DESERTLINKS

COMBATING DESERTIFICATION IN MEDITERRANEAN EUROPE
LINKING SCIENCE WITH STAKEHOLDERS

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DELIVERABLE

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Functional indicators for monitoring Desertification.

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3D – EC

Introduction

Ecosystems may be thought of us providing functions for the people who live in them. Desertification can change the way that these functions are provided. It effects the environmental "goods and services" to which they have been accustomed and on which their livelihoods and well being depend.. For example, soil degradation may mean that the water cycle is regulated in a way that results in less water being available for irrigation and less water and salt accumulation can cause a reduction in crop yields. At a more general level, the landscape contains elements that make it resilient and able to resist pressures that cause desertification. This may be thought of as a "desertification protection" function.

This paper explains the relevance of functional indicator concept for Desertlinks. For more information about other indicator concepts, reference is made to Imeson (2005)

Desertification Sensitive Areas

The Desertlinks indicator system evolved largely from procedures used to identify desertification sensitive areas (ESAs)(Kosmas et al 2002) in the Target areas of Medalus Project III in Spain, Greece and Italy. One of the requirements of the UNCCD Annex IV National Committees was for indicators that could be used to identify areas where desertification might happen if critical threshold conditions were exceeded. Parts of this methodology formed the basis of the methods used by Dismed (Desertification Information System for the Mediterranean 2002 http://dismed.eionet.eu.int/index_html# as well as by many other National Programmes in different parts of the world. Dismed is a programme supported by the European Environment Agency, Italy and the UNCCD.

The Desertification Sensitive Area approach is appropriate to an initial phase of a policy cycle in which the goal is to evaluate the extent of desertification and to identify the relative risk of desertification in different areas. The strengths and weaknesses of the approach were analysed at a meeting that formed part of the MEDRAP concerted action. (see Enne et al 2003 and Imeson 2003).

The conceptual basis of the ESA approach is described in detail by Kosmas (1999) and it has much in common with the traditional approach of land evaluation in which emphasis is given to the quality of climate, land and management. Measured data of different kinds (for example of soil properties, erosion and vegetation) are used for their evaluation. Selection and development of the indicators and indices relies very much on the strength and significance o statistical relationships. Although the selection of measurements is based on process understanding, the approach remains essentially statistically (not process) based, The ESA method uses relationships found between the ESA results and independent indicators of desertification, for example, to assessments of erosion. The methodology also applies statistical procedures for combining socio-economic and physical aspects of desertification. A concern sometimes raised is that the data used for evaluating the method is not entirely independent of that used to assess the degree of desertification. Desertification is by its nature not something that can be measured directly and this is the reason why indicators are necessary. Another practical concern is the relative weight given to the different qualitities. This is based on expert opinion and statistics, not on any underlying theory. The ESA method is nevertheless very practical and works provided the information needed to calculate the indices is available.

A complimentary approach of functions

A different but complimentary way of considering desertification indicators is the approach that employs *"functions"*. Whilst it is true that desertification concerns land and soil degradation, and that these reflect how the drivers of climate change or poor land management impact on the quality of land, soil, and vegetation, changes in these also have an impact on the way in which the land is perceived by the inhabitants as providing for them the functions that they expect. Desertification therefore is connected to the capacity of the ecosystem to meet the needs of the people who live there. The decisions taken by people regarding the provision of such ecosystem services and the way in which these affect the quality of the environment is only a part of a bigger and more broader reality in which the relative advantages of living in an area undergoing desertification relate to the benefits of migrating to a different region. The migration of young people from economical marginal areas to cities such as Athens or Alicante reduces the attractiveness of these areas to the older people who remain behind. Migration and land abandonment are clearly an indicator of social and economic degradation on the one hand but on the other are, they are also a phenomenon of globalisation and increased opportunity and quality of life. If the policy is to maintain people in rural areas, then combating desertification requires improving the quality of life in these areas, as well as the quality of the physical environment. There are socio-psychological and organisational issues as well as a bio-physical one involved in desertification. The "Function" approach is useful as it allows these different dimensions to be linked.

One aim of this deliverable is to raise awareness of the potential benefits of applying functions to desertification. It can be used to guide the selection of key or headline and early warning indicators from among all of those being gathered for the DIS4Me system.

