DESERTLINKS

COMBATING DESERTIFICATION IN MEDITERRANEAN EUROPE
LINKING SCIENCE WITH STAKEHOLDERS

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DELIVERABLE

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Indicator Concepts for Desertification Policy

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3D – EC

Objectives and Background

This paper reviews indicator concepts and systems relevant for Desertlinks; indicators that are relevant for connecting science to policy. The objective is to provide a rationale behind the choices that were made within Desertlinks and to explain how the concepts used in the Desertlinks are related to other indicator systems.

Desertification is defined by the UNCCD as "Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" The main goal of Desertlinks is develop indicators for desertification (land degradation) that is taking place today. The focus of Desertlinks is on providing indicators that enable the current progress of desertification to be monitored and on providing early warning of desertification in areas not yet affected. It is to help the user understand how, if and why his land or region is sensitive to desertification.

The report is discuss Indicator requirements; Concepts of indicators frameworks; potential headline indicators
.
There is a general agreement that Desertification is a process affecting large areas of the world and that actions to tackle it are urgent. At the same time desertification is not an issue at the top of the political agenda. Indicators can provide a vital tool for assessing the true extent of the problem. Actions that combat desertification also contribute to biodiversity restoration and the reduction of greenhouse gases.

During the course of Desertlinks, the author followed the developments and application of indicator concepts. These were presented in reviews and project reports. An earlier version of this deliverable was communicated during the first year of the project and this described the situation three years ago. This version of the deliverable updates earlier work and describes the current situation relevant at the time of writing.

During the earlier review of indicators developed by other organisations dealing with environmental issues such as sustainable forestry (http://www.aboutsfi.org/sfistandard02.pdf) and sustainable urban development (IIUE 1997), and sustainable agriculture, it was clear that the much could be gained by benefiting from experience elsewhere. Whereas at the start of the project groups such as the above were concentrating on describing and explaining indicators, during the last three years there has been a move towards the application of indicators for example accreditation and compliance.

Desertification indicators and desertification policy

Indicators have long been used for policy. The use of indicators involves generic conceptual issues that have been faced by many organisations and authors in the past who have wanted to bring together scientific knowledge and policy. Indicators can be used as instruments of social control so that they often meet with resistance. On the other hand control is necessary to make sure that agreements are adhered to or that measures being taken are having effect.

It is often argued that indicators should be neutral. Recommendations for this are described by the JRC position paper on indicator concepts (see 1).

Rules derived from the "neutral tools" principle (Table reproduced from JRC http://esl.jrc.it/envind/theory/handb_01.htm)

- indicators should support controversial political debates with *non*-controversial but relevant information;
- complex political debates should be made more transparent by using a *system* of indicators (not just a "basket");
- highly aggregated indicators/indices are needed to communicate the most relevant information to those who have an interest in the debate, but do not want to be flooded with all the details;
- value elements (weighting coefficients, valuation rules) must be clearly separated from objective elements (emissions of xyz);
- indicators are not necessarily tools in themselves; in order to make them useful, they must be presented within their framework, and linked to standard socio-economic statistics;
- the indicator system should provide enough detail to cover the political debates;
- it should give continuity to the societal actors, in order to provide them with a good basis for the planning of e.g. investments or political instruments;
- the indicator system should reflect the structure of the existing debates (and not try to introduce a "better" structure)

It is clear that most of these principles have been applied by Desertlinks as it used the UNCCD Commission of Science and Technology documentation as a guideline.

Abstract –to Concrete

***Abstract concepts such as "erosion" must be quantified by real evidence of erosion that can be measured*.**

It is often stated that indicators involve moving from the abstract conceptual level to the concrete and observable. Many proposed indicators such as "soil erosion" and "organic matter" and "soil stability" are relatively easy to describe in theory but present enormous challenges of quantification. When such indicators are described for an individual soil sample at one moment in time they can be measured and quantified. When such values are presented as indicators on maps for several square kilometres the indicators used have only an abstract meaning and they are impossible to validate and control. There is simply not the data or knowledge available to fill in the blank spaces and verify the claims being made. This makes such indicators unsuitable for control. In Desertlinks Visual indicators of soil erosion and evidence of actual past erosion can be easily recorded and such information is factually accurate. Modelled values of future erosion risk although used by policy to identify sensitive areas enable differences in risks to be predicted but not much more as the models ignore many processes and driving forces. Visual indicators of erosion provide unequivocal evidence of soil loss and desertification but such data are only just recently being widely collected.

The System Limits: what is desertification and what is not?

Related to the above problem is the question of limits. Where should limits be place limits on the system we are concerned with?

There are always limits of space, time and process. In developing an indicator system it is useful to structure and organise this in a hierarchical way so that the limits can be moved as necessary.

In the case of European Desertification, it is a paradox that many areas undergoing desertification are increasing in wealth as a result of development. The exodus of people from rural areas to cities could be part of a desertification issue but it could also be due to the desire for a more fulfilling life in the city.

A totally different example is the case of badlands. These are that are poor in vegetation cover and where they may be very high natural rates of erosion. When is erosion the result of the lithology and not associated desertification and when is it a result of poor land management.

