time taken to undertake a Baseline Survey of land degradation over a large area with low population density. Carrying out regular surveys thereafter will detect changes in the intensity and extent of degradation in different areas. But care is needed so that the limitations of the technologies employed are fully recognized. Matthew Turner, of the University of Wisconsin at Madison, warned in 2003 that many studies of the Sahel are superficial and have "not only insufficient accuracy assessment but with very limited on-the-ground observations". Descriptions of changes in land use and land cover are produced "with little attempt to link this to underlying causes of these changes nor to how they affect the productive capacity of the land. Especially for data of poor spatial resolution, ... it is often difficult to identify uniquely human signatures on the dryland landscape...[V] isual descriptive analyses are produced with little connection to human context and ecological process."

5.3.2 Measuring Vegetation Degradation

Monitoring the degradation of vegetation cover in dry areas is difficult. For instead of the continuous closed canopy forests found in the humid tropics, drylands are covered by trees scattered at low density over grasslands. Measuring changes in the overall tree density or biomass of individual trees in these 'open forests' is difficult even when high resolution satellite imagery is used (Lambin, 1999).

So great care is needed when interpreting studies that employ coarse resolution satellite images, from which a Normalized Difference Vegetation Index (NDVI) is typically computed to measure vegetation cover. Since the NDVI is very sensitive to changes in rainfall, any reduction in it in a particular area could simply reflect a decline in rainfall, rather than degradation of vegetation.

The link between the NDVI and rainfall is, according to empirical studies, not straightforward, and a linear relationship only exists in areas receiving 250 - 500 mm rainfall per annum (Milich and Wiess, 2000; Nicholson and Farrar, 1994). Research at the Belgian universities of Liege and Louvain has discovered much local variation in this relationship, influenced by soil type, ecological factors, seasonality and land use etc. (Diouf and Lambin, 2001; Hountondji et al., 2006).

If the NDVI is corrected for the effects of rainfall it is possible to draw reliable inferences about the effects of other factors. For example, Emma Archer, of the University of Cape Town, showed in 2004 that a corrected NDVI can distinguish between the effects of different grazing strategies on rangelands. Micael Runnström, of Lund University, showed in 2000 that biological production on rangelands in China's Ordos Plateau rose between 1982 and 1993 in areas where rainfall had not changed significantly. Better management practices could have contributed to this.

Cyclical rainfall patterns are an obstacle to reliable image interpretation, especially at low resolution. When rainfall is increasing it can be difficult to determine whether a greater profusion of vegetation is a result of this, or of some other cause. Thus, while there is evidence that rainfall has risen in the Sahel since the low point of the 1970s and 1980s, research at Lund University concluded that simply using this to explain the increase in plant growth apparent from satellite images was not reliable, and that land use change and migration could also be influential (Olsson et al., 2005). Research at the University of Arizona reached similar conclusions (Herrmann et al., 2005).

The general conclusion to draw from these studies is that while satellite imagery has long been a reliable operational tool for monitoring vegetation change in the humid tropics, this is not yet the case in the drylands. In the hands of skilled scientists, satellite images can yield qualified insights, but the temptations for wider use, especially in the case of low-resolution images, should be avoided.

5.3.3 Measuring Water Erosion

In his detailed evaluation of the use of satellite remote sensing for monitoring soil erosion by water, Anton Vrieling of Wageningen University cautioned in 2006 that "although the mapping of erosion features is an important application of aerial photography, the limited spatial extent of the features often inhibits its detection using satellite imagery." Large- and medium-sized gullies are visible on the high resolution images collected by sensors on LANDSAT, SPOT and similar satellites, but not their development over time. He concluded that "it cannot be expected that a standardized operational erosion assessment system using satellite data will develop in the near future."

5.3.4 Measuring Wind Erosion

Wind erosion does not generally leave behind the same large scale physical artefacts as those seen in water erosion, and the main utility of satellites here is to monitor trends in the extent of sandy areas. Based on high resolution satellite imagery collected by LANDSAT satellites, research at the Chinese Academy of Sciences, the Chinese Academy of Forestry and Wuhan University has shown that while in some regions of China the expansion of desertified areas has been reversed, in others it is still proceeding (Jabbar and Chen, 2006; Wu and Ci, 2002; Zhang et al., 2003).

Table 5.1. Biophysical Indicators and Monitoring Procedures

		Remote Sensing	Ground Data	Contextual Knowledge
1.	Vegetation Degradation			
a.	Vegetation Cover	Y	Y	-
b.	Vegetation Quality	O	Y	Y
2.	Soil Degradation			
a.	Wind Erosion	P	Y	Y
b.	Water Erosion	Y	Y	-
c.	Salinization	Y	Y	-
d.	Waterlogging	Y	Y	-
e.	Soil Health	-	-	Y
3.	Water Resources			
a.	Surface Water Availability	Y	Y	Y
b.	Ground Water Availability	-	Y	Y
c.	Water Quality	-	Y	Y
4.	Climate: Annual Rainfall	-	Y	-

Key: Y = desirable; P = partial; O = optional; - = not essential

5.3.5 Measuring Salinization and Waterlogging

There is considerable experience in using satellite images to monitor the desertification of irrigated croplands. The spectral signatures of salinized and waterlogged areas are sufficiently distinctive to ensure their separation from non-affected areas, influenced by the reflective capabilities of salts on or near the surface, and water, respectively. However, a comprehensive review by G.I. Metternicht, of Curtin University in Australia, and J.A. Zinck, of the International Institute for Geo-Information Science and Earth Observation in the Netherlands (2003), cautioned that best results are obtained by combining the interpretation of satellite images with field and laboratory data, and comparing a series of maps on a computer-based Geographical Information System (GIS).