Scope of this paper

"Procedures for evaluating candidate indicators for monitoring changes in function" was the original title of this paper. This was because the intention was to using the outcome of the interviews with stakeholders in the different target areas to identify the "functions" that were being threatened by desertification. Candidate indicators for measuring these functions would then be suggested. In practice, DESERTLINKS developed somewhat differently, as the focus was placed on "issues". The word issue was used because it explicitly link problems with solutions. However, concerns with issues can also be seen as reflecting the values being placed on functions. These include the eco-goods and services that the landscape is providing and which people regard as being threatened by change. In addition it was decided to develop an indicator system with a large choice of indicators. In a complex holistic world that can be described from many points of experience, the different descriptions of a degrading system are complimentary points of view, stakeholder specific and not mutually exclusive. Because many things are related or connected, the main concern is not "what" indicator is being measured but "who" is measuring it and "how" it is understood. It can be sometimes helpful but not necessary to describe these in terms of functions.

Functions are increasingly being applied .

The use of functions has been promoted during the last decade in many neighbouring areas. These include, environmental economics and soil science. In particular it was promoted by authors such as de Groot (1976) and Blum (2004). It is a major element of the Research recommendations for the future European soils directive (see for example Blum and Busing 2004). It has been applied to desertification by Imeson et al 2004.

The function approach has three advantages:

- Areas that have geographic contrast areas can be compared, because the question is how well a function is being performed and not what the threshold value of an indicator is. For example, critical values of soil depth to support a particular crop may change in time and vary from place to place. Whether or not the depth is adequate to support the "production" function, of say wheat, is what is relevant.
- Economic values can be placed on functions so that alternative functions can be assessed and compared. Land has "cultural" and "recreational" functions that can be assigned values in Euros.
- Functions integrate socio-economic and physical systems. They link cultural values and perceptions with the perceived reality of the physical system. When this is considered, it is clear that desertification will be defined differently by every culture. That "natural resources are cultural appraisals" was explained by Hartshorne already in 1939.

The possibilities and advantages of the function approach can be seen from its use in soil quality assessments. The soil quality site of the US Department of Agriculture NRCS http://soils.usda.gov/sqi/ is recommended for this purpose. The authors of the soil quality site ask the question "What does the soil do for you."

The late French scientist M. Robert provided the widely used illustration shown below,

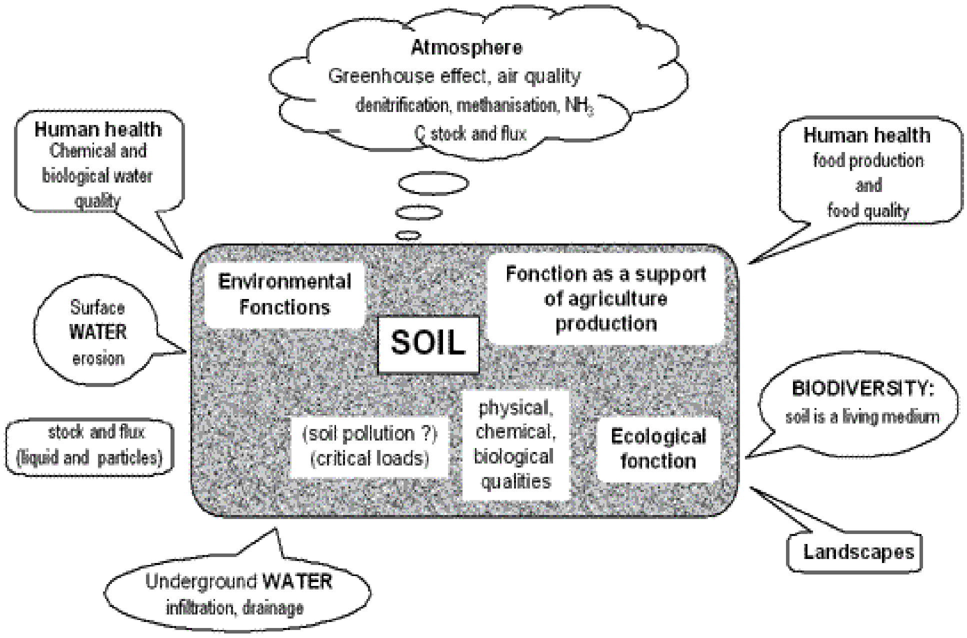

Figure 1. Soil functions according to M. Robert (2004)

As mentioned already, the DSA indicator system (Kosmas 2002) is also based on evaluations of different qualities (soil, water, management). This concerns a very different usage of the term quality. Quality is not assessed from simple functional indicators but from measured data. The relationships established are then used to identify indicators and to calculate indices. The question of whether or not a function is being performed is indirectly asked in relation to the search for threshold values.