In all cases indicators are needed that enable the different causal factors to be identified.

Relevance needs to be understood

It is frequently claimed that indicators should use available information. In other words no organsiation volunteers to pay for new measurements and monitoring. However, indicators must be relevant. The challenge of relevance means that causality should be known and incorporated into the selection. Using indicators, therefore, requires an understanding of why the measurements are relevant. For example, the user must understand and appreciate the difference between the effects of past and ongoing processes. What happened in the past conditions what is happening today? Where should we draw the line between the impact of a present cause of desertification and the consequence of something that happened in the past? Fortunately new concepts of change and resilience are available to the user of indicators.

Finally, it could be argued that the use of indicators must be an art. An indicator should capture the essence of change (Plato). Most of what we observe is a reflection of our will and intention and in the domain of space time and causality. This makes each observation site and case specific. Nevertheless as an indicator should capture the essence of the issue it should have a general universal validity (Schoppenhauer 1840) that we can all agree on.

The scientist working with indicators is faced by several obstacles. One of these relates to the different views of data held by scientists and organisations. It is often claimed by funding agencies that there is enough data and we have a sufficient knowledge to act. Unfortunately, because conditions in desertification affected areas are always changing; former assumptions made about processes are invariably being revised; data has no intrinsic value on its own, outside of the scientific framework within which its collection was designed. The soil strategy of the EU recognises that data and monitoring need data that reflect the functions provided by the soil. With regard to desertification, there is a need for targeted data collection that makes use of new and efficient methods. It needs to make use of more modern process based paradigms than the statistical ones that are now mostly used.

Indicators should be Multifunctional

Aspect relevance is that desertification indicators should also be applicable to many other issues. Desertification indicators should also be indicators that enable the actual impacts of desertification related to present human impact and climate change to be identified and monitored. They should also be applicable to sustainability, climate change and biodiversity loss. The outcome of the Desertlinks system should therefore not only be an indicators that enables the different rates of desertification in southern Europe to be monitored. It should also contain procedures that are useful for monitoring climate change and biodiversity

Risk of ignorance

In the USA and Canada extensive use is now being made of the Rangeland Health system. This is described in several key publications that can be downloaded. In the preface there is a warning about the need for expert knowledge. One of the greatest problems in Europe is the lack of relevant understanding and the inappropriate curriculum that do not deliver scientists or technicians with the knowledge of desertification processes that they need. The warning about using indicators is reprinted below

Interpreting Indicators of Rangeland Health (see part 3 for details).

This publication provides you with a more detailed assessment of rangeland health. This publication as well as numerous others are available online:

"*It is important to note that this approach was specifically designed to:*

- *Be used only by knowledgeable, experienced people.*
- *Provide a preliminary evaluation of soil/site stability, hydrologic function, and integrity of the biotic community (at the ecological site level).*
- *Help land managers identify areas that are potentially at risk of degradation.*
- *Provide early warnings of potential problems and opportunities.*
- *Be used to communicate fundamental ecological concepts to a wide variety of audiences in the field.*
- *Improve communication among interest groups by focusing discussion on critical ecosystem properties and processes.*
- *Select monitoring sites in the development of monitoring programs.*
- *Help understand and communicate rangeland health issues."*

The message from the USA is that indicators need to be used by knowledgeable and experienced people as the concepts on which they are based are not appreciated sufficiently by the citizen at large.

Desertification

The history of the concept of desertification has been described by many authors and it is assumed that this is known to the reader. It is explained fully in Dis4me.

Desertification is treated in this paper as a process. Land may be to various degrees in a desertified state as a result of the impact of past and ongoing desertification processes. The landscape is full of indicators that bare witness to this. It can be seen from measurements of indicators such as “soil depth” and “floodplain sediments” and from the results of archaeological and geomorphological studies that enabled the nature of former soils and vegetation to be reconstructed and the impacts of past agriculture to be seen. In general soil and land degradation are cyclical and not continuous at any one place.

Written records bare witness of past farming in areas today, such as in western Lesbos, where hardly any soil now remains. Agricultural activities have affected the region since at least 4000 BC. In Classical times the pattern and nature of soils in the landscape may have been quite different from today. It is also well known that land degradation often took place quite rapidly in phases during limited periods of time, often as the results of new land use practises and techniques. It is also evident from studies such as those by Butler (1952) and others in Australia that erosion and land degradation occurred in areas not affected by European agriculture. At the scale of centuries, periods of erosion and sedimentation were always followed by periods of stability characterised by soil formation. Erosion is cyclical partly because once the soil is eroded; time is needed to accumulate new soil material in depressions that can be again eroded. Much of the erosion in the Mediterranean occurred before living memory and there are only limited records.

With respect to the latest cycles of erosion that affected the soils formed during the late Holocene, the impact of past land degradation in the Eastern United States is perhaps the best documented as it occurred almost during living memory. The pioneer of soil conservation in the United Sates, Bennett (1943) compares the soils on the farm where he lived as a boy with those found by the first soil surveyors a generation later. Vast areas of agricultural land in New York State and New England were abandoned and relief programmes set up during the first part of the last century to help resettle farmers elsewhere. Are the large areas of the North Eastern United States that had their soils eroded and deposited in valleys and floodplains during the 1800 desertified? Today these areas are forested and support functions other than modern agriculture. The descendents of the farmers moved on and out of agriculture into other sectors of the economy.

