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Land Degradation Assessment in Mediterranean Europe

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Abstract

Due to the LADAMER time schedule information products have until now mainly been delivered from WP2 (Geoinformatics and remote sensing data analysis) and WP4 (Land use change modelling). Besides, preliminary information products of WP6 (Dissemination and end-user integration) have been prepared. Since this report is at a very early stage, WP5 (Validation and methodological refinement), which are in still in a conceptional project phase, will only present first preliminary information products at the end of the year.

Maps of vegetation trends derived from NOAA-AHVRR time series analysis on different resolutions (8km / 1 km) have been produced and preliminary results of detection of hot spots of land degradation are available. These information products can support decision makers on EU and national level to receive an overview about changes in vegetation cover and risky areas regarding land degradation. Regarding the interpretation of trends and hot-spots, it is important to take into consideration thematic layers like maps of land cover. Since only Corine Land Cover 1990 is available at the moment, a multi temporal land cover classification was started on the 1 km NOAA AVHRR MEDOKADS data. In this way two comparable land cover maps will be created of two different dates (1990 and 1998) which allow to infer vegetation trends in relation to land use changes.

Procedures for assessing changes in land use triggered by socio-economic conditions have been partly set up, since these may both cause but also be the result of land degradation. These processes are to be integrated into a single assessment model of the physical, ecological and socio-economic dimension of land degradation, which will be applied to the Western Mediterranean. On the basis of a constrained cellular automata representation, the development of an integrated land use model representing land use changes in the linked socio-economic, ecological and physical systems is ongoing. The processes will be represented at a high level of abstraction and the model will operate at two coupled geographical levels.

The identification of main stakeholders in the context of Land Degradation Management and Assessment, both at the National, EU and Global levels is on the way. So far an extensive list of potential end-users of LADAMER products in Portugal is available, which are now being integrated into schemes, providing information on their functions and hierarchic relationships.

The acquisition of satellite and ancillary data for LADAMER has been more time-consuming than expected, mainly due to problems with administrations in charge of most of ancillary data such as digital elevation models, soil data base, statistical data etc. The European Soil Data Base is still not available to the LADAMER project due to national restrictions in distributing this essential data set. Data sets which have already been paid for by the European tax payers (statistical data) had to be obtained from institutions (EUROSTATS) at high costs, with corresponding implications for the LADAMER project budget.

Obstacles are mainly due to data availability and data quality. Most of the occurred problems had been solved based on additional data sources and pre-processing steps. Besides, internal co-operation between the partners allowed the solution of the prevailing remaining problems. Therefore, at the present stage LADAMER is well on schedule.

Information product

WP2 - Geoinformatics and remote sensing data analysis

Important milestones of WP2 (Geoinformatics and remote sensing data analysis) are the assessment of vegetation trend-classes based on NOAA-AVHRR time series analysis and the detection of hot-spots of land degradation. These tasks require longer time-series of small-scale satellite images. These coarse resolution datasets offer the possibility to monitor large areas like the Mediterranean over a long time period with a high temporal resolution.

The methodological procedures were developed based on the 8 km NOAA AVHRR Pathfinder dataset, which covers a time period from 1981 to 2002. Subsequently, these procedures were implemented using the 1 km NOAA AVHRR MEDOKADS dataset encompassing a shorter time-period (1989-2002).

The most important information layers derived from the implemented time series analysis procedures are maps of vegetation trends and their significance (fig. 1). Out of these results hot spots of land degradation are detected. A further interpretation of these products needs to incorporate thematic layers like for example the Corine Land Cover Classification.

The provided maps can support decision makers on EU and national level to obtain an overview which regions in the Mediterranean are concerned by changes in vegetation cover, positive as well as negative. Especially regarding negative trends, investigations have to be carried out which developments or incidents caused the detected vegetation changes, which are responsible for the identified hot spots. If these changes are anthropogenic and lead to land degradation, considerations have to be made in which regions new policies have to be implemented to avoid a proceeding of land degradation.