Although it would be desirable to measure the degree of salinization from satellite images, experience shows that this is difficult, owing to sensor limitations and variability in spectral responses. However, Metternicht and Zinck did show in 1997 that it is possible to distinguish between areas affected by salinization and alkalinization, which involves a build up of sodium ions near the surface.

An impressive series of satellite-based surveys of salinization and waterlogging in India's large area of irrigated croplands, carried out by its National Remote Sensing Agency, have distinguished between different types of salinization and alkalinization (Rao et al., 1995; Dwivedi et al., 1999; Dwivedi and Sreenivas, 1998). Researchers at M.V. Lomonosov Moscow State University have distinguished salinized soils from non-saline soils with 70% accuracy (Karavanova et al., 2001).

5.3.6 Risk Assessment

Many of the studies that use models to predict desertification hazards have used satellite images too. This typically involves combining data on vegetation cover from these images with rainfall data, and topographic data from maps (e.g. Symeonakis and Drake, 2004; Symeonakis et al., 2007).

5.3.7 Proposed Measurement Procedures

Remote sensing techniques can clearly play an important role in the Baseline Survey, but they should only be used when applications are proven. Even then, the results obtained require careful analysis. Ground measurements must feature strongly in the Baseline Survey and subsequent monitoring. The measurement procedures proposed for each indicators are listed in Table 5.1. We suggest that:

1. Each country should use remote sensing imagery to classify land use and land cover in drylands conforming to the UNCCD classification into the following categories:

a. Closed Forest
b. Open Forests/Rangeland
c. Rainfed Cropland
d. Irrigated Cropland
e. Other Categories
f. Water Bodies
g. Natural Desert

2. The degree of degradation of the main land cover categories can be assessed as follows:

a. Open Forests/Rangelands: combine aerial photography and high to very high resolution satellite images with ground measurements, and contextual information on vegetation cover and quality.

b. Rainfed croplands:

i. Water erosion: employ high resolution satellite images (or aerial photography), supported by ground truth data collection, and accompanied by contextual knowledge on Soil Health.

ii. Wind erosion: rely on ground measurements, accompanied by contextual knowledge on Soil Health. The extent of sand dunes can be measured by medium to high resolution satellite images.

c. Irrigated croplands: use a combination of high resolution satellite images, supported by ground measurements of salinity and alkalinity, and accompanied by contextual knowledge on Soil Health.

3. Surface water and groundwater availability and water quality: these may be assessed by satellite imagery, field measurements and contextual knowledge.

4. Climate: Annual Rainfall can be measured by long-term monitoring stations.

5.4 PRACTICAL ASPECTS OF THE BASELINE SURVEY

Spatio-temporal variation in soil and vegetation degradation leads to major problems when trying to undertake a reliable Baseline Survey. This section suggests how to meet these and other challenges when designing and implementing the survey.

5.4.1 Allowing for Spatio-Temporal Variation

5.4.1.1 Scientific Evidence

Various studies, starting with that of Tucker and Choudhury (1987), have shown that interpreting remote sensing images of vegetation in dry areas is made difficult by confusion between (a) trends in anthropogenic land use and land cover change and (b) trends in vegetation cover resulting from variation in the rates of annual vegetation growth linked to changes in precipitation. A survey coordinated at the Catholic University of Louvain in Belgium has concluded that this is one reason why reliable remote-sensing studies of land cover change are not as plentiful for the drylands as for other parts of the world (Lepers et al., 2005). This will affect the reliability of estimates of both the baseline extent of desertification and the baseline degree of desertification in particular areas.

5.4.1.2 Choosing the Baseline Year

A map of vegetation cover that does not allow for the irregular fluctuation in vegetation growth with rainfall could give estimates of the baseline extent and degree of degradation that are misleadingly high or low. So when the next survey is undertaken in, say, five years time, the difference between the two findings will not give a reliable estimate of the trend in desertification in that period.

For example, a survey using satellite images found that that the boundary between the Sahara desert and the Sahelian region shifted south in 1981, but in 1985 it moved north when rainfall returned (Tucker and Choudhury, 1987). In other words, the Sahara desert appeared to expand between 1981 and 1984, and then to contract in 1985. So a survey that used 1981 as the baseline year could be interpreted to provide evidence for desertification, but one with 1985 as the baseline year would not.