In general society and land use patterns have become adapted to past land degradation. They are also adapting to the present phase.

In Europe land degradation and soil loss comparable to that in the United States occurred from about 5000 BC up until today. Fifty years ago Marsh (1953) compiled a benchmark study detailing the nature and extent of the human impact on the landscape and this includes many studies from Europe that describe the changes that man has brought about. Nevertheless, much of the land degradation in the Old World is ancient and the people responsible no longer live there. However, some Old World land degradation is very recent and most usually related to policy decision by governments to develop industries that required fuel or to change land use. In southern Europe, examples include (e.g. Portugal as a result of the wheat campaigns in the middle of the last century and the destructions of the forests that occurred in the Capathians. In Northern Europe severe land degradation has occurred in some areas during the last decades as a result of land use changes and agricultural policy.

In the dry regions of Europe, where desertification can take place according to the definition, there is much evidence that agricultural drivers and other changes are producing desertification. The UNCCD National Action programmes certainly believe this to be the case and the problem is taken seriously by the European Parliament and by the European Soil Strategy.

WHAT ARE INDICATORS EXACTLY ?

Two definitions of indicators below illustrate two views of indicators that capture several important points'

http://www.vcn.bc.ca/volbc/tools/glossary.html

"Critical information about selected areas of performance, usually expressed as an index or ratio, monitored at regular intervals, and compared to one or more standards. Indicators describe various aspects of the operation of a program, service, or institution. They must be relevant (actually represent what they purport to), reliable (based on statistics that can be assembled consistently and accurately), accessible (constructed on a regular and consistent basis), and clear (easy to understand). They are frequently tracked for over three to five years. In the institutional evaluation process, indicators relevant to the operation and performance of each program and service are collected and reviewed annually and as trends over a three to five-year period."

The second definition is from http://www.scoea.bc.ca/glossary2001.htm which is a glossary of evaluation and accountability terms.

"An observation or measurement that is assumed to be evidence of the attributes or properties of some phenomenon. Indicators involve moving from the abstract conceptual level to the concrete and observable. We observe the indicators of a variable, not the abstract variable itself. [e.g., We have indicators for poverty (such as income level), but we cannot actually observe poverty.] There may be more than one indicator of a variable. Indicators may be quantifiable (a number or percentage) or qualitative (such as a canary in a coal mine).

Key attributes of indicators according to the definitions

By Definition	Desertification
Critical	The information should be critical to the process of desertification. What are the critical processes?
Selected areas of performance	The indicator should relate to desertification. Other causes of change should not interfere with the indicators performance. What is being performed can be described as functions.

Regular monitoring Comparison with standards	Regular monitoring is needed to measure change Standards mean there are agreed procedures and benchmarks.
Operation of programme	The objectives of the programme define what is relevant an this is the UNCCD.
Relevant	The fact that indicators actually reflect what they are claimed to do requires scientific underpinning
Reliable	The measurements need to be repeatable and consistent
Accessible	Regularly collected and made available
Clear	Easy to understand
Abstract to concrete	The indicators of a variable are observed, not the variable itself. Desertification can not be measured itself, it can only be inferred from indicators

Indicators have a long history. They are particularly needed when we are in danger of being overwhelmed by the sheer volume of information which instead of helping us hinders decision making (Boyd 1998). He argues that the purpose of indicators is to get information into the correct form so that decisions can be based on it so that good indicators present information in a clear and usable form at the right time to those who need it.

Relevant Indicator Concepts

Introduction

The methodology involved consulting and identifying the concepts described in reports and documents on indicators. This included those of the UN, and European organisations and Environment Agencies as well as those in being implemented in other continents and used in other contexts such as biodiversity and for evaluating agro-environmental impacts.

Relevant source material for indicator concepts can be found by different programmes of the US Environmental Protection Agency, the USDA (Soil Quality and Environmental Health Indicators) and the US Forestry Services. The International Sustainable Forestry Programme and the Programme for Sustainable Urban Development and the indicators used for Biodiversity and Climate Change are also useful sources of Guidelines . The indicator programmes in the USA are valuable as indicators can be tested and supported by relatively large amounts of environmental data.

A challenge in Europe is the lack of available data for many indicators and the reliance placed on models that seem to be seen as cheap alternatives to data collection. The EIONET, DISMED, MEDRAP and MEDACTION programmes and projects provide introductions or provide information about the indicator programmes being used in Europe. The OECD Environmental Indicators for Agriculture (vol 3 Methods and Results) is a useful source of indicators. The OECD (2003) organised a conference on indicators that reflects the current state of the art in terms of practice. The World Bank indicators on land quality and the rangeland health indicators developed in the United States will be discussed later as examples of two different conceptual approaches. The LADA project of the FAO provided a useful electronic workshop reviewing the subject of land degradation indicators. .

Different Conceptual Approaches

The table below illustrates some of the different approaches to indicators that will be discussed below.

What is it that we can see ?