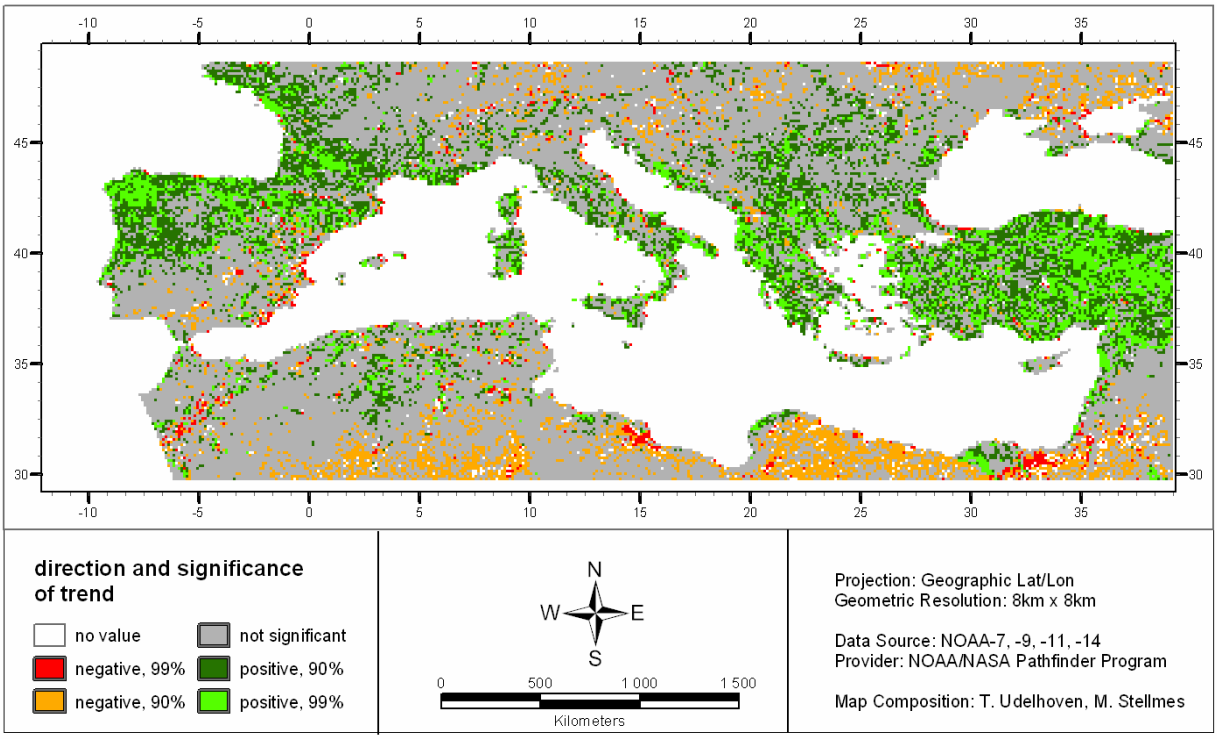


Figure 1: Trends of vegetation cover derived from NOAA AVHRR Pathfinder time series (1989-1999).

A closer examination of the hot spots regarding the land use can be used as a basis for regional decision-makers and planners in land management to judge if a land cover is appropriate for a region or if measures have to be taken to counterbalance inappropriate developments in land use.

WP3 - Land degradation modelling

Two major objectives for WP3 are: 1) the ecologically-sound assessment of the current land condition in Mediterranean Europe, and 2) the modelling and prediction of changes in land condition over time given the current condition and different types of future land use. In the reporting period we have focused on the first objective.

An existing procedure for the assessment of dryland degradation status at the landscape scale (Boer, 1999), has been revised and adapted to a sub-continental study area and coarse resolution (i.e. 8 km) input data. The proposed procedure quantifies dryland condition in terms of the land's capacity to retain and utilise local water resources. The land condition index (LCI, see Fig. 2) is calculated from the deviation between the modelled climatic maximum sustainable vegetation density (V_{max}) and the actually observed vegetation density (V). Time-integrated NDVI (TINDVI), calculated from 60 monthly NOAA Pathfinder images covering five hydrological years (i.e. Sep. 1996-Aug.2001), is used as an indicator of V. A regional regression model for the prediction of V_{max} is built from a selection of reference sites that represent maximum TINDVI for given climate conditions and soil water holding capacity.

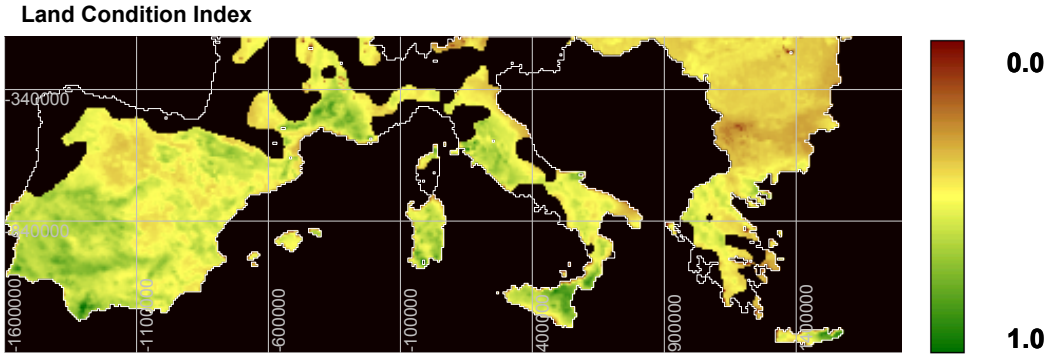


Figure 2: Land Condition Index for all grid cells with aridity index[1] greater than 1.0.