The Parties, advised as appropriate by scientists, will need to decide how to address these problems before proceeding with the Baseline Survey. Possible options are:

1. Ignore vegetation degradation and base estimates of the degree of desertification solely on indicators of the degree of soil degradation. This option was chosen when undertaking the GLASOD survey used in the UNEP World Atlas of Desertification (Middleton and Thomas, 1992).

2. Ask a group of scientific experts to predict, based on historical trends identified by a time-series of satellite images, the most appropriate *baseline year* for each country. The Baseline Survey will be undertaken in that year. Because this would lead to a wide spread of survey years in different countries, adjusting all surveys to refer to a common *reference year* to produce aggregated global estimates could involve substantial projection errors (see Fig. 2.1) (Grainger, 2008).

3. Commission the production of a method to adjust current vegetation maps for spatio-temporal variation due to rainfall, again using historical trends identified by a time-series of satellite images compared using a computer-based Geographical Information System (GIS). This would need to be applied carefully to one country at a time. The results of these

adjustments could then be used to identify suitable starting points as 'baselines', since cyclical variation would be removed from the overall trend in order to identify the long-term progression of degradation.

To the best of our knowledge, the techniques required for options 2 and 3 have not yet been developed through scientific research. The CST would need to appoint a group of experts to devise a method that would win the confidence of the scientific community and be practically feasible.

5.4.1.3 Estimating the Degree of Vegetation Degradation

Another challenge is to find how to estimate the *degree of degradation* in a reliable way. There is now a scientific consensus that universal '*natural benchmarks*' for a fully non-degraded ecosystem in most dry areas are difficult, if not impossible, to identify. They may only be meaningful in relation to the current 'state' of the ecosystem, but to identify this requires a detailed study of long-term trends. So even if the cyclical trend in vegetation cover can be subtracted from the overall trend to provide a proper set of baseline measurements, relating these to the top of a scale (i.e. the 100% reading) in order to estimate the baseline degree of degradation will not be straightforward (see Fig. 2.2).

Various options are possible for tackling this challenge. They include:

1. Ignore vegetation degradation and base estimates of the degree of desertification solely on indicators of the degree of soil degradation.

2. Follow the approach taken by GLASOD (see section 4.2.7) and ask a group of scientific experts to nominate the optimum ecosystem cover for a given ecological zone or sub-zone, on the basis of the best available data. This will provide a benchmark against which the degree of degradation can be estimated using current measurements.

3. Decide that a proper estimate of the degree of degradation can only be made after an extended time series of measurements have been accumulated to identify the current ecosystem state. So the Baseline Survey can be undertaken as soon as practical but no party will be committed to using the results as a baseline against which to measure progress in

implementing the Convention in their country. Instead, legally binding values of the baseline degree of desertification will not be estimated until a number of surveys have been undertaken and their maps compared using a GIS. The utility of this approach, however, will depend on undertaking further scientific research.

5.4.2 Adjusting for Spatial Variation

As the intensity of degradation can vary greatly from place to place, a method must be devised to combine measurements at different spatial scales so they are fully representative of the broader picture and what is visible on the ground. To do this the Baseline Survey must take full account of both scientific measurements and the contextual knowledge of people living in each area.

Once the degree of degradation of each area of land has been evaluated using this multi-scalar approach, the degree of degradation of each mapping unit could be assessed to allow for contextual variation. We suggest using the GLASOD algorithm:

1. Low: Slight 0-10%, Moderate <5%
2. Medium: Slight 10-50%, Moderate 5-10%, Severe 0-5%, Very Severe 0-5%
3. High: Slight 50-100%, Moderate 10-50%, Severe 5-25%, Very Severe 5-25%
4. Very High: Moderate 50-100%, Severe 25-100%, Very Severe 10-100%

5.4.3 Combining Scientific Measurements and Contextual Knowledge

The importance of complementing scientific measurements with contextual knowledge has been stressed in this report and particularly in this chapter. The working set of indicators proposed in section 5.2.5 contains specific contextual indicators for soil and water resources.We suggest that one way to combine them with the scientific indicators would be to use them to modify distributions of the extent and degree of degradation computed using the latter. Formal procedures for doing this should be finalized by the group of experts responsible for detailed survey design.

5.4.4 Combining Measures of Vegetation Degradation and Soil Degradation

To compute an estimate of the extent and degree of 'overall desertification' in each area it will be necessary to agree on algorithms for combining the different forms of vegetation degradation and soil degradation.

With regard to combining different types of vegetation degradation, a single indicator may be sufficient for vegetation cover (e.g. tree density) and for vegetation quality (e.g. carbon density).

With regard to combining different types of soil degradation, we suggest using the dominant form of degradation seen in a particular area as the leading measure.

In respect of combining vegetation degradation and soil degradation we suggest following previous practice and defining the degree of overall desertification by two measures: the degree of vegetation degradation and the degree of soil degradation. Although relations between the two are not simple, it can be generally assumed that high values of one will be associated with high values of the other.