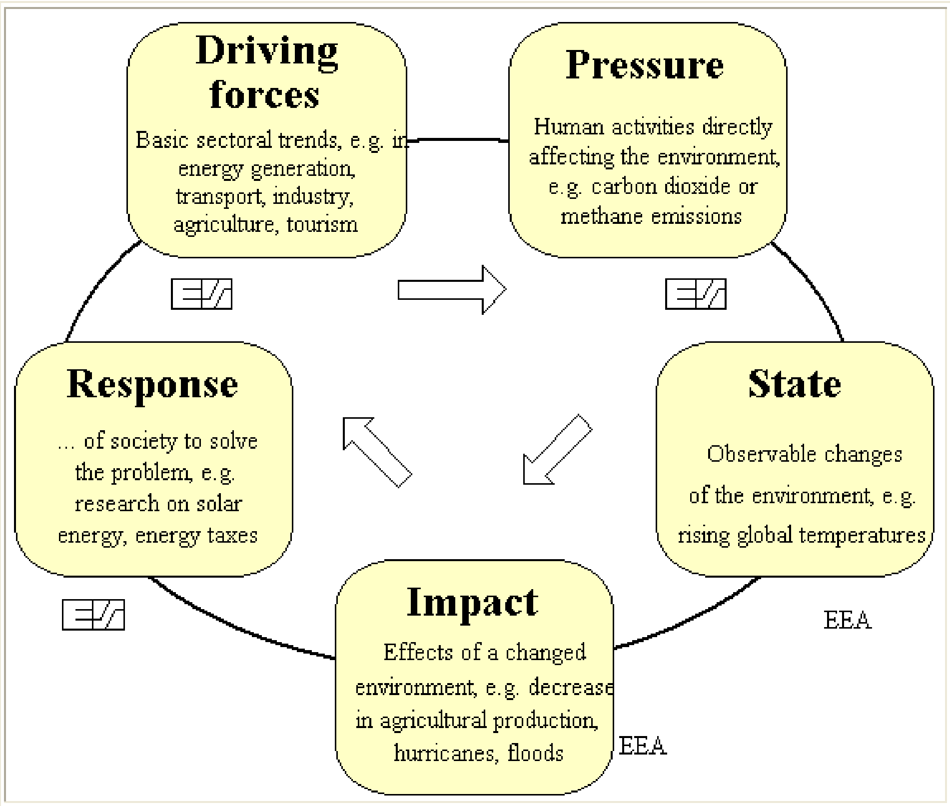
Type of Evidence used to construct indicators	**Questions and concerns**	**Approaches**
Evidence of state and condition	Is there a desertification problem today or one that is imminent?	Indicators of rangeland health (see Pellent et al)
Evidence from Critical factors known to affect Desertification	Are critical threshold values of factors known to influence erosion being reached?.	Erosivity, erodibility, cover, slope, carrying capacity etc Water yield

Functional indicators	Are the critical functions of the soil being lost thus threatening sustainability?	Soil water regulating and production functions (see paper Imeson 2005)
Viability	Is the present exploitation of the soil sustainable. Is the natural economic and ecological capital being maintained	Loss of soil, organic matter and biodiversity
Resilience	Can the soil remain within its current state of attraction	State and Transition thresholds
Control	Am I doing what I promise and does it help?	Complience indicators

Applying the DPSIR framework to Desertification.

Because if is playing such an important role in current environment policy, it is useful to explain the DPSIR approach in relation to desertification.

Figure 1: The Driving force-Pressure-State-Impact-Response model (reproduced from from JRC esl.jrc.it/envind/ theory/handb_03.htm



Desertification of the land is mainly driven by human activities, such as intensive agriculture, overgrazing, deforestation and changes in the local population, in combination with adverse physical environmental conditions. In order to understand and manage desertification, policy makers found it necessary to develop a framework that will take into account the various human activities (driving forces) that exert pressure on the physical environment together with changes in its quality (state). The changing physical environment in turn has impacts on other environmental and socio-economic issues such as loss in plant productivity, a decrease of farm income and flooding. Society usually responds to the changes and impacts by implementing environmental, general economic and sectoral policies.

A good example of the application of this scheme to desertification is by the LADA project of (FAO. http://lada.virtualcentre.org/pagedisplay/display.asp?section=method&expand=1023). However the LADA programme is being implemented in very many countries and a very large number of approaches are being used.

It is believed that desertification indicators can be developed to define the desertification risk for a certain piece of land and for continued environmental monitoring. Such indicators can be divided into a number of different types: (a) driving forces indicators (related to intensification of agriculture, overgrazing, increase of local population, increase of tourists); (b) pressure indicators resulting from the driving forces, imposing unsustainable land use practices and overexploitation of natural resources (deforestation, forest fires, ground water overexploitation); (c) state indicators related to the physical environment (soil water availability, soil erosion vulnerability, land suitability to support specific type of land use) and describing the extent to which an area will be affected by desertification; (d) impact indicators resulting from land degradation and desertification and related to on-site (loss in plant productivity, loss in farm income) or off-site impacts (flooding of lowland, dam sedimentation); and (e) response indicators related to implementation of programs for protecting areas from desertification (such as the application of sustainable farming systems, terracing, ground water recharge, storage of runoff water, controlled grazing, protection forest from fires).

