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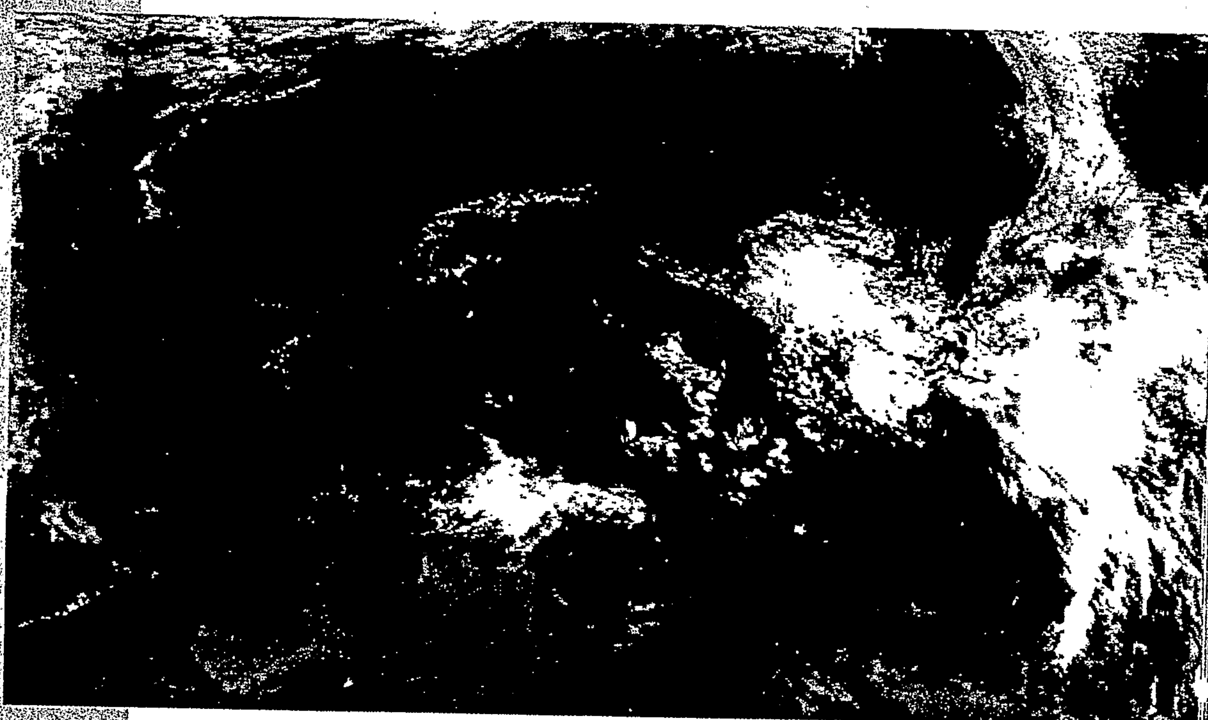
L'OBSERVATION SPATIALE : UN OUTIL POUR L'ETUDE DU BASSIN MEDITERRANEEN

INTERNATIONAL SYMPOSIUM

SATELLITE-BASED OBSERVATION: A TOOL FOR THE STUDY OF THE MEDITERRANEAN BASIN



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CAMELEO : A CONCERTED RESEARCH EFFORT TO DEVELOP VALIDATED DESERTIFICATION MONITORING TECHNIQUES IN NORTHERN AFRICA

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RESUME - Le projet CAMELEO a pour objectif la mise au point d'une méthode de suivi de l'état des milieux arides de la rive Sud de la Méditerranée, qui prenne en compte l'ensemble des mesures disponibles sur les quatre observatoires étudiés. La démarche ascendante suivie intègre les observations de terrain et les données satellitales à haute et moyenne résolutions spatiales. Entrepris en 1998, ce projet doit conduire 12 institutions du nord et du sud à proposer à la fin 2000 une approche concertée capable de fournir des indicateurs opérationnel de niveau de désertification, qui soient précis au niveau des zones tests et recadrés dans le contexte régional. Cette communication présente les grands axes de recherche de ce projet qui a reçu le soutien de la de la Commission Européenne (DGXII).

ABSTRACT - The objective of the CAMELEO project is to develop a comprehensive method for monitoring desertification in the south of the Mediterranean basin, which integrates all available data on the four studied ecological observatories. The bottom-up approach will include data collected on the ground as well as data acquired by various Earth Observation programmes. Undertaken in 1998 this project will bring until 2000 twelve institutions together towards a concerted method providing reliable desertification indicators, bringing both precise diagnosis at local level and a regional vision. This paper describes the main research axis of this project supported by the European Commission (DGXII).