The Land Condition Index quantifies the fraction of the actual and maximum amount of plant available soil water that is retained and utilised on site by the current vegetation mass. According to this criterion, much of Mediterranean Europe is currently in rather poor condition (Fig. 3). A preliminary interpretation showed that low LCI values are especially frequent in areas of rainfed agriculture.

[1] Aridity index: ratio of mean annual potential evapotranspiration and precipitation (Budyko, M. I., 1974. Climate and life. - Academic Press)

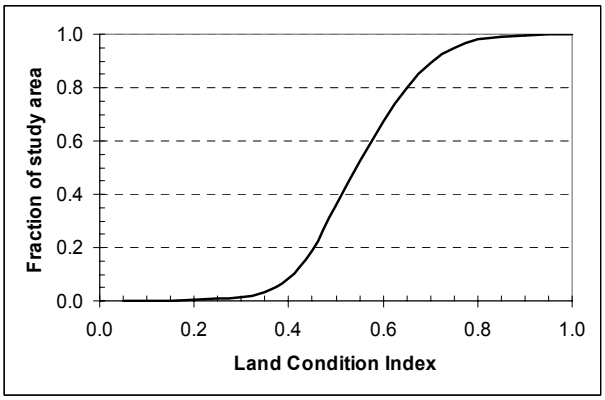


Figure 3: Distribution of the Land Condition Index in the moisture-stressed environments of Mediterranean Europe.

WP4 - Land use change modelling

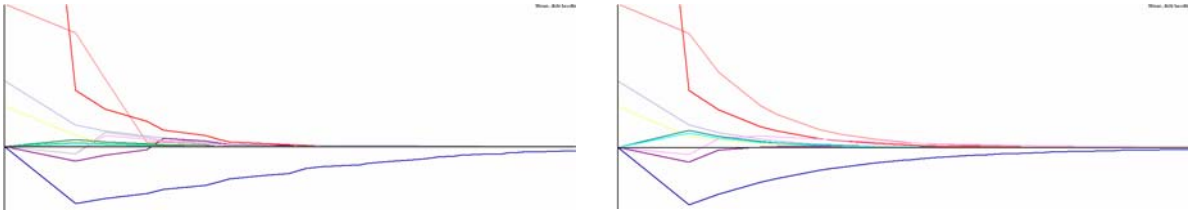
Forthcoming deliverables for Ladamer WP4 (Land use change modelling) of major importance are D4.1 and D4.2. These are foreseen for delivery in month 16 of the project and involve a *Strategy paper on integrated land degradation modelling* and an *Integrated land degradation assessment tool.* Efforts supporting these deliverables are progressing, which is reflected in a range of information products.

Information products take several forms in this work package. There are (draft) documents reflecting research in progress, furthermore Model Building Blocks (MBB's) have been produced. MBB's are calculation modules that can be used from within the Geonamica development environment. Apart from MBB's some experimental versions of models have been implemented as MS Excel spreadsheets and Mathematica Notebooks.

A literature review has been conducted for the macro scale modelling of land use change; this has been reflected in a document detailing the different macro level models that are available, their advantage and disadvantages as well as their mathematical description. Most of these models (one excluded, which is implemented as an MS Excel spreadsheet) have been implemented in C++ as Model Building Blocks. The models are being tested with use of data from Eurostat's Regio database. The data that are used are historical employment and population figures from 1987-1999 at the NUTS2 level. The models are evaluated on their predictive quality, data need and required calibration effort.

A new type of Densification module has been developed. This module describes the density of activity (employment, population) in a region. The module has been functionally and mathematically described in a working paper, furthermore it has been implemented as a Model Building Block. The correct functioning of the model has been verified and it will be further tested in conjunction with the macro-level land use models.