The **DPSIR approach**, is being increasingly applied to environmental issues and is for example being applied by the European Environment Agency, amongst other things to land degradation and soil erosion.This approach essentially forces the user to apply systems thinking and concepts. Nevertheless, it has been criticized because the classification of an indicator in this can be different according to the scale and question of interest. One response to this difficulty is to simplify the system so that it considers only **Pressure Impact and Response**. At different points in the "desertification system" a good indicator should cover or integrate all three aspects. The World Bank land quality system does just this and provides an excellent example of how it can be applied and further it illustrates that desertification or recovery from desertification must be established by changes in time. If a societal response has resulted in a positive impact in addressing desertification, this can only be demonstrated from historical information. Another difficulty with the DPSIR approach is that attention maybe withdrawn from the underlying key issues (linking problems and solutions). As Desertlinks is setting out to find solutions to issues identified by end-users this is a disadvantage. The main focus should be the issue itself. This was the rational behind the process of matching problems to indicators.

Recently Castillo et al reported to DG Environment using this framework as mentioned elsewhere..

Systems based approaches

Systems approaches are essentially holistic. They take the broadest possible view of desertification. They can be applied at different hierarchical levels are supported by dynamic systems and hierarchy theory.

Hierarchy Theory and Desertification Response Units

The most recent applications link processes operating at different spatial and temporal scales in connected socio-economic and biophysical processes. The Hierarchy theory concept was at the root of the Desertification Response Unit methodology developed in Medalus 1. Phenomenon such as "incorporation" "emergence" and "connectivity" were shown to be helpful in interpreting causal relationships as well as in explaining how process-pattern interactions from positive feedback looks generated structures in the landscape providing resilience. "Patterns and structures" at all scales have a great potential for desertification indicators because the changes can be monitored by direct observation. They do need to be pinned to processes however by field observations. (Examples of such indicators include those that measure changes in: soil aggregation and permeability (fractal dimensions); patterns in the vegetation and bare area; patterns in soil moisture and evaporation; patterns in ground surface reflectance properties; patterns in land management and land use; patterns in consumption).

Patterns in some cases evolve in time and as they evolve there is an increase in heterogeneity and resilience.

An important conclusion: Patterns and structures are indicators of processes.

Scale and Connectivity

The concept of scale became widely used in environmental sciences after the introduction of the hierarchical systems theory (Allen and Star 1982, O'Neill et al. 1986). A focal level is first define, this is our level of interest and which is our direct concern. Above this is a coarser level, associated with relatively broader spatial and temporal scales, at which changes occur more slowly. At a lower level, where changes occur rapidly on fine spatial and temporal scales changes take place that drive the dynamics of the higher level.
Connectivity of nature across both adjacent and more distant systems is important as ecological buffering and transmitting takes places across various scales, both in human and natural systems. Tourists travelling to Spain as well as interventions and migrating insects connect systems at a European level. Connectivity is a vital element of landscape structure (Taylor et al., 1993) the hierarchical structure has to be considered,

Adaptive Cycle and Panarchy

More recently Holling and co-workers and Walker (2002) have shown how hierarchically described processes are explained passed through different phases of degradation in an adaptive cycle linking human societies and natural systems.

The dynamics of desertification can be represented by an adaptive cycle, in which four distinct stages have been identified: (i) exploitation or growth, (ii) conservation, (iii) release or collapse and (iv) reorganization (see Figure 1). There are two major transitions in the adaptive cycle. A) From exploitation to conservation; the slow, incremental phase of growth and accumulation. B) From release to reorganization; the rapid phase of reorganization leading to renewal. The first but not the second is predictable with higher degrees of certainty. The second phase is unpredictable and highly uncertain. The adaptive cycle can be more completely understood as a dynamic loop in multidimensional conceptual space. For examples of what such changes means the reader should consult Gunderson and Hollin (2002). An example for soil erosion is described by Doren and Imeson (2006)

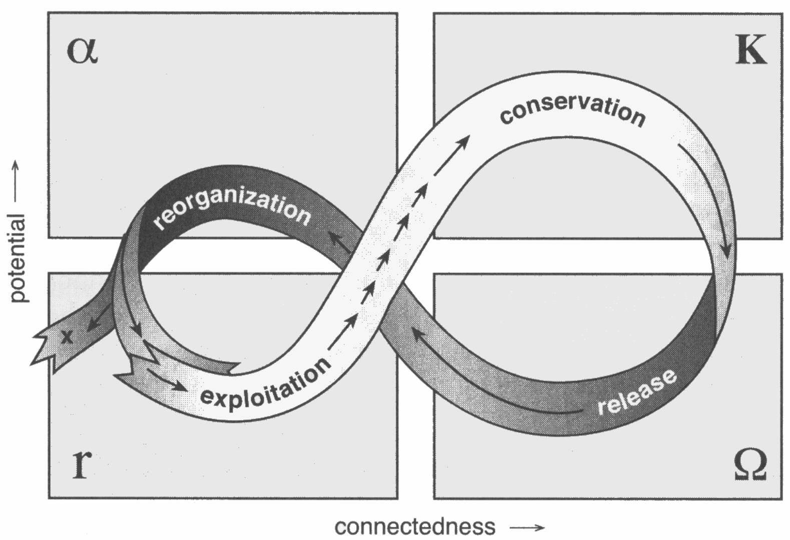


Figure 1. A conceptual representation of the four distinct stages within an adaptive cycle (after Gunderson and Holling, 2002)