Candidate indicators

The expression "candidate indicator" refers to all of those indicators that have been proposed for evaluation and which form the basis of the indicators originally proposed for the Desertification Indicator System.

Desertification regulation functions of landscapes

Some benefits of considering desertification indicators within a functional framework have already been introduced above. A description and demonstration of how the functional approach can be applied to desertification can be found in the MEDALUS III Target Area Projects reports of the Alentejo and Guadalentin. (see Imeson 2001 Imeson 2002, and Imeson 2003). The value of the approach was stressed by Imeson and others at the Tuscon Desertification Conference where a comparison was made between Spain and the American Southwest. From a comparison of the policy requirements of indicators needed in New Mexico and Europe, it became clear that the way communities valued functions determined the choice of indicators they considered relevant. A functional perspective enabled totally different areas to be nevertheless compared according to the ways in which the functions were being met.

Figure 2

Cinque Terra Italy: Artficial terraces maintained on a steep slope to provide a production and soil and water conservation functions (Photo SCAPE 2005)

Scientific Frameworks and their limitations

A "framework" is a conceptual or physical metaphor that is useful in describing how different pieces of factual information or knowledge can be brought together. Examples of alternative frameworks are provided, for example, by dynamic systems, hierarchy theory and by panarchy (adaptive management), but also by the DPSIR scheme (see Imeson 2002 and Imeson 2005). Frameworks are practical tools for integrating information and ideas from different areas of knowledge originating in the social and physical sciences. The "functional framework" discussed in this paper has some advantages and compliments a data driven "statistical" framework because it explicitly includes cause and effect relationships and links arbitrary socio-economic needs and values with the capacity of the landscape to provide them. Although the function approach is very useful in the context of environmental issues such as desertification, it has its limitations. It is only one of many possible metaphors that could be used; one way of structuring knowledge about desertification. More comprehensive frameworks are available but they require the user to possess more expertise and experience They may be less effective in that the increased abstraction makes it hard to explain the results to stakeholders not familiar with the concepts.

An essential limitation of the functional framework, is its sometimes rather anthropocentric interpretation by some users. The landscape is the habitat of man and it will provide him with not only future food, clean air and water but also a place to satisfy all of his other long-term cultural and psycho-social needs.

The concept of sustainable development is also one of functions as it is defined in terms of the ability of the landscape to support the needs of future generations.

The risk of adopting an entirely anthropocentric position towards functions is a real one. Attempts at controlling, optimising and managing functions can lead to environmental catastrophes including land degradation. It involves unnecessary risks unless the value and benefits of many earth support functions are allowed for (see for example Mefke and Hollin 1996). Examples of failures cited by the authors are in areas of soil erosion control, river water regulation and fire suppression. Thus relatively extreme flood events are necessary in rivers to maintain the resilience of the system and prevent unwanted changes such as the invasion of exotic plants and fish.

Functions involved in land degradation and their beneficiaries

Functions provided by the soil and land have for example, been classified as production, regulation, carrier and transport functions, all of which can be quantified (see Figure 1) However, other types of function, including habitat, cultural and heritage functions, may have cultural and psychological dimensions that are less easy to define and measure. Although monetary values can be given to functions in order to provide a rational basis for evaluation and planning these are often common goods. The beneficiaries of functions are not concentrated. A resource may provide functions locally directly supporting the inhabitants but alternatively the benefits can also be provided regionally, nationally or at a European or global level. Following from this, all areas are multifunctional supporting a multitude of people who may live locally or far away and be conscious or unconscious of the functions that others are benefiting from. Different beneficiaries will rank and value subsets of functions quite differently. The complexity and variety of functions highlights the multi-sectoral nature of the values and demands that are being placed on landscapes.

Functions, their over-exploitation and sustainability

It is well known that over using or exploiting a few "functions" (e.g. production function for crops or water) can lead to the damage of other ones. It is easy to deplete natural resources and degrade the capacity of the system to support other functions including that of survival. The spatial and temporal variation in the provision of functions should be incorporated in evaluations. In other words, as well as a spatial complexity, there is also a temporal dimension in land use and management.

The production functions of dryland systems reflect the inherent quality of the land itself but also fluctuations in the amount of energy and water that influence the actual productivity and the knowledge and insight of people who manage and use the land. Ideally desertification indicators should be able to monitor the collective effect of these and other factors.