Research on the Micro level land use model concerns especially the formulation of the neighbourhood rules. A reduced (as compared to the Moland and Murbandy projects) parameter set has been defined and first results indicate that the reduced parameter does not lead to reduced model performance and is easier to calibrate (fig. 2). Work on the Micro level model is reflected in a draft working paper which besides introducing the methodology and test results also considers the empirical background of neighbourhood rules.



The original manually calibrated rules for the category low density urban area

The same curves adjusted to the reduced parameter set

Figure 2: The reduced set of parameters was tested on the Moland case

Calibration and validation of cellular models is a major concern for the WP4. Especially the lack of good measures of goodness-of-fit for spatial models is a challenge. Earlier work on an alternative form of map comparison, making use of Fuzzy set theory has been continued. This has been reflected in the development of a Fuzzy Set Map Comparison module, to be used from within the Map Comparison Kit (fig. 3.).

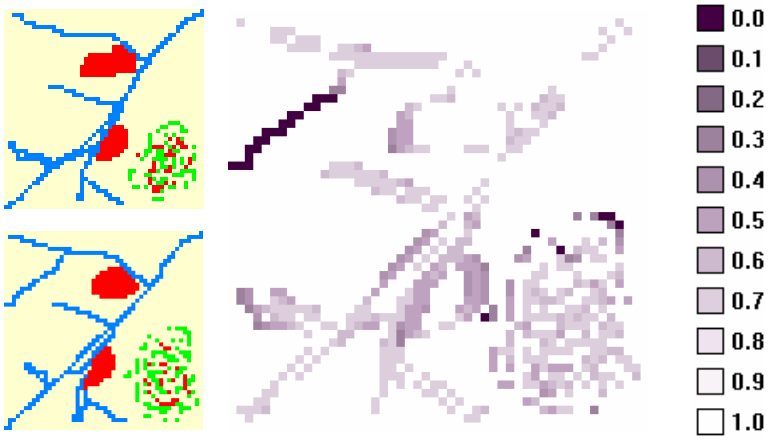


Figure 3: A demonstrative application of the fuzzy set map comparison, to illustrate how proximity relations are used to distinguish small differences from large differences.

A new method for the comparison of spatial dynamics has been developed, which is labelled the State-Space map comparison. This method makes use of chaos and complexity theory. The method expresses that states are represented in a "before" and "after" map as a *State-Space* plot. Consequently, sets of "before" and "after" maps are compared by comparing their corresponding State-Space plots.

WP6 – Dissemination and end-user integration

A major task developed at this early stage of WP6 (Dissemination and end-user integration) was to identify the main stakeholders on Land Degradation Management and Assessment, both at the National, EU and Global levels. This provided an extensive list of potential end-users of LADAMER products, which are now being integrated into schemes, providing information on their functions and hierarchic relationships (fig. 4).

Secondly, a simple and preliminary inquiry is being set forward and launched to all the previously identified institutions, in order to characterise these end-users needs and involvement concerning land degradation management and assessment. More specifically, it

will focus on their interest and ability to use a cartographic model for Land Degradation management.

The results will be integrated into a database which will provide an overview of end-users interests and needs. Based on these results, a second inquiry will be launched on specific requirements and knowledge needed to use LADAMER products, as well as on its potential results. This second questionnaire will be more detailed and specifically targeted at core institutions.