Resilience and the adaptive cycle

An important consequence of the adaptive cycle is that the resilience of a system changes throughout an adaptive cycle. A full discussion of the different meanings of Resilience can be found on the web site of the resilience alliance (http://www.resalliance.org/ev_en.php,) Engineering resilience is the time of return to a global equilibrium following a disturbance. Ecological resilience is the amount of disturbance that a system can absorb before it changes to an alternative stable state. A resilient ecosystem can withstand shocks and rebuild itself when necessary. The alternative meanings of resilience have significant implications for application of the concept to understanding and managing complex systems (Gunderson and Holling, 2002). Resilience is high during the growth phase and it shrinks as the cycle moves towards the conservation phase, where the system becomes more fragile. Resilience expands again as the cycle shifts rapidly into a back-loop in which system resources are organized for a new initiation of the cycle.

A panarchy, as defined by Holling (2000) and Gunderson and Holling (2002), represents a hierarchical structure in which both human and natural systems are linked together in adaptive cycles. By examining complex natural systems within this structure it should be possible to identify moments or periods within a single cycle where the system is most receptive to actions that create positive change and enhance sustainability (after Gunderson and Holling, 2002). In other words this framework should help identify which actions are necessary and which are redundant.

Returning from the theory on adaptive cycles to the reality of desertification in Europe. Why has desertification become an important issue. Is desertification quantitatively greater today than it was thirty years ago? Most experts would probably claim that erosion is indeed more extensive in certain areas where it was formerly absent. On the other hand the nature of desertification makes the opposite also the case.

Desertification is more prevalent because the resilience of the landscape and soil has been reduced. At the same time it has come under greater pressure from development and the exploitation of resources.

Am important aspect of resilience is that it varies in time. Resilience and therefore indicators have a different significances according to their position in time..

The benefit of a systems conceptualisation is that it is easy to communicate and dicuss relationships in simple language with an end-user. The end-user can exchange ideas with the scientist and together they can improve their collective understanding of the system and what this means for solutions. Justifying policy with correlations that defy common sense logic of how the end-user sees the landscape changing can result in the end-user terminating further dialogue. The alternative to a hierarchical and evolutionary systems approach is a mass of data and statistics that defy interpretation.

Indicators and index of rangeland health

For several years it has been apparent the in the US that the soil survey was not providing the data needed for managing rangelands. Consequently a huge interdepartmental effort was made to establish a new quantitative approach that could be used for establishing rangeland health. A prototype methodology was developed by Pellant and presented at the 2nd Tuscon Conference on Desertification about 5 years ago. This approach was tried by Imeson et al during Medalus III in the Alentejo and Guadelentin target areas. Meanwhile in the USA it has been developed and accepted by the relevant US agencies and documents in concept describing its use can be downloaded from the web (see references). Many of the indicators (biological and physical) are relevant to Desertlinks. The need for expert consultation when they are used has been mentioned. These indicators are ideal for identifying problems but need expert knowledge from people familiar with the area. The concept of "health" means that healthy areas need to be distinguished from unhealthy ones by means of comparisons with "ecological reference areas" As with the ESA method, the rangeland health index is calculated from the individual indicators.

The evaluation of indicator concepts and systems relevant to Desertification and land degradation was undertaken in the report of the soil strategy. The Soil strategy working group WG on erosion prepared a Task Report on Desertification (Env 2004) and this was also used to test the usefulness of the concepts developed for the Desertlinks system. During the reporting period there was increasing interest in soil quality both in Europe and the United States and this provided useful information relevant for Dis4me.

The Conceptual basis of the method is illustrated in the page inserted below. This methodology would be highly appropriate to southern Europe.Figure 3. Application of rangeland health approach in Alberta Canada.

The methods apply the concept of State and Transition. A review of this concept is published by Herrick (2003)

http://www3.gov.ab.ca/srd/land/m_rm_classification.html

Rangeland Classification and Ecology

In order to manage vegetation for range, timber, wildlife and recreation the ecology of the plant communities in the presence and absence of disturbance must be understood. Vegetation classification helps to reduce the complexity of natural vegetation to a manageable number of similar groups, often called community types. Community types are defined not only by their vegetation composition but also by the environmental conditions under which they occur.

Two major classification tools are commonly used to assist in the classification process. These include the mathematical approaches, which involves the mathematical analysis of plant species data through measures of dissimilarity or similarity. The other approach is the Landscape Classification approach which incorporates both vegetation and site conditions (climate, soils and geology) into subregions. Each subregion is subdivided into ecodistricts by distinct physiographic or geologic patterns. An ecodistrict can be divided into an ecosection, which has similar slope, landform, soils and vegetation. An ecological site or ecosite is a further division of the ecosection and usually has a unique combination of moisture and nutrients.