5.4.5 Combining National Baseline Surveys to Give a Global Baseline Survey

The final challenge is to find how to aggregate numerous national baseline surveys in different years into a global survey referring to the same year. The scope of this challenge was discussed in Section 2.5. Again, we advise tackling it in two parts: vegetation degradation and soil degradation.

Projection difficulties are exacerbated in the case of desertification by the possibility of a lack of a consistent trajectory in the short- to medium-term. Both vegetation degradation and soil degradation are reversible over time, but apparent vegetation degradation seems to fluctuate more rapidly with rainfall, as discussed earlier in this report. Since it is not possible to predict this, once a reliable estimate of vegetation degradation has been obtained for a particular country in a given year it may be advisable to use this value rather than attempt to project it to the common reference year. If all national surveys are carried out within a five year period the errors involved should be relatively low.

In the case of soil degradation we might expect the temporal dynamics to be rather different, in that the extent and degree of degradation will merely increase as a result of any increase in pressure in drought periods. The trajectory will remain the same. Consequently, it may be possible to make a forward projection from each national Baseline Survey year to a common reference year. However, if all national Baseline Survey is carried out within the same five-year period then it would probably make better sense to use the actual survey readings and not project them.

5.4.6 The Need for Discussion

All the proposals made in this section are based on the best scientific evidence available to this consultant and on his own judgement. They merely represent a basis for discussion with other scientists so that the final procedures required to tackle these complex problems can be identified.

5.5 A CONCEPTUAL FRAMEWORK FOR AN INTEGRATED SURVEY

5.5.1 Introduction

Sets of desertification indicators have, until now, mainly consisted of biophysical indicators. When economic indicators have been included it has been as substitutes for these, e.g. in the form of agricultural yields, and the grounds for this have been questionable. In the real world of the drylands, people continually make decisions about how to exploit natural resources to gain income and how to distribute this. The environment takes third place behind economic and social considerations, as it does elsewhere. One big difference is that the drylands are inhabited by some of the poorest people in the world, who have some of the most precarious livelihoods anywhere. So if we wish to gain a comprehensive picture of human-environment relationships in the drylands we must look at both the human dimensions and the environmental dimension, preferably in an integrated way.

To do this successfully, economic and social indicators cannot be chosen in isolation, but be selected within a suitable conceptual framework. Over the last twenty years various frameworks have been constructed to model sustainable development, and these provide a good starting point for discussion. This section therefore begins by identifying the strengths and weaknesses of two established theoretical models of sustainable development. It then describes a new model which can overcome their weaknesses and provide a conceptual framework for desertification indicators.

5.5.2 The Political Context

Sustainable development was added to the international political agenda by the report of the World Commission on Environment and Development (1987), "Our Common Future". This defined sustainable development as “development which meets the needs of the present generation without jeopardizing the ability of future generations to meet their own needs”. But it did not specify how to achieve such intergenerational equity. It also claimed that economic growth must continue, in order to alleviate poverty and maintain development. This would must be a "new form of growth" which did not harm the environment or deplete stocks of natural resources, but how this was to be achieved was also not explained. Political considerations were important here: as with desertification, developed countries stressed better environmental management and developing countries more development. Political negotiations on sustainable development continue in this ambiguous and largely atheoretical context, at the most referring to simple models like the DPSIR framework, rather than scientific models that integrate the economic, social and environmental dimensions of development.

5.5.3 Ecological Economics Model

One of these models has been proposed by ecological economists. It assumes that the human economic system is part of the global ecological system, or biosphere, and that economic sustainability depends on the continued healthy functioning of the biosphere. As economic growth occurs the economic system expands at the expense of the biosphere and becomes increasingly subject to the laws governing the biosphere and less subject to market forces. The resilience of the biosphere, on which human resilience depends, is also undermined.

The principal ecological economics condition for sustainability is to keep the scale of the human economy below a critical threshold, above which it threatens the sustainability of the biosphere (Daly, 1990). This threshold is represented by the concept of carrying capacity, defined as "the amount of use that can be exceeded only by impairing an environment's future suitability for that use". Just as rangelands have a notional carrying capacity of grazing animals, so there is also a limit to the number of human beings and their economic activities which the planet can support.

One popular sustainability index, the Ecological Footprint index, tests for this condition by comparing the area of land which a country needs to provide all of its consumption and waste disposal needs (its 'footprint)' with the mean global availability of such land (the biocapacity ratio).If the index is less than or equal to 1 then development is sustainable (Wackernagel and Rees, 1996).

The disadvantage of the ecological economics approach for providing an integrated framework for desertification indicators is that it focuses on physical sustainability, and does not explain how to integrate this with the social and economic dimensions of development. Nevertheless, a group of US, Swedish and French scientists has proposed that this can be partly achieved by linking the Ecological Footprint index to the Human Development Index (see Section 2.9.2) (Moran et al., 2008).