Desertification relevant functions

The following table is based on research by Hein and others (Medaction 2004) in the Guadalentin catchment and illustrates desertification relevant functions.

Function	**Description**	**Potential impacts**
Regulation functions		
1. Water supply	Better groundwater availability and moisture retention, through good infiltration of rainfall	Loss of ground water resources
2. Water regulation	Lower runoff and flood risks, due to good infiltration of rainfall, or to retention of water in ecosystems.	Loss of surface water resources, and/or increased flood risks
3. Soil retention	Vegetation cover important against erosion	Increased erosion leading to loss of productive capacities of the oil and/or to sedimentation
4. Soil formation and maintenance of fertility	By litter formation and organic matter addition, or by accumulation of sediments.	Loss of resilience of ecosystems because of negative impacts on the soil formation processes
5. Carbon sequestration	Sequestration of carbon in biomass	Loss of the amount of carbon sequestered
Production functions		
6. Food supply	Production of dryland crops.	Loss of productive capacity of the land
7. Grazing	Sheep and goat grazing.	Loss of pasture quality
8. Raw material	Fibre for fabrics	.Loss of possibilities to extract raw materials
9. Genetic resources	Old cultivated varieties, or wild plant species diversity.	Loss of genetic diversity
Habitat functions		
10. Refugium	As habitat for natural species	Loss of biodiversity and nature
Information functions		
11. Recreation	Drylands may provide opportunity for tourism and recreation, including outdoor activities.	Loss of opportunities for recreation
12. Historic information.	Heritage value of traditional agricultural practices	Loss of historic information
13. Aesthetics	Valuable scenery.	Loss of scenery
14. Existence /bequest value	Desert landscapes or water resources may have special value in regions of water scarcity.	Impacts on landscapes

Desertification as loss of function

Desertification can be interpreted with respect to losses of functions. This requires a broad consideration and evaluation of the processes of change that are actually taking place in the landscape. In reality this is probably a future and challenging research task.

Land degradation and desertification manifest themselves in the disappearance or degradation of specified functions. However, there could be many reasons why functions disappear and without knowing the causality, there is no reason for assuming that desertification is the cause. Loss of function could be because of climate change, loss of biodiversity, soil erosion or even the loss of the people with the knowledge to generate the eco-services that the land might be able to provide. In the Northern Mediterranean many functions are threatened or disappearing indirectly as the result of the optimisation of other functions. Recent examples of this can be found throughout Europe where groundwater overexploitation for irrigated farming is leading to the disappearance of rivers (Cerdá 2005). Loss of rivers is also happening all of Europe, for example in southern and eastern England, which according to this criteria are thus also experiencing aridification.

Part of this challenge can be seen as a methodological problem whereby complex causes have complex effects. For example, soil erosion is a process that has been active for thousands of years, resulting in the gradual long-term transfer and movement of soil from the slopes to the river valleys and channels. Man has been the main driver of this process for perhaps ten thousand years. However, this process has not occurred continually but intermittently under specific social and climatic conditions, related for example to developments in technology. Desertification today is not concerned with this past erosion but rather how erosion today is influencing the function of a landscape that is highly heterogeneous with regard to the impact that erosion has had in the past. The resilience of an ecosystem is a key characteristic but paradoxically, the higher the degree of past degradation, the more resilient an area is likely to be and the less likely it is to experience further desertification.

The Water and Nutrient Regulation Functions of the Soil

The water and nutrient regulating functions can be deregulated by several processes. Water regulation functions require a soil medium which is able to store and retain water. This is closely related to the maintenance of soil porosity and permeability. This is in turn favoured by the agglomeration of primary particle into larger water-stable aggregates. The aggregation processes are often a consequence of biological activity of the soil and reflect the dynamics associated with the input and mineralization of organic matter.

Water-stable soil aggregation can be considered as an indicator 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.

It is for these reasons that soil structural stability is seen as a key indicator of soil quality. It reflects all of these functions that are indicative also of soil health.

In desertified areas, there is a strong chance that a decrease in some measure of the vegetal cover will be accompanied by a reduction in the amount of soil organic matter. This reduction sometimes has a direct effect on soil structure by reducing the water-stability of soil aggregates. The weakened soil aggregates break into smaller ones upon the impact of the raindrops, by slaking caused by wetting and as a result of compaction and cultivation. This can results in crust formation, sealing and in the soil having a lower infiltration rate. This degradation of the surface structure of soils may also have a negative effect on the biomass productivity of the soil by reducing water availability for plants and hampering the restoration and re-sprouting of vegetation. Thus, alterations of the water and nutrient regulation function can bring about a feedback self-accelerated mechanism that, if not arrested, accelerates land degradation.