The rangeland classification system combines both the mathematical and Landscape classification approaches to vegetation classification. Mathematical procedures of ordination and cluster analysis are used to group the sites into community types. Community types are aggregates of similar plant communities based upon existing floristics regardless of successional status. After the community types are defined they can be linked to ecosites and ecodistricts within a Natural Subregion. There are 6 Natural Regions and 20 Natural Subregions described in the Province of Alberta.

Adaptive cycle and policy: different indicators needed at different times and places.

The benefit of an adaptive systems approach is that it describes the physical and socio-economic factors. The adaptive cycle framework clearly allows desertification indicators to be linked to a policy cycle. As an area passes through a policy or adaptive cycle, a different type of indicator will be needed. This representation is helpful in explaining the dynamic nature of desertification and why indicators and their representation are inevitably dynamic.

The concept of Natural Capital

The idea of that certain soil or landscape properties represent a capital that generates or allow production is an old one described by Huxley (1886). Farmers are no longer solely dependent on this natural capital if they can get income from elsewhere. Presenting desertification as a loss of capital could prove to be effective in policy.

Patterns as Indicators of sinks and sources

Another methodological development concerns the use of changes in vegetation patterns as indicators of changes in water availability in semi-arid systems.

Score cards

With respect to the application of indictors for soil conservation purposes, the simple use of (balanced) scorecards is interesting. These are used as a means of training end-users in evaluation. They provide a simple means of combing different types of indicator. Examples of the use of scorecards can be found in the USA and on the LADA web site.

HAPP

The phenomenon of Desertification has also been addressed by the LUCC community (for examples see Geist and Lambin 2004) In addition some remote sensing desertification indicators used to identify the impacts of climate change were also reported in the recent literature. These related to land use change, change in organic matter content and forest fires. Indicators used in the wider field of global change can have considerable relevance as desertification indicators. An example of a general indicator is human appropriation of net primary production (HAPP) that approximately describes the proportion of biomass used by humans (see for example http://earthobservatory.nasa.gov/Newsroom/NasaNews/2004/2004062317190.html When this is too high, it can have a negative impact not only on for example biodiversity but also on aspects of the soil quality that are linked to the soil functions described in earlier reports. It is recommended that HAPP be considered as a potential headline indicator.

Functional Indicators

The conceptual basis of functional indicators is set out in the accompanying deliverable (Imeson 2005b) The use of functional indicators as a key indicators as recommended by Castillo et al (2004).They concluded that the water and nutrient regulation functions of the soil could form the focus of key indicators. It is recommended that one way of doing this is to use "soil water stability" as a key indicator and to measure this by means of a soil stability test. This is already being done in the USA by the NRCS (2004). http://soils.usda.gov/sqi/soil_quality/assessment/kit2.html and instructions for doing this can be found. Alternatively, as a key headline indicator soil according to data availability and context, use could be made of organic matter or soil bulk density.

Kibblewhite (2004) recently proposed that attention be given to the soil as a living habitat. He points out that the soil does not just have a structure but rather an architecture produced by the animals and plants that live in it. Soil degradation and soil functions are partly the result of the loss of this architecture that occurs when organisms are interfered with inadvertently.

Some Recommendations for headline indicators

It is recommended to collect indicators at different scales.

Fine scale headline indicator.

At the finest scale a soil stability index is recommended similar to that employed by the soil quality programme in the USA. The loss of water and nutrient regulating functions can be caused by the deregulation of several processes. "Water-stable soil aggregation" can often be considered as an indicative of the success and failure of biological activity in creating and maintaining the water and nutrient regulation function which, in turn favours retention of available soil moisture and water and nutrient transport. This biological activity depends on there being both a sufficient input of suitable organic matter and periods of time during which soil moisture and temperature do not limit the activity. In many desertified areas, the loss of vegetal cover brings about a diminution of soil organic matter or its quality. This reduction has a direct effect on soil structure by weakening of the soil aggregates. The degradation of the structure on the surface has a negative effect on the biomass productivity of the soil by reducing water availability for plants and hampering the re-vegetation. Thus, the loss of water and nutrient regulation function brings about a feedback self-accelerated mechanism that, if not arrested, accelerates land degradation. The water and nutrient regulating functions indicated by soil stability is of course linked to the activities of organisms. " The soils stability" key indicator reflects this because the stable pores and aggregates are indicators of the architecture that these organisms produce in the soil. Water-stable soil aggregation can often be considered as an indicative not only of the success and failure of biological activity in creating and maintaining the water and nutrient regulation function. Biological activity depends on there being both a sufficient input of suitable organic matter and periods of time during which soil moisture and temperature do not limit this activity. It is therefore indicative of the production function of the system.

The first recommended indicator is therefore the **soil stability index** A **second** recommended indicator is there the **biological index** calculating the number of days that growth is not limited by water and temperature (indicator 2)

Medium scale indicator of the soil and water conservation function

Landscape can be seen as a mosaic of hydrological or ecological response units whose spatial arrangement is the result of the processes of water, nutrients and sediment transport at hillslope and catchment scales. These processes are regulated by positive feedbacks between the vegetation, soil and water that reinforce the redistribution of rainfall and runoff within each unit. Quantitative indicators can be obtained from indicators of vegetation/cover pattern changes. These indicators can also be used as a "hillslope water regulation" indicator that can be used as the basis for a "flood risk" indicator. Vegetation pattern indicators are also indicators of ecosystem resilience, climate change and have relevance for biodiversity.