5.5.4 Environmental Economics Model

Environmental economists, on the other hand, do incorporate the economic and social dimensions of development in their models. Building on neoclassical welfare economics, they portray total human welfare as including economic, social and environmental welfare, and define sustainable development as development that “leads to non-declining human welfare over time” (Pearce, 1991).

To integrate the economy and the environment, they portray nature as another form of capital. Conventional 'productive' Capital is now called Man-Made Capital. Human Capital refers to the stock of human knowledge and skills, health status, educational attainment etc. The environment comprises a stock of Natural Capital, divided into Resources Capital, i.e. stocks of natural resources, and Environmental Quality, determined by the quality of land, atmosphere and water sinks, the functioning of global cycles and ecosystems, and human aesthetic perceptions. In this theory, as development occurs, Natural Capital is depleted and Human and Man-made Capital accumulate.

Of the various environmental economics conditions for sustainability the one that best integrates the three dimensions of development is the Very Weak Condition, proposed by the late David Pearce (1991). This requires no decline in the sum of Natural and Human and Man-Made Capital. Thus, Natural Capital can decline, as long as the loss is more than offset by the value of Human and Man-Made Capital accumulated. The condition derives from the Hartwick-Solow Rule proposed by the Nobel Prize-winning economist Robert Solow (1986). It is the basis of the Genuine Savings Index.

For the purpose of forming an integrated framework for desertification indicators, the Very Weak Condition has the advantage of integrating the economic, social and environmental dimensions of development. Unfortunately, it has one flaw: it aggregates Man-Made Capital and Human Capital in a single variable. This gives no scope to assess relative changes in these, and in the intragenerational equity and social welfare which are crucial to the conventional idea of economic development.

5.5.5 Three Dimensional Welfare Model

One way to overcome the limitations of these two approaches is to use a Three Dimensional Welfare Model that divides the impact of productive activities on human welfare into three dimensions: (a) economic, determined by income; (b) social, reflecting the equity of distribution of income; and (c) environmental, determined by the balance between environmental benefits and costs (Grainger, 2010).

Environmental welfare is a function of the physical quantity of environmental quality, mediated by human perceptions. Human beings still receive a large amount of environmental benefits from the environment, but this is reduced through the costs incurred in our productive activities. If these costs are not paid when they are incurred an environmental welfare deficit will accumulate.

The condition for sustainable development in this model is that social welfare should increase, changes in income and environmental welfare are not negative, and there is no environmental welfare deficit.

A limitation of this model is that natural resources do not constrain production. While controversial, it removes the problem of accounting for substitution and complex flows of natural resources between countries with open economies, which are limitations on using the Very Weak Condition. On the other hand, in this new model the environmental costs associated with natural resource depletion are fully accounted for, including those which undermine life-support systems.

This condition is consistent with, and extends, the existing indicators of economic growth and economic development. If income increases then a society experiences economic growth, and if there is also a rise in collective social welfare it experiences economic development. As most societies have achieved economic growth and economic development by not paying all the associated environmental costs they have accumulated an environmental welfare deficit, and so have not developed sustainably.

5.6 SELECTING ECONOMIC AND SOCIAL INDICATORS

5.6.1 Principles for Selecting Economic Indicators

If the Three Dimensional Welfare Model provides the conceptual framework for an integrated set of indicators then economic welfare is represented by income, which can be divided into four categories:

1. Agricultural
2. Wood-based
3. Non-farm
4. Remittances

The first two categories cover the major land use Pressures. The last two cover other sources of income that become more important when groups diversify their livelihoods during droughts (Bradley and Grainger, 2004). If data are plentiful then the income groups themselves can be estimated (Kamanga, 2008). Otherwise yields can be used as proxies for the resource-based categories.

5.6.2 Principles for Selecting Social Indicators

One key indicator to estimate the social impacts of desertification is the population of the territory being surveyed.

It is also necessary to estimate how the social welfare of different groups within each population is affected. Poverty, or the inequality of income distribution, can be measured:

1. Directly. The Gini Coefficient remains a popular index of inequality (a value of 1 means perfect inequality and a value of 0 perfect equality) (Hillerbrand, 2008). It is even possible to estimate it in non-monetary terms by using consumption of goods instead (Druckman and Jackson, 2008).

2. Indirectly. The Human Development Index is estimated as the average of three indicators:

a. An adjusted per capita income indicator
b. An educational attainment indicator
c. A life expectancy at birth indicator

So it assumes that as equality in a country increases, educational attainment and life expectancy will rise. Environmental economists would portray this as accumulation of Human Capital. A study in 1997 by Douglas Hicks of Harvard University found that it is justified to relate the values of these two indicators to access to education and health care, though the rankings may be different.

But are two social welfare indicators needed? Stephen Morse of the University of Reading (2003) criticizes their aggregation in the HDI, on the grounds that this assumes that educational attainment and life expectancy are substitutes. It has long been realized that there is much redundancy in the three indicators (McGillivray, 1991). Research carried out at the

Australian National University shows that it is feasible just to use Life Expectancy at Birth as a counterpoise to income (Dowrick et al., 2003).