In more arid soils the water regulating function is greatly influenced by gypsum, water soluble salts and the dispersion of clay minerals. Dispersive conditions are frequently found in soils that contain low amounts of salt but where a large proportion on this consists of sodium. The clay dispersion is a climate-sensitive process. A climatological threshold above or below which the soil will be either flocculated or dispersed has been proposed for southern Europe (Lavee et al.,1996). Where the annual precipitation is below about 400 mm yr^{-1} dispersion is the key process regulating infiltration and water storage in the soil. The areas of soil affected by dispersion vary both temporally according to the amount of rainfall and spatially, and anywhere salt accumulates in soil. The SAR (sodium adsorption ratio) and the ESP (exchangeable sodium percentage) are excellent indicators of how the soil is functioning.

Soil and Water Conservation Function

How landscapes function to regulate water at the landscape scale is important. Human activity (e.g. farming) degrades or destroys some structures and creates others. Those that are degraded are the ones formed over long periods of time through the interaction of plants and animals with the soil, as they modify their own habitats. Those that are formed could be man-made structures and terraces.

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. The degradation of water and nutrient regulation functions of soil caused by land degradation and desertification can result in an increase of runoff and erosion at coarser scales (hillslope and catchment scales) and the reduction of landscape performance for soil and water conservation.

Changes in the distribution of sediment and runoff source and sink areas are indicators of how this function is being performed (see Imeson and Prins 2004). There are changes in the size, behaviour and location of sink and sources of water and sediments on slopes in response to desertification. A general loss of soil depth usually occurs at source sites with a potential increase at accumulation sites. An increase of hydraulic connectivity between bare patches, increasing runoff volumes during extreme rainfall events is another consequence. At the catchment scale, the impact of desertification because of the loss of soil and water regulation function is a change of hydrological and erosive response, which manifests itself as higher discharge peaks and sediment loads after extreme events, and results in:

- Increasing fluvial erosion of river banks.
- Channel incisions and ephemeral gullies development resulting from heavy winter rainfalls.
- Silting up of reservoirs and other water storage structures.
- Spreading pollutants on valleys and downslope areas.

2. The DiS4Me indicators and functions

The section illustrates how the indicators in the DIS4ME system could be used for evaluating changes in desertification relevant functions.

In developing the DIS4ME Indicator system, almost two hundred indicators were selected and described. These are all actual desertification indicators relevant in a specific context. In practise the selection of a desertification indicator by an inquirer will reflect his personal aim, his understanding of the problem and the data available.

As already mentioned neither Dis4Me nor the ESA indicator methodology were explicitly structured according to functions. The ESA procedure in DIS4ME is essentially a land evaluation framework that assesses the different qualities of the soil according to measured indicators such as "soil depth" and "precipitation". A statistical framework was employed to establish critical values of indicators in areas that had different expressions of desertification.

It was assumed that compound values of indictors provide indices that can be applied throughout the target areas in which they were established but may not apply to larger regions. It has proved relatively easy to calculate the indicators according to the methodology in the target areas but elsewhere there may be only limited data available to validate and test the system. Within a functional framework it is often easier to identify one specific indicator that integrates the effect of many of the other indicators.

Bottom-up: indicators and self assessment

By definition, an indicator is a quantitative and easily measurable variable that in some way enables critical aspects of the behaviour of complex systems to be measured in a very simple way. Placing the indicator in the context of a framework that includes "quality", "health" or "function" helps the user to link the indicator to his own values and knowledge. Thus, as explained above, the soil may be thought of as performing environmental functions or services to people or society. Soil quality indicators enable soils to be evaluated in terms of the provision of these functions. The notion of health is applied by comparing the differences between soils that have had their functions degraded and those that are from healthy reference areas. This approach has recently been adopted and applied to all of the rangelands throughout the United States (Rangland Health (Pellent et.al) Bureau of Lands and Canada.

However, such indicators also enable the user to evaluate the quality or health of a location. This is done by means of evaluation scorecards that can be completed. Scorecards enable the meeting of targets to be assessed and at the same time reveal the changes that are taking place as a result of different impacts.

The Guidelines for using desertification indicators put forward by the UNCCD Committee for Science and Technology are essentially bottom-up. One of the critical requirements was that affected people should be able to measure their own indicators and apply these to their own situation, to see if the actions being taken had been effective in combating desertification. In practice, in areas suffering land degradation, intuitively people, aware of land degradation record and collect data and information that can be retrospectively used as indicators to mobilise actions.