1. RATIONALE: THE NEED FOR RELIABLE DESERTIFICATION MONITORING TOOLS IN NORTHERN AFRICA

In the Mediterranean basin the countries of the southern shore are the most severely affected by «desertification » because of their inherent ecological fragility and of a high population growth, as recently confirmed by UNEP reports. However big efforts, particularly at national level, have been undertaken to combat desertification with some spectacular recoveries of degraded areas after restoration efforts (e.g. in Southern Tunisia, see Floret et al., 1992), but a strategy is needed to address the problem in a more comprehensive way.
An important international effort towards more co-ordinated actions for arid land degradation prevention has been impulsed by the Convention to Combat Desertification (CCD), signed by most of the countries affected, and specifically all the countries participating in the current project. Research is still under progress concerning the analysis of causes and mechanism of desertification (see the numerous presentations on this topic in the present conference).

As stressed in the UN report (UN-CCD, 1994) accurate hard data to assess the degree and the rate of desertification is still a most urgently needed information. Despite significant local results, monitoring of changes in arid landscapes remains often an effort of small research teams, limited in time and space. Decision-makers are still waiting for tools to provide a clear and wide picture of ecological changes at national and regional levels, with the necessary long-term perspective to assess the results of past actions and to define future strategies. With a consortium gathering twelve experienced institutions and using the network of existing ground ecological observatories in Morocco, Algeria, Tunisia and Egypt (ROSELT concept, OSS, 1997) this project takes up the challenges of bringing an answer to these needs.

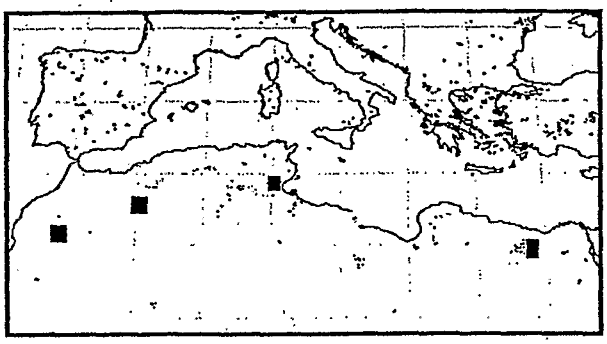


Figure 1. Situation map of the four test areas (observatories) of the CAMELEO project

2. DEFINING THE PARAMETERS TO BE MONITORED FROM SPACE

Although remote sensing is recognised as a unique source of information for environmental watch, this technique as not yet fulfilled the regional desertification assessment and monitoring needs. Satellites with continental view used in many climate change research programmes have a too coarse resolution to provide information for land management. Suited to follow large seasonal fluctuations of green vegetation, they are inefficient in detecting patchy degradation of non-green steppe largely dominant in the northern fringe of the Sahara. At the opposite, high-resolution data have been used for local studies and practically each country/team has developed its own methods, not always precisely related to ground data and leading to results difficult to compare. In the approach selected we have chosen to start from the ground, to determine first what are the surface features which are both significant from the desertification point of view and likely to be remotely sensed.

2.1. Particularities of steppic ecosystems

Besides the man made structures of the urbanised areas, the land surface is made of rocks, soils and plants. The major parts of the studied surfaces are characterised by a steppe with scarce shrub vegetation. Locally, fields and fallow land tend to gain extension for the cultivation of rain-fed cereals. Thus, soils are dominant at the land surface, the vegetation cover is low (below 30%), and usually green only during a short period following rainfall events.

2.2.Spectral reflectance of arid soils and plants

Previous studies done by teams of the project have shown the variability of arid soil and plant spectral properties. Different surface components have been subjected to laboratory and field measurements in the wavelength domain covered by the satellites used. Portable radiometers and spectroradiometers have been proven very efficient tools (Escadafal and al.1993) and will be used intensively in the project to study the spectral features of the main ecosystems and of their various

degradation states. Each observation will be carefully documented following the procedures recently summarised in workshop of the project and precisely geo-referenced with GPS receivers.
A database allowing handling the large amount of information recorded in the ground has already been developed for other test sites, it will be extended to this project. Thus, the selection of the spectral features to be remotely sensed and the radiometric calibration of images will be tremendously facilitated (see Bohbot et al., this conference, for a description of the database structure).
The results already obtained (Escadafal et al., 1996) show that whereas steppic vegetation in dry condition is generally spectrally 'flat', soils vary widely in brightness and colour. As they form the major component of these surfaces when viewed from above (like the satellites do), the potential application of these features will be fully explored during the project, soil changes such as sand movement may particularly indicate longer term trends (Escadafal et al., 1997). The collection of individual spectra of plant and soil samples will also be used for remote sensing of soil and vegetation composition (green and dry) at sub-pixel level with the spectral mixture analysis techniques already successfully used in other Mediterranean landscapes (see Hill et al., 1995, and Sommer et al., this conference).