It is also important to take account of the findings of recent research into vulnerability (see Section 3.8.8). If human-environment relationships in the drylands are really coupled, as the Drylands Development Paradigm asserts (see Section 3.8.5) (Reynolds and Stafford-Smith, 2002), then it would be wise to complement the social welfare indicator with a vulnerability indicator. As no universally accepted vulnerability index currently exists, we suggest a simple distributional indicator. This measures the proportions of the population of a territory (which may be a country, region or locality) who live in areas suffering from Slight, Moderate, Severe and Very Severe desertification.

5.6.3 A Working Set of Economic and Social Indicators

Our proposed working set of economic and social indicators is therefore:

1. Economic:
   a. Farm income
   b. Wood-based income
   c. Non-farm income
   d. Remittances

2. Social:
   a. Population
   b. Poverty: life expectancy at birth
   c. Vulnerability: susceptibility of livelihoods to drought

Using DPSIR Framework terminology, negative changes in the States of soil and vegetation may result from decisions to use land to generate positive economic Impacts in the form of crop and animal product yields. These may lead to positive or negative changes in the State of social welfare.

So while negative changes in economic indicators, such as crop yields, provide supporting evidence for land degradation, the primary evidence should come from biophysical indicators. Indeed, low values of economic and social indicators do not by themselves prove the existence of land degradation. Low agricultural productivity and poverty have many causes, as Amartya Sen has demonstrated (see Section 3.8.8). Moreover, economic and social conditions in areas affected by desertification are not the sole or even primary driving forces of land degradation. The latter are far more widely distributed within a country or region (see Chapter 4).

5.6.4 Quantifying the Working Set of Economic and Social Indicators

These indicators can be quantified by field surveys and census statistics. Economic indicators (a) and (b) could be estimated using farm yields and wood harvests as proxies if necessary. Data to quantify social indicators (a) and (b) should be available in national census data in developed countries. Developing countries may require more field surveys for estimation.

5.7 IMPLEMENTING THE INTEGRATED SURVEY DESIGN

5.7.1 Combining the Integrated Set of Indicators

Combining the set of economic and social indicators with the set of biophysical indicators results in the proposed integrated set of desertification indicators listed in Table 5.2.

Using the terminology of the DPSIR framework, biophysical indicators measure changes in the States of soil and vegetation; economic indicators measure the Impacts of this on income associated with crop yields; and social indicators measure the Impacts on social welfare. A decline in soil fertility and vegetative cover lowers crop and livestock yields, and reduces human (and animal) health.

One advantage of the Three Dimensional Welfare Model is that indicators of the three dimensions of development do not have to be combined into a single index, like the Genuine Savings Index of environmental economics (Pearce and Atkinson, 1993). Even combining indicators of the economic and social dimensions of development leads to problems (Morse, 2003).

Table 5.2. An Integrated Set of Desertification Indicators

A. **Biophysical**

1. Vegetation Degradation
a. Vegetation Cover
b. Pasture Quality

2. Soil Degradation
a. Wind Erosion
b. Water Erosion
c. Salinization
d. Waterlogging
e. Soil Health

3. Water Availability

4. Climate: Annual Rainfall

B. **Economic**

5. Yields from each land use (as a proxy for income)
6. Other Income

C. **Social**

7 Population
8 Poverty: life expectancy at birth
9. Vulnerability: susceptibility of livelihoods to drought

From the perspective of the Three Dimensional Welfare Model, agricultural production can increase economic and social welfare, but if it increases the degree of degradation, as measured by biophysical indicators, then this diminishes environmental welfare. The present distribution of desertified land in a country is an indication of the size of the environmental welfare deficit which has accumulated.

The rainfall indicator allows long-term degradation caused by human action to be distinguished from (a) temporary changes in ground conditions (e.g. poor plant growth) caused by low rainfall; (b) the effects of long-term regional or global climatic change. This indicator helps to relate observed soil and vegetation degradation to climatic driving forces, and select the optimum baseline period.

5.7.2 Establishing a Sustainable Set of Monitoring Institutions

It is assumed in this document that the Baseline Survey and subsequent surveys will be carried out at national level by each of the Parties. Designing a set of institutions that can sustain long-term monitoring in a manner that is (a) appropriate for each country and (b) consistent with the provision of regional and global estimates to support decision-making by the Conference of the Parties will be a major challenge for every Party. This is because of the need for multi-scalar and multi-source monitoring to quantify indicators using a combination of remote sensing, field and contextual data (shown for biophysical indicators in Table 5.1). Ideally, these institutions will be designed and established prior to the Baseline Survey.

5.7.3 Reporting the Results of the Integrated Baseline Survey

As stated in Section 1.5, the Baseline Survey will provide the following pieces of information for a given country in its baseline year and for all affected countries in the reference year:

1. The area of land affected by desertification, classified by degree of degradation.

2. The social impacts of desertification, comprising the number of people affected by different degrees of degradation, the impact on their welfare, and the distribution of vulnerability within each population.