When people have a strong relationship with the land and have a sense of place and history this brings with it an understanding of the changes that are taking place and there is no need for a debate about indicators. However, when this link is not present, indicators may be needed to make newcomers aware of changes and the responses that these require.

Top- down: Indicators for management and control

Somewhat different is the selection of indicators arising from the need to monitor and manage and evaluate improvements. This could be the actual "condition or state" of the land and environment or the "compliance" to regulations and guidelines. The cost of collecting data and information is generally perceived by policy makers as being high. There is therefore a wish for the requirement for relatively few "headline" indicators that can be used to propose targets to which policy can aim. Headline indicators should be quantitative, reliable and enjoy general acceptance. Ideal sources of such data are earth observation data, river monitoring stations, or statistical data collected by responsible authorities. Such data are published by organisations such as the EEA,
http://themes.eea.eu.int/indicators/all_factsheets_box .
These are invariably explained in terms of functions.

The DPSIR framework and functions

Environmental issues are being evaluated using the DPSIR approach which has elements of a kind of systems framework. This is helpful because it links the effects (impacts) to the causes (pressures and drivers) as well as to the solutions (responses). It is very convenient for agencies or organisations such as the OESO and the Environmental Agency who need to report on the state of the environment. The framework is good for identifying problems but it is not a good basis for classifying indicators nor for selecting indicators for monitoring.
It is a poor system as it is hard to move from the abstract to the concrete (for more details see Imeson 2005). The most appropriate indicators for a specific situation depend on the scale and context of the specific case as well as on the moment in time. An indicator that is appropriate in 1995, might be irrelevant ten years later.

The UN Sustainable Development programme found that it was much more effective to focus on issues. The initial analysis should be in relation to the concerns expressed by people. In real situations when the causes of desertification are obvious the DPSIR checklist may be extremely useful and valuable for drawing attention to cause and effect.

Desertification and global scale functions

At this moment perhaps the most serious desertification and erosion problems in the world are occurring outside of Europe in Asia, notably northern China, and in Amazonia as the result of the spread of agriculture production for consumers in the EU and China. or in China as a result of desertification. A few years earlier there were big desertification problems in Vietnam as a result of the expansion of coffee production into former rain forest areas. To avoid disasters such as these what needs to be monitored is the way in which the economic system is function and linked to the environment. It is apparent that at the world scale, sustainability threatened because there are no criteria of sustainability that are used to assess and evaluate the complex impacts of economic development. The GEF sustainable land management programme is responsible for providing the resources to implement the UNCCD in developing countries and recognises this (GEF 2002). The guidelines for supporting projects recognise one main problem as being the lack of organisation and integration of measures to combat desertification into other policies and programmes. Administrations must function in a way that allows sustainable land use to take place. The need for indicators in this case is demonstrated by the support of the LADA programme.

Headline issues and functions in the context of desertification

This section attempts to combine indicators on the basis of clusters of environmental functions which are referred to as headline issues. In this sense they may help in the adoption of headline indicators.

The main environmental functions can be clustered as:

a) Productivity and energy
b) Water provision and regulation
c) Habitat function
d) Social and Cultural needs

These headline issues have been matched against all of the indicators available in the DIS4ME system and elsewhere in relation to the following questions:

Function	**Supply**	**Requirement**	**Provision of service (examples)**
Production and productivity	Growth Production	Income Services	Abandonment and land use change Loss of productive area Benefits of services
Water	Water supply	Consumption	Abandonment Loss of production Land use change
Habitat	Air water and soil quality	Good and safe eco-services	Air, water and soil quality Heat and water
Social and Cultural needs	Provision of services	Services	Migration Disappearance of services

3.1. The Production function and its provision

The headline issue here concerns the degree to which the goods and services, in the form of food and materials produced by the land are being met. In China, the human carrying capacity of the land has been recently proposed as an indicator of this (Komatsu (2005). When this capacity is exceeded this implies that the land is not being used sustainably so that the provision of services will decrease and people forced to migrate. Concepts such as carrying capacity work in ecological systems but they do not work with people unless applied in a very complex way due to the complications of factors such as trade, other sources of income and subsidies.