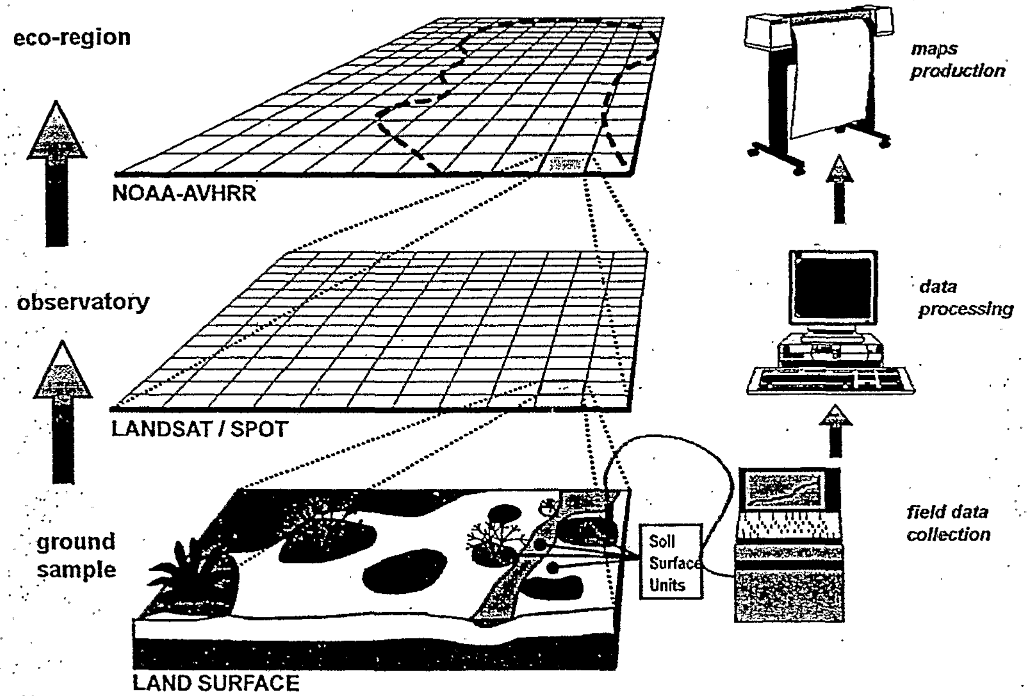


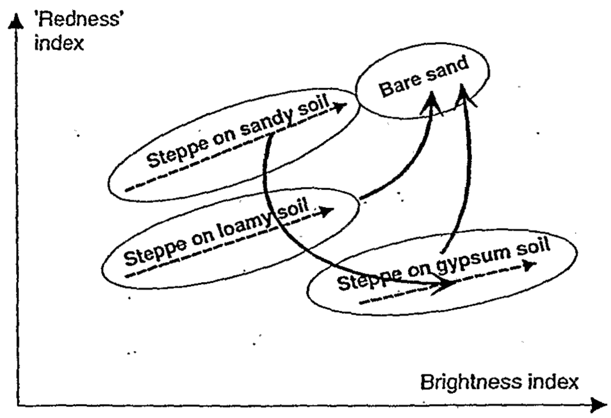
Figure 2. Global scheme of the bottom-up approach used and associated techniques

3. APPLICATION TO LOCAL ECOLOGICAL CHANGES DETECTION

The links, established in the first phase, between the land surface degradation features and their spectral properties will then be applied to satellite data to characterise *local changes*. As opposed to global changes, local changes are documented at much higher resolution for operational use and require data from satellites such as Landsat and Spot. The rationale for the study of the surface optical properties discussed above appears clearly here, only data from optical sensors will allow both high spatial resolution and long term studies.

Indeed, parameters retrieved from one satellite imagery are most of the time insufficient by themselves to derive information on land condition. Soil colour for instance is not in itself linked to soil degradation. However, in a known ground context, changes in soil surface colour can be a strong indication of degradation. Similarly, brightness is a relevant information on scrubby vegetation cover when considering brightness changes in a context where other parameters are stable (illumination angles, atmosphere, soils). Therefore, for the assessment of desertification we need to be able to detect changes.
Between images recorded at different dates over the same area, many variables can interfere (Bowker & Davis, 1992) such as the sensor properties, the atmospheric effects (optical thickness), and the geometry of the measure (sun elevation, sensor viewing angle). All of them may alter the information we are looking for: the modification of the ground target properties. Several physical models have been developed to take into account these different effects (Tanré et al., 1990). But they require data on sensor calibration and atmosphere composition that are difficult to obtain over the studied areas and out of reach for images recorded several years ago. To get round this difficulty the approach based on "pseudo-invariant areas" (see Caselles et al. 1989, and application by Delaitre & Escadafal, this conference).