3. The magnitudes of agricultural productivity, production and income in affected areas, representing the economic benefits that offset the above environmental and social costs.

This will enable the social, environmental and economic consequences of maintaining economic production in different areas of the drylands to be assessed.

5.7.4 Applying the Integrated Set for National Planning Purposes

5.7.4.1 Basic Principles

The proposed integrated set of desertification indicators is well suited to reporting by the Parties. But it can also be used as the basis for a simpler system for national planning by building on a routine rational land use planning method (Mather, 1986). This takes place in two stages: land capability classification and land suitability assessment:

1. Land capability classification maps the inherent biological potential of an area by dividing it into various 'landscape units', each of which is roughly homogeneous with respect to soil type, topography and climate, and its ability to support a given community of plants and animals.

2. Land suitability assessment then ranks the suitability of each landscape unit for different agricultural, forestry or conservation uses, according to whether they can be practised sustainably without degrading the land and undermining their own productivity.

The dominant criterion by which land suitability is assessed is soil erodibility, so land above a certain slope angle is designated as unsuited to cultivation. Land suitability assessment does not by itself allocate areas of land to specific uses. It merely gives planners a range of suitable and unsuitable land uses for each land unit.

Good land use planning should lead to the most intensive farming being concentrated on the most fertile and flattest lands. Poorer soils should either be left under forest cover for management or conservation, or used only for low-intensity cropping or agroforestry.

5.7.4.2 Application to Desertification

If desertification is taking place, then by definition the type of land use practised in a given area and the level of its intensity exceeds the capability of the land to support it. Maintaining the same land use at this level of intensity and without external inputs is a recipe for continued desertification.

Degradation therefore causes the actual land capability of an area to decline in comparison with its potential level. Reversing desertification, on the other hand. will raise actual land capability closer to its potential level, and sustainable agricultural production in each capability class should rise too.

Government planners could therefore:

1. Produce maps that divide national territory into classes of land capability, land suitability, and degradation.

2. Combine these maps on a computerized Geographical Information System (GIS).

3. Use the GIS to compare the type and intensity of land use with the recommendations of the national land suitability classification.

4. Assess the present land capability of each area, diminished by degradation, with the potential for that area.

5. Set targets to increase land capability by reducing degradation, through a combination of better management techniques and land restoration.

6. Put this in a sustainable development context by optimizing the balance of economic welfare, social welfare and environmental welfare for each land capability class.

So instead of being a negative event, the Baseline Survey of desertification will help each country to (a) establish the current status of its agricultural productivity and sustainability and (b) set targets for where it wants these to be in the future.

CHAPTER SIX

IMPLEMENTING THE BASELINE SURVEY

6.1 INTRODUCTION

This chapter discusses some issues concerning implementation of the Baseline Survey that the Committee on Science and Technology (CST) will need to consider.

6.2 THE NEED FOR REFINEMENT

Although this document provides tangible proposals for designing and implementing the Baseline survey, its main purpose is to provide a framework for detailed discussions by the CST and the groups of scientists and other stakeholders it appoints to finalize the design of the Baseline Survey.

Refining the design of the Baseline Survey could take up to a year and require various workshops and consultations. It will be helped by the new format agreed for the CST, which involves the participation of scientific research institutes. The CST might make the Baseline Survey the theme for the first of these special sessions, scheduled for 2009. This would be convenient because the consortium appointed to host this session has excellent credentials for commenting on the scientific design of the Baseline Survey.

6.3 MAKING MEASUREMENTS

Ideally, each Party will undertake the measurements needed to quantify the set of indicators for its own country. This will maximize the perceived legitimacy of the findings.

Indicators should be selected with due regard to the institutions which will monitor them. Sophisticated estimates of soil structure, for example, are of little use when the majority of measurements will be made by soil laboratories in countries with only a limited range of equipment. Indicators should also be defined, and measurement techniques specified, so that measurements in different countries are comparable. Without homogeneous data it will be impossible to make aggregate regional and global assessments and some results may be contradictory.

Since some governments may not have the technical capacity to undertake the measurements themselves - especially remote sensing surveys - the CST may need to arrange for appropriate external scientific institutions to assist government agencies in this work.

Bearing in mind the doubts raised by scientists about the reliability of earlier estimates of desertification, the scientific credibility of the findings of the Baseline Survey would be enhanced if established practice in the Intergovernmental Panel on Climate Change were followed, whereby findings are subject to detailed peer review by an independent network of scientists. The consortium of scientific institutions chosen to host the first meeting of the Committee on Science and Technology in its new format in 2009 is sufficiently comprehensive in its range of expertise, which includes remote sensing, field observations, and agricultural development, to undertake this role.

6.4 CHOICE OF BASELINE YEAR

The choice of which year to use for the Baseline Survey requires care. Planning and obtaining funds for this Baseline Survey will naturally take a lot of time. Ideally, the survey would take place either at the end of a decade (e.g. 2010) or in the middle of one (e.g. 2015). The time taken for preparatory work may make 2010 unfeasible. However, as Chapter 5 made plain, decisions on the choice of the Baseline Year can only be taken after detailed consideration of the scientific issues involved.