3.2 The Water provision and requirement function

<u>Water Provision</u>

Many of the DIS4ME indicators relate to this function (for example disappearance of springs groundwater depth, ground water recharge, duration of zero flow in rivers). All of these indicators are closely and obviously interconnected and are better indicators than those of production. The strong correlation between well levels, spring discharge and delayed flow has been explained and modelled by hydrologists and hydro-geologists for more than a century. In simple hydro-geological situations, changes in the depth of groundwater depth cause an increased head of pressure in an aquifer that causes an increase in discharge at a spring. Groundwater recharge occurs when the amount of rainfall is such that it is enough to infiltrate through the soil and percolate to the groundwater. Percolation may occur very slowly though pores or rapidly along preferential joints or cracks in the rock. When percolating water reaches the groundwater, the water-table rises so that there is a change in groundwater depth. This rise also leads to a rise in the ground water level in valley bottoms or depressions where springs might reappear and rivers might flow again.
Springs can occur where the groundwater table intersects the surface. The disappearance of springs means that there has been less groundwater recharge or increased groundwater withdrawal. The duration of zero flow in rivers has been used as an indicator of water resource availability in Northern China. The disappearance of springs is a long-term indicator and use can be made of old maps or records. Maybe by comparing different areas it is possible to separate disappearance resulting from different causes. Groundwater depth can be recorded easily from well records or logs. Groundwater recharge can be observed from changes in the level of wells. However, since well levels reflect the balance between recharge and withdrawal, it is better to have an independent indicator. A simple indicator could be obtained by the very simple Thornthwaite Water Balance Method that enables the recharge to be calculated on a monthly basis. The annual range in temperature of spring water can be used to indicate the depth of water. The-water quality of springs indicates if the water is in equilibrium for example with carbonate, bicarbonate, and gypsum and if there are water soluble salts present that constitutes a risk of salt accumulation. The SARp (sodium adsorption ratio) value is a good indicator of quality, as are concentrations of nitrates and phosphorous.

Meeting water needs

The above indicators can be linked to the critical water requirements of individuals or communities. These can relate to the threshold above which some service is lost (e.g. no longer possible to irrigate maize; there is a need to import drinking water or keystone fish species are no longer present. In some cases loss of water can result in loss of livelihoods and this is particularly the case for industry and agriculture. In other cases they may result in the adoption of water saving strategies and in new technology. Trends in a decreasing availability of water are recorded in all kinds of statistics. In fact these may also be the impact and the response indicators of the DPSIR framework. Water is a highly political issue so that indicators are affected by efforts made by governments to alleviate the hardship that a reduction in the supply of water causes. These can be in the form of subsidies or involve investments in infrastructure that enable water to be imported from other regions. Such indicators are also included in DIS4ME.

Habitat function

Provision of habitat function

The concept of a "habitat" function is useful but complex in relation to quantification. How the soil and land function as a habitat and how this is affected by desertification is organism and ecosystem specific. Air, water and soil quality are central. For example, as a result of desertification there could be less evaporative cooling of the surface soil, more soil erosion and more dust. Heat waves and deaths, particularly in urban areas, maybe indirect impacts of desertification. Desertification in particular leads to a deterioration in water quality as there is much less water in rivers. The summer discharge of many rivers in Europe is often mostly return flow and effluent.

Another issue is biodiversity. In the USA, (de 98)) desertification is especially seen as the biological degr Soyza, A. G., W. G. Whitford, et al. (19adation of the environment. Loss of keystone species (such as the Kanagaroo rat in the Chejuanan desert .
In order to improve the habitat function, one societal response is forestation. Another is the implementation of soil and water conservation measures or the training of scientists and technicians to tackle the problems.

In Europe, loss of habitat is not so much driven by climate but by subsidies and modern agriculture that decrease the amount of energy moving through the ecosystems that is not used by man. Urbanisation and industrialisation also results in loss of habitat, partly through the impact of sealing.

Amongst the different types of indicator that can be used (see deliverable on indicator concepts) these are those that describe soil quality and those that relate to ecosystem health.

Social and Cultural functions

The landscape fulfils the psychological and social needs of the inhabitants. Many surveys have shown that people consider desertification principally as social desertification (Lauro 2005). The quality of life in desertification threatened rural areas is perceived and experienced as harsh. Life in cities has more to offer so people move to be near them. The movement of people to cities is not always attributable to desertification but nevertheless it is associated with land abandonment and land degradation. The main argument is that the functions that people aspire to are not present in the areas they leave. Farmers in rural areas find it no simple matter to find partners unless they are immigrants seeking a new life and bringing a partner. Of course in many areas tourism is allowing the rebirth of many rural is functions in rural areas, as are intervention schemes and agro-environmental measures. Land Abandonment is seen as an important indicator of desertification. Land abandonment means that the land is no longer able to meet the socio-psychological or economic production functions that the former inhabits required. This may have nothing to do with the land itself but simply reflect an increased perception of and ability to respond to better choices elsewhere. The degree to which these functions are being provided is easy to assess by quantifying the infrastructure and provision of services (schools, road density and quality, banks, subsidies, hotel and tourist facilities etc.).