From reflectance data at two different dates simple change detection is obtained by computing absolute differences channel by channel. Indices are also less sensitive to atmospheric effects and as an example over the Tunisian test site of Menzel Habib, the redness index has been found to decrease with increasing desertification level, due to the exposition of less coloured soil material after erosion. (Escadafal et al., 1994). Strictly, this simplified rule is applicable only to the studied soils and soil surface colour decrease cannot be considered a universal desertification index. However, in arid regions many degradation or restoration phenomenon are affecting the aspect of the soil surface, including colour (e.g. salinisation, alluvial deposits, erosion of the topsoil,..). Thus, colour changes are an important information derived from satellite, the ecological meaning of it can only be inferred with the input of ground expertise (Escadafal, 1996). To be able to interpret changes of satellite derived indices values, they have to be discussed in the context of ecosystem dynamics (see Aronson et al., 1993) as sketched on fig.3.



Legend :
Changes in satellite derived indices are easily interpreted when linked to known ecological phenomena
Within each soil type, dotted lines correspond to a diminution of the vegetation cover.
Soil degradation occurs when healthy sandy soils are eroded, or when soils are covered by mobile sand dunes (solid lines). Most of these degradation patterns can be reversed through restoration.

Figure 3. Scheme of ecological change in remote sensing data space over the Tunisian test site

An essential step in comparing data from two images on the same area is a careful geographic registration. Only an error better than one pixel was found to allow to compute changes witho artefacts (pixels recorded over different targets erroneously attributed to the same one).

This technique gives acceptable results with images which are not too strongly affected by atmospheric and geometric effects. Particularly, under these latitudes the solar elevation varies significantly along the seasons. To avoid changes only due to shadow modification, whenever possible, comparisons will be made between images recorded under similar sun elevation angles.
Over each test site an effort will be made to collect the longest time series of Landsat data possible to apply local change detection also to *historical data* in an attempt to rebuild the history of each site during the last 24 years. Considering the large inter-annual climatic fluctuations we believe that only such a long time span study may detect real desertification/recovery trends.

4. REACHING THE REGIONAL DIMENSION

Pursuing our bottom-up approach beyond the local change study phase, each of the test area will be replaced in its regional context by using medium resolution data covering in full the southern shore of the Mediterranean. Clustering NOAA-AVHRR data and the identification of the optimum number of classes (by parametric and non-parametric statistics; Maselli et al., 1996) will give a first classification into Ecologically Homogeneous Zones. Then seasonal monitoring of each of these zones will be obtained through extraction of monthly averages, regression analysis with respect to time for the identification of possible trends and correlation analysis with meteorological and other data for the identification of environmental relationships. An integrated regional GIS (based on commercial and specific programmes written in-house) will then allow the inter-comparison of high and low resolution data and a final analysis for production of output materials (cartography, tables,...) This integration will allow to combine local changes monitoring with the regional vision.

5. FINAL PHASE: INTERFACE WITH SOCIO-ECONOMICS AND VALIDATON

The human dimension part of the project will first concentrate on a case study in Tunisia, where a research program is currently undergoing (Picouet, 1994). Socio-economic data are collected in the field from farm to administrative levels, while taking care of localising these parameters as much as possible in the environment (farm location, eco-climatic conditions, and agronomic background). From the inventory phase the selected relevant variables will be inputted in the database. Then techniques usable within the GIS will be tested to merge data on observed ecological changes with data on human aspects of environmental changes. This will requires the conceptualisation of the relationships between the two type of data and a then the implementation in a same system.
The soundness of the integrated approach developed relies on the *validation* made at each step from ground ecological parameters to radiometric properties, from ground radiometric properties to high resolution imagery and finally from high to low resolution data. In addition, at different steps of the project, the results on land degradation features detected at various scales will be discussed with end users, to better tailor the products to their needs. The concerted effort based on study sites in four different countries will here bring the generalisation needed for a truly regional view.

6. CONCLUSION AND LINKS WITH OTHER PROJECTS

Through the integration and co-ordination of data collection, exchange and analysis and strengthening of scientific capabilities, it will develop operational assessment and continuous monitoring of desertification. This is in full agreement with the recommendations of CCD, particularly of the article 10 on the national action programmes. The project results will allow comparison of arid zones condition in Northern Africa and critical analysis of important figures : areas affected by degradation, area protected, area under recovery,.... In conjunction with the other research efforts ongoing to design land degradation monitoring tools on the northern shore (described elsewhere in this conference), this project should contribute to a better strategic vision for environmental policies at national levels and in the Mediterranean basin.

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