6.5 REPORTING FORMATS

The format in which the findings of the Baseline Survey are reported should be decided by reference to both scientific judgement and the needs of the Conference of the Parties. Consistency with earlier reporting formats need not be the dominant criterion, though comparing the findings with earlier surveys would be helpful. The most important consideration is to ensure that the reporting format for the Baseline Survey is compatible with the needs of long-term monitoring.

The formats in which the results of the Baseline Survey are published will depend on the types of measurements made, who undertakes them, and other factors, e.g. the amount of funding available. The Conference of the Parties will wish the results to be summarized in an official document available to all Parties. The results could also be published in another Desertification Atlas.

The needs of scientific stakeholders are also important. These could be met by publishing the findings in a high-profile paper in a top scientific journal, such as *Science* or *Nature*, and making the digital maps available for download from the UNCCD Website. If these maps are available in georeferenced format as well as PDF format this will facilitate subsequent scientific analysis, and their incorporation into government development planning tools that include desertification.

6.6 IMPLEMENTATION DESIGN

Reaching decisions on the design and implementation of the Baseline Survey could well require two sessions of the CST, separated by a period of consultation in which the Parties submit their own proposals and reactions to a draft design circulated by the CST.

The Parties will need to discuss how best to design a set of national institutions for the Baseline Survey that are appropriate for each country, can sustain long-term national monitoring, and provide regional and global estimates to the Conference of the Parties.

6.7 APPLYING FOR FUNDING

Undertaking the Baseline Survey will be very expensive, and given all the factors that must be considered in specifying its design and implementation structure the budget may take at least a year to finalize. Applying to various Parties and other donor agencies for funding will take even more time.

6.8 TRAINING MATERIALS AND WORKSHOPS

To successfully undertake a global survey with a uniform surveying system, all members of national and international survey teams should receive detailed descriptions of the survey design in the form of paper-based and Web-based manuals, training materials and data collection forms. At least six months should be allowed for preparing these. Survey personnel should also attend training workshops. A further six months to a year should be allowed for this. The preparatory procedures of the UN Food and Agriculture Organization's Forest Resources Assessment 2005 can serve as a valuable model for both training materials and workshops (FAO, 2006).

6.9 CONTINUED MONITORING

Once the baseline survey has been undertaken another survey should be made after a suitable interval to estimate the rate of desertification in the intervening period. A possible date for the second survey would be five years after the Baseline Survey.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

1. Sufficient experience exists in undertaking desertification surveys to: (a) provide a sound foundation for designing a Baseline Survey for the UN Convention to Combat Desertification; and (b) indicate some mistakes to avoid when doing this. However, while this document provides a framework for Baseline Survey design, considerable scientific work is required to finalize this.

2. The limitations of previous surveys include: confusion between biophysical and economic indicators; lack of integration of biophysical, economic and social indicators; and relying on subjective expert assessments rather than scientific monitoring procedures. Transcending the last limitation is crucial if desertification, and estimates of its extent and rate of change, are to gain increased scientific credibility.

3. An appropriate conceptual framework is essential to ensure that the Baseline Survey employs a set of indicators that is comprehensive, coherent, integrated and (above all) compact. The DPSIR framework provides a starting point for this but it conflicts with recent research findings on desertification, which are encapsulated in the Dryland Development Paradigm.

4. Undertaking the Baseline Survey, and repeating it on a regular basis to monitor trends in desertification, will require: (a) measurements at a variety of spatial scales from global to local; (b) the combination of scientific and contextual knowledges; and (c) the establishment of sustainable institutions.

5. It is assumed that the Baseline Survey will be implemented by individual Parties in their own countries. However, Parties may also find it both technically and institutionally convenient to collaborate with international scientific research institutes to fill gaps in capabilities, especially in the analysis of remote sensing data.

7.2 RECOMMENDATIONS

1. This framework for Baseline Survey design is commended to the Committee on Science and Technology (CST) of the UN Convention to Combat Desertification.

2. This document has not been subjected to informal or formal peer review by fellow scientists, as is normal in scientific procedure. Following consideration by the CST, it is recommended that it be used as a basis for discussion by an international scientific workshop which can take forward and further refine the design of the Baseline Survey.

3. Undertaking a Baseline Survey is crucial to the successful implementation of the UNCCD. As it will be the first global survey of desertification ever to be undertaken through empirical measurement, proper prior planning of its design and implementation is essential.

4. Key decisions to be taken by the CST include:

a. The choice of baseline year.
b. Whether to survey both soil degradation and vegetation degradation.
c. Reporting and publication formats.
d. The planning of training workshops and the production of training materials to support them.

5. The members of the CST are urged to recommend to the Conference of the Parties that the Baseline Survey be followed by frequent monitoring thereafter. As explained earlier in this document, this is vital to put this survey in its proper spatio-temporal context. It is also essential if humanity is to gain a better understanding of the long-term trend in this highly complex phenomenon.

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