The example of the water availability function as a means of integration

Functions can be used to integrate the indicators in Dis4me.
This will be demonstrated by applying the framework of functions to the water issue.

A drainage basin, area or region would have been providing its inhabitants with water resources in different ways for many decades or centuries. Within the context of the ecological and environmental functions, being provided by the landscape the main fear will be that there is or will be less water available to support all of the water related functions (e.g. irrigation, domestic use, fishing and industry) to which people are accustomed or adapted.

DIS4ME lists under different categories at least the following indicators that are relevant to the water issue. How can we condense these or chose between them?

Climate	**Water**	**Economic Water use**	**Runoff**
Aridity index (1) Aridity index (2) Climate quality index Drought Drought index Effective precipitation Potential evapotranspiration Rainfall Rainfall erosivity Rainfall seasonality Rainfall spatial distribution Air temperature Wind speed	Disappearance of water springs Groundwater depth Ground water recharge Water quality	Aquifer over exploitation External water resources Groundwater exploitation Irrigated area Irrigation intensity and seawater intrusion Irrigation percentage of arable land Irrigation potential realised Pumping/recharge ratio in groundwater Runoff water storage Water consumption by sector Water leakage Wastewater recycling Water scarcity Water availability	Area of impervious surface Dam sedimentation Drainage network density Flooding frequency Flood-plain and channel morphology Rainfall-runoff relationship River discharge Soil permeability

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Water Availability

From a hydrological perspective it is clear that nearly all of the indicators in Table 1 are functionally linked at different scales in the hydrological cycle and the water balance equation. This means that to a great degree the choice may be irrelevant as most things are related anyway.

The term “available water” has a long history in hydrology as meaning the water that is available for plant growth or consumption. A major hydrological challenge has always been in quantifying or estimating the actual amount of evaporation in order to know how much water is available for different uses or functions.

Duration of low or no river flows

A good indicator is one that expresses availability in terms of the ratio between demand and supply. For example, as mentioned, the increase in the duration of the period (days) with no river flow is an indicator used for water availability in China. This shows the ability of the river to function as a river and summarizes many things. It is easier to measure than any of the rainfall, evaporation and groundwater indicators.

There are many records of river flow that can be used for this purpose. These include both measured data and remotely sensed data. Each user of this indicator will have different threshold values that are important to him according to his function of interest. This could range from the use of the river for irrigation, canoeing, fishing or dilution of effluents.

Critical water availability for crops

Water availability for crops is another area where vast amounts of data and information are available for calculating indicators. On the one hand there is the amount of available water which can simply be calculated using Thornthwaites method developed more than half a century ago. A water balance diagram can be drawn from monthly rainfall data and potential evaporation calculations for which only monthly or weekly rainfall and temperature data are needed. Available water (provided by the soil and rainfall) can them be linked to the critical water requirements or consumptive demand of crops or with the amount of water needed for domestic use. As with river data, each person will have his own function for which he will be interested in function specific threshold values. Typical questions might be "Is there enough water to irrigate an area without promoting salinisation? Is there enough water for wheat production? And "How much groundwater recharge will there be to compensate for the pumping of groundwater"

Conclusions

The use of functions has many benefits and is gaining ground. Two main advantages are that they enable totally different areas to be compared and that they provide a means of integrating socio-economic and bio-physical knowledge and understanding.
This deliverable looked at two rather distinct questions:

- How does degradation affect the functioning of a landscape or ecosystem?. The system was considered to have the function of regulating fluxes of water and soil in such a way that the system can maintain itself against the driving forces of land degradation.
- How desertification affects the provision of functions by the landscape? The water provision function was found to be very useful for expressing the integrated effects of desertification on an area. Water availability is a good indicator and this can be calculated from readily available meterorological and hydrological data that are readily available.

It was also concluded that problems arise when the multiple functions of landscapes are not appreciated. Over optimalisation for one function is often at the expense of other functions. Balancing different functions requires negotiation between the experts who understand them.

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