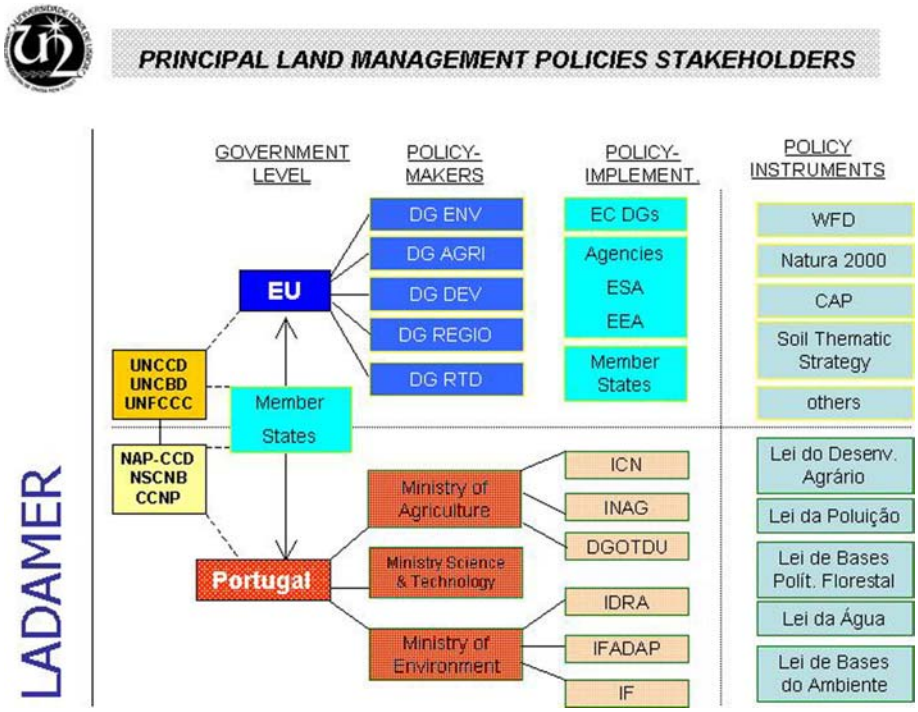


Figure 4: Principle land management policies stakeholders

Obstacles to information production and solutions

The acquisition of satellite and ancillary data has been more time-consuming than expected, mainly due to problems with administrations in charge of most of ancillary data such as digital elevation models, soil data base, statistical data etc. The European Soil Data Base is still not available to the LADAMER project due to national restrictions in distributing this essential data set. Data sets which have already been paid for by the European tax payers (statistical data) had to be obtained from institutions (EUROSTATS) at high costs with corresponding implications to the LADAMER project budget.

WP2 - Geoinformatics and remote sensing data analysis

Since the implemented time series analysis could not be performed directly on the delivered satellite datasets (8 km NOAA AVHRR Pathfinder (1981-2002), whole Mediterranean area; 1 km NOAA AVHRR MEDOKADS (1989-2002), actually only Iberian Peninsula), a pre-processing of the datasets had to be conducted before analysis. For both datasets it was important to perform a missing value and an outlier analysis. Because such values would distort the times series analysis, the missing values as well as the outliers were corrected using an interpolation algorithm. Additionally a maximum value compositing on the decadal data of the NOAA AVHRR MEDOKADS dataset was performed resulting in monthly NDVI values. The compositing was necessary because the decadal data still contain artefacts of clouds. Afterwards a homogeneity test for the detection of discontinuities in the data series was implemented. Discontinuities are caused by switching between satellites, atmospheric perturbations, errors in post-launch calibration and satellite orbital drift. Thus the orbital drift of NOAA AVHRR since 1999 was detected in the NOAA AVHRR Pathfinder data. This led to the decision to perform the time series analysis only till 1998.

In an additional step, the influence of the spatial resolution of the two datasets to the results of time series analysis was examined. Therefore the time series analysis for the Pathfinder dataset which covers a longer time period than the MEDOKADS dataset was also performed for the time period from 1989-1998. The time series analysis was performed both for the monthly data and for annual mean values. The latter one was implemented to eliminate phenological fluctuations between the years.

The analysis of the time series showed positive trends for the deserts in North-Africa. This “greening of the deserts” is a problem because this area is mainly free of vegetation and should not show any trend in the NDVI values. Therefore an attempt was performed to eliminate these underlying trends from both time series. This procedure can be only carried out if the trend underlies the whole examined scene. The Pathfinder data mainly showed no significant trend after a linear trend correction. The MEDOKADS data could not be corrected because the trend is not linear. Further investigations have to be undertaken to describe and eliminate this trend component. Nevertheless both datasets showed the same areas concerned by negative trends with a high significance.

The task of deriving hot spots from the vegetation trend classes proved to be difficult due to the ill-defined term “hot spot”. Hot spots can in a simplified way be described as areas which show a highly significant trend. But this trend can be caused by different developments and incidents. Thus hot spots of negative vegetation trends can be a consequence of fire incidents, changes of land cover or climatic parameters. In the case of land cover change a negative trend in vegetation cover can cause simply a leap from higher NDVI values to lower ones.

Whereas in the other case a steady decline of the vegetation cover can be reason for a hot spot and thus a hint on a wrong land use.

Regarding the interpretation of the trend classes and the hot-spots, it is important to take into consideration thematic layers like maps of land cover. Unfortunately, at the moment only Corine Land Cover 1990 is available, because the updated Corine Land Cover 2000 has not been completed yet. However, the evaluation if a change in land cover change causes land degradation depends on land cover maps of at least two different time steps. Thus land cover changes can be detected, followed by an examination if these land cover changes cause negative trends of vegetation cover, which can lead to land degradation. Therefore, a multi temporal land cover classification was started on the 1 km NOAA AVHRR MEDOKADS data. In this way two comparable land cover maps will be created of two different dates (1990 and 1998).