A means of obtaining quantitative indicators of such changes has been demonstrated to be Ladar. An application in Austria (Mayer 2004) showed that this can be used to monitor the growth of individual trees and plants. Changes in productivity obtained in this way can be used as a means of obtaining indicators of vegetation/cover pattern changes that are responses to for example drought or fire.

The third recommended indicator is the **change in vegetation cover pattern**

Natural capital indicators

Both organisms and people transform their environment by investing in the capital that will generate and sustain future life. The functions mentioned above arise initially as a result of the transformation of energy by plants into substances that can be accessed and utilized by animals and man. Nearly all of the work done in a landscape is performed by plants and animals who invest in a capital that man can access through domesticated animals and plants. Imeson (2004) proposed a universal desertification indicator. It considers desertification pressure as the ratio between a) the amount of capital generated locally and b) the capital being supplied from elsewhere. This applies throughout the system, both in the soil and in agriculture. Non sustainable practices occur when the supply of external capital causes the amount of natural capital to decrease. The "threshold of sustainability" occurs at a value when the amount of local resources or capital providing capital that enable the functions to be provided start to decline as a result of neglect and/or degradation. This type of indicator applies equally to the loss of local services, infrastructure or culture (local television, theatre, restaurants and transport services, e.g. under the pressure of ,cheap imported television and fast-food restaurants) as to agriculture and the impact of subsidies and alternative income sources as it does to bio-physical processes in natural and organised ecosystems.

The destruction of the surface vegetation cover locally reduces the habitat function of the soil for organisms that can then not flourish, for example in the higher temperatures. This of course can a result in there being less soil organic matter. Several mechanisms may result in the soil becoming less stable and in it being a less suitable habitat for pore creating organisms. It might be expected that these changes not only influence the structure and productivity but also respiration. These changes are therefore not only indicated by soil by a reduced availability of water for plants but also by the evolution or respiration of CO_2.

As well as the soil stability, the CO_2 production or plant respiration could also be used as a general habitat function indicator. This concept can be extended to see capital as an aspect of the habitat function that sees the soil as a living entity. The transformation of energy by plants into substances that can be accessed and utilized by animals and man, is of course also a spin-off of the habitat creation that is going on in a healthy soil.

The **fourth** recommended indicator is a **pressure-capital ration index**

Water availability

The performance of the above functions are also summarised by a number of hydrological parameters for which data is available. Recommended are the evaporation efficiency index described elsewhere or the low flow hydrology discharge data from rivers.

4. Socio-economic relevance and policy implication

The four indicators mentioned above cover the DPSIR policy requirements. They can be developed from existing data, can be used to forecast early warning and integrated across sectors and scales. They enable a link to be made to agricultural policy and can be either calculated from readily available data or measured or estimated directly by the end user. The policy relevance was demonstrated by the WG Erosion Task Group on Desertification that made extensive reference and use of the information provided in this project.
The conceptual development and implementation of the DIS has in some senses gone further than was envisaged in the original proposal. The interest in the methodology shown by the National Committees of the UNCCD and more recently by the FAO is extremely encouraging.

CONCLUSIONS AND RECOMMENDATIONS AT THE CURRENT STATE OF THE ART

- The indicator concepts that can be used for indicators and make the least unrealistic assumptions about the true nature of desertification are probably those that apply the adaptive system paradigm. Research groups of Holling and Walker and the publications that can be assessed at the resilience alliance home page are very useful.
- A key message is that the significance of indicators will be continually changing in space and time due to the interactions of people with their environment.
- Hierarchy theory shows how indicators can be used at different scales and how these scales are interacting.
- A key message is that as the scale increases, other emergent indicators can be used that incorporate the effects of fine scale processes. Also patterns and structures can be used as sensitive early warning indicators.
- Dynamic systems concepts are incorporated into the concepts mentioned above. The DPSIR applies a systems approach but it is not process based.
- A key message is that understanding and describing caused and their effect can provide a shortcut. It is not per se necessary to systematically analyse DPSIR when the causes, problems are solutions are known.
- Statistical approaches give results that can be difficult to interpret by people who do not understand the processes.
- A conclusion is that process based understanding of desertification should be used as a basis of stratification. Published statistical data can be used to calculate headline indicators.
- The concepts of HEALTH and QUALITY are very useful and are being extensively used in North America. These concepts lend themselves to desertification and it is recommended that they be developed for European conditions. Quality is closely linked to FUNCTION
- The concept of STATE and TRANSITION is also valuable for desertification. This is more realistic than succession. Again it is being applied extensively in the USA and Australia. Desertification occurs when a threshold is exceeded and the land passes into an alternative state.
- The SCORE CARD concept is very useful and is widely used in America and by LADA. Scorecards are valuable when they are regularly filled in by stakeholders. They could provide measurements that allow desertification to be monitored.

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