Remote sensing techniques for monitoring desertification

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Introduction

The existing assessments of the global extent of land degradation all have major weaknesses, and although European Research has already produced substantial advances in this field, the shortcomings of available assessments point to the need for a systematic and standardised approach. Large collections of desertification indicators have been provided, and the integrated use of satellite-based remote sensing with ground-based observations and spatial data can provide consistent, repeatable, cost-effective information on vegetation cover and other surface properties relevant to desertification. Continuity of observations (long-term monitoring) is required to account for the high inter-annual variability of dryland ecosystem services, and to distinguish between the role of human actions and climate variability in vegetation productivity. Valid interpretation of remote sensing imagery for desertification requires careful calibration and validation against ground measurements (such as vegetation cover, biological productivity, evapotranspiration, soil fertility, and compaction and erosion rates).

The introductory section shortly summarizes a general view on land degradation and desertification dynamics; starting from the generally accepted definitions of the problem we shall try to explain degradation syndromes that have an impact on land surface conditions which may cause a reduction in its capacity to deliver goods and services (e.g. erosion, disturbance of the water cycle, deforestation, etc.). Starting from this summary it will be demonstrated that efficient efforts in mitigating and preventing desertification will depend on precise and unbiased information on the extent of affected areas and their development in time. This includes spatially explicit maps on land use, bio-physical vegetation and soil parameters and their changes over time. Given the global dimension of the desertification problem and the diversity of its syndromes, it is evident that remote sensing systems have a high importance in this task. Therefore, and with regard to the global extension of the problem it is clear that improving available assessment, monitoring and early warning strategies will remain one of the most important challenges also in the future (Hill, 2006).

The Impact of Desertification Processes on Changing Land Surface Properties

It is widely agreed that environmental change in arid, semi-arid and dry sub-humid ecosystems is not necessarily driven by climatic variables but through processes which result from adverse human impact on these fragile ecosystems. It must be demonstrated how bio-physical properties of land surfaces are altered under the impact of these process domains (desertification syndromes), i.e. by changing land use systems, loss of vegetation cover, changed vegetation properties (pigment and water content, canopy LAI), modified soil properties (surface crusting, biotic crusts, truncated profiles, salinisation). Also the productivity of dryland systems largely depends on these surface properties. Since they control water redistribution and availability, the spontaneous emergence and development of new plants and dust production during wind storms, changing surface properties as a consequence of environmental change might easily exceed the impact of climatic effects. The

physical properties of the Earth surface in turn provoke specific effects when interacting with electromagnetic radiation of different frequencies: this is the primary source of information for using remote sensing systems.

Remote Sensing Principles and Remote Observation Systems

Remote sensing is commonly introduced as the science to collect information about objects without coming into physical contact with it; in earth observation the most important medium to transmit this information is electromagnetic radiation in the optical and microwave region.

Here, it will be attempted to treat remote sensing assessments of arid and semi-arid ecosystems as a continuous process which includes aspects of energy-matter-interaction, radiation propagation, sensor characteristics and image processing. In this context the most important categories of remote sensing (RS) systems will be presented by which Earth surface characteristics can be observed and measured. Past and present RS systems group in functional types according to their spatial/spectral resolution capacities and revisit capabilities (high or low frequency observation systems), and available satellite archives will be presented which form the basis for the identification of long-term ecosystem dynamics.

The chapter will also include a short introduction into concepts and methods for interpreting remote sensing data and for converting them into useful data products. Particular emphasis will be given to the issue of spatial and temporal scales (global dynamics vs. local process assessment), and to the special sensorial and conceptual requirements for monitoring land surface dynamics in time.

The Global Perspective and Regional Degradation Dynamics

A particularly important issue in assessing and monitoring desertification is connecting the global dimension to regional and local processes. We shall introduce a strategy which is based on connecting the analysis of data archives from global observation systems (spatial scale 1 km, temporal coverage 1985-today) with less frequent, but spatially and spectrally more detailed observations from earth observation satellites (spatial scale 10-30 m). While the first will allow identifying regions where land surface characteristics have changed during time into more critical or eventually more favourable conditions (here termed hot spots), the latter can be used to unveil the underlying processes on a more detailed spatial scale.

On a European scale, the results of analysing a calibrated time series of 1-km-NOAA-AVHRR data over the Mediterranean basin suggest that environmental change over the past 15 years is primarily characterised by increasing vegetative cover within agricultural and semi-natural ecosystems, owing to intensification and irrigation on one hand, and the widespread land abandonment which has already started many decades ago on the other. This provides strong evidence for the socio-economic drivers of environmental change in the Mediterranean which trigger substantial changes of the hydrological cycle, shrub encroachment and increasing wildfire risks, as well as an accelerated depletion of ground water resources.

The Detailed View: Processes on Regional to Local Level

Earth observation satellites with high spatial resolution and enhanced spectral observation capabilities can be used for quantitatively mapping bio-physical vegetation parameters and soil characteristics and, if sufficiently frequent observations are available, for identifying their variability in time. Remote sensing thus allows both analysing and following the state of the environment and of available resources, and combining this information with land use and land use change maps derived from satellite imagery as well This unique capacity provides an important link to the socio-economic framework of desertification, such that remote sensing

information can be used to determine desertification factors, support decision-making in defining relevant measures for environmental restoration and management.

Perspectives

Understanding the impacts of desertification on human well-being requires that the knowledge of the interactions between socioeconomic factors and ecosystem conditions are improved. Advanced concepts aim at producing a representation capable of integrating physical, ecological and socio-economic processes at a high level of abstraction, so that an application is possible to member states of the European Communities as well as non-European regions. This would be a major step to support designing and evaluating strategies aimed at lowering the threats for desertification and degradation in affected areas. Needless to say that such approach must to be complimented by an adequate spatial information infrastructure.

References and Glossary

Hill, J., 2006, Desertification: regional assessment and monitoring strategies for a global problem, in: C. Brüning and E. Lipiatou, eds., Climate Change Research Challenges, Climate Change and Natural Hazards series, 5, EUR 22042, (Luxembourg: Office for Official Publications of the European Communities), 60-66.