WP3 - Land degradation modelling

In this workpackage we are developing an assessment approach within the constraints of existing spatially distributed data. The concept of local resources retention and utilisation, as a measure of land condition or functionality, is rather robust for changes in spatial resolution and should be compatible with the proposed mapping resolution of 1 km. Mean monthly climate data layers have been made available to LADAMER, but may in some areas lack the accuracy that we need for our modelling work. A preliminary analysis of the accuracy of the mean monthly precipitation data layers suggest, for example, that precipitation amounts in areas of smaller mountain ranges may be strongly under-predicted by the MARS-based data layers. We will investigate these problems and their consequences for the land condition assessment in greater depth for the Spanish part of the Iberian Peninsula using an extensive data set monthly climate records.

To be able to model and predict changes in land condition over time given a starting condition and different types of future land use we need spatially distributed classifications of land cover types that cover a total period of one or more decades. A decadal timescale is crucial in order to be able to separate short-term variability from changes in land condition. We have communicated these data needs with the relevant project partners.

WP4 - Land use change modelling

The only, but very important, obstacle for WP4 (Land use change modelling) in the development of an *Integrated land degradation assessment tool,* is the lack of multi-temporal data. Since modelling land use change involves the modelling of spatial dynamics, rather than a static situation, it is necessary for validation and calibration of the models to have series of land use maps that are consistent with each other.

This issue has been extensively discussed with project partners and is being addressed as part of WP2 (Geoinformatics and remote sensing data analysis) by partner 1.

WP6 – Dissemination and end-user integration

Work Package 6 is still at an early stage, as LADAMER final product is being developed. Within this WP, the first difficulty faced is to identify end-users and find ways how to assess their interest and ability to manage a product that has not yet been created.

Another difficulty has been arising from addressing the inquiries to stakeholders at the larger EU and Global level, since in this frame it is difficult to establish direct contacts with responsibles qualified to answer on behalf of the institution, and simultaneously provide their personal view on LADAMER products. Using e-mail communication is a simplifying tool, but it does not assure a timing response.

Another relative difficulty is related to the Policies dynamics and the changing role of institutions in what concerns Land Degradation. The current implementation of the EU Soil Thematic Strategy is a good example of such changes, which are not always easy to follow and update.

Project`s details

Team

- Remote Sensing Department (FEUT), University of Trier (UTRIER), Trier, Germany
- Estación Experimental de Zonas Aridas (EEZA), Consejo Superior de Investigaciones Científicas (CSIC), Almeria, Spain
- Research Institute for Knowledge Systems (RIKS), Maastricht, The Netherlands
- Institute for Environment and Sustainability (IES), Joint Research Centre (JRC), Ispra, Italy
- Departamento de Geografia e Planeamento Regional (DGPR), Faculdade de Ciências Sociais e Humanas of the Universidade Nova de Lisboa (FCSH-UNL), Lisbon, Portugal

Timing

Due to the tight schedule of the first phase of LADAMER according to the restrictions of GMES phase I the Kick-off meeting of the project was carried out almost two months ahead of the official project start. This advance won almost two months in data acquisition and made the later change of the date of the fourth GMES forum compensable.

Following the project time frame LADAMER is well on schedule so far. Most of the planned deliverables and information products have been delivered in time. Delays of deliverables of WP5 (Validation and methodological refinements) and WP6 (Dissemination and end-user integration) were mainly caused by administrative reasons (WP5) and difficulties arising from addressing the inquiries to stakeholders at the larger EU and Global level (WP6).

Next steps

Several objectives will be fulfilled during the remaining time of the LADAMER phase 1. Preliminary results of the time series analysis and the hot spot detection will be improved and validated. Major issues in this context are the optimisation of the land use classification results and the vegetation assessment. The setting up of a procedure for assessing and monitoring of dryland degradation and the implementation of procedures for monitoring changes in land use resulting from and causing land degradation as a function of the socio-economic framework will be of major interest for the LADAMER project. Additionally, the review of existing land degradation assessment concepts will be finished and preliminary user requirement documents will be made available.

The next LADAMER project meeting will take place at the beginning of November. This meeting is expected to be a mile stone for the conceptional discussion regarding the following two years of LADAMER. Key objectives for these two years are information products of stakeholders and decision-makers at regional, national and European-wide level. Based on user needs and feedback from end-users the delivered information products will be evaluated and optimised to meet these end-user requirements.