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# Data Model and Analysis for Spatial Assessment of Environmental Impact and Targeting of Agri-Environmental Schemes at regional scales

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Table of Content

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Objective:

The report introduces the concepts and strategies for implementing spatial based methods for the assessment of actual environmental impact of Rural Development agri-environmental measures. The objective of the research work is to propose an array of possibilities to identify, assess and to map the impact of the Rural Development schemes related to the Community environmental priorities in contribution to the EC defined evaluation indicators. The work is to be carried out in several pilot sites complemented by specific research adding to the spatial dimensions of the impact assessment.

Experiences are being linked and made available through the establishment of a technical Pilot Site Network. Specific research results will be reported separately.

# I. Rationale and Pilot Sites

## 1. Introduction

Rural areas cover over 90% of the European Union’s EU25 territory and are home to close to half of its population. A distinguishing feature of Europe’s rural areas is their diversity both in geographical and landscape features, and in the different challenges they face. These range from restructuring of the agricultural sector, remoteness, poor service provision and depopulation to population influx and pressure on the natural environment, particularly in rural areas near to urban centres or in specific environments such as the Mediterranean. The pressures of facing with these challenges are manifold. Rural people are more concerned with living and working conditions while other citizens are appreciating the landscapes and rural quality of life as weekend alternative to urban stress. Both desires need to be addressed properly and dealt with at political level as to maintain and ensure the multi-functionality the rural areas can offer to society. The European

Union's Common Agricultural Policy (CAP) is designed to meet this ambition across the diverse social, economic, geographical and climate zones of the Union. Within the recent reformed Common Agricultural Policy (CAP), Rural Development is of increasing importance. Rural Development plans (RDP) of the Member States include measures on social and economic aspects along with agri-environmental measures. The latter represent a real opportunity for environmental improvements through adapting agricultural land management to the fragile dynamics of the ecosystems. The preparation of the next Rural Development programming period (2007-2013) brings to the forefront the need to correctly assess the relevance of such schemes and the impact of related farming practices on the environment.

# 2. Activity background

Within the Institute for Environment and Sustainability (IES) the Agri-Env Action of the Rural, Water and Ecosystem Resources Unit (RWER) is focusing on how to assess the effectiveness of the Agri-Environmental schemes implemented by the Member States. Quantifying effects of agro-environmental measures on biodiversity, landscape, natural and water resources remains a challenge. Local, as well as European decision makers need adapted methods to assess environmental outputs, outcomes and impact of their policy. The recent evaluation reports[1] on the impact assessment of Rural Development Programmes show, however, that evaluations of environmental effectiveness are not fully reflecting the actual environmental impacts. The Agri-Env Action contributes to improve assessment of scheme effectiveness and aims therefore at testing local to regional scale spatialized models.

# 3. Policy requirements

The Agricultural Council adopted the EU strategic guidelines for Rural Development in view of the full implementation of Council Regulation (EC)1698/2005 on Support for Rural Development by the European Agricultural Fund for Rural Development – EAFRD([2]). These guidelines set out a strategic approach and a range of options that Member States could use in their national strategy plans and Rural Development programmes.

The European Commission through DG AGRI needs a basis of understanding of actual and potential impact of rural development plans. Furthermore, Member States will have to establish an on-going evaluation for each Rural Development

[1] EC DG AGRI "Impact Assessment of rural development programmes in view of post 2006 rural development policy", Final Report, Nov 2004 (http://ec.europa.eu/agriculture/eval/reports/rdimpact/index_en.htm and http://ec.europa.eu/agriculture/eval/reports/rdmidterm/index_en.htm)

[2] http://ec.europa.eu/agriculture/rurdev/index_en.htm

Programme. Although, Rural Development Plans (RDPs) for the new 2007-2013 campaigns are to be submitted to the European Commission already by the end of 2006, being too early to benefit from this study, the possibility for programme course correction during the next 6 year period is foreseen.

During the recent past, DG AGRI has established a framework of EU-wide indicators for the evaluation of the effectiveness of the Rural Development Policy. For most of these indicators a baseline situation is now being compiled[3]. During this design process, it was clear that implementing objective ways for assessing the environmental aspects of the programmes remains the bigger challenge. A number of IRENA ([4]) indicators were included in the list for environmental impact evaluation. The proposed indictors being focused on European wide assessment of the Rural Development Policy effectiveness are still coming short in being able to reflect region specific environmental success. The work outlined in this report is therefore aimed at providing an operational approach for local and regional agri-environmental impact assessment while including options to feed into the EU wide assessments.

[3] http://ec.europa.eu/agriculture/agrista/rurdev2006/index_en.htm
[4] http://reports.eea.europa.eu/eea_report_2005_6/en

**BOX1: THE RDP REPORTING SYSTEM (2007-2013): INDICATORS**

Regulation (EC) No 1698/2005 foresees strategic monitoring of the Community and national strategies. The basis for reporting on progress will be the common framework for monitoring and evaluation, to be established in cooperation with the Member States.

This framework will be based on a limited number of **common indicators**. It will be supplemented by programme-specific indicators to reflect the character of each programme area.

A common set of indicators will allow aggregation of outputs, results and impacts at EU level and help assess progress in achieving Community priorities. Baseline indicators defined at the start of the programming period will allow for assessment of the initial situation and form the basis for the development of the programme strategy. Evaluation activities will take place on an ongoing basis and will be accompanied by thematic studies. The exchange of good practices and the sharing of evaluation results can contribute significantly to the effectiveness of rural development.

From the list of proposed indicators it is clear that these are aimed at evaluation at Community level. Data might be available either at regional or sometimes only at national level. Therefore local pilot studies will contribute to providing the needed information resulting from focused analysis at large scales and the possibility for up-scaling to the regional or EU level.

| **OBJECTIVE RELATED BASELINE INDICATORS** | | |
|---|---|---|
| AXIS 2, Improving the environment and the countryside through land management | | |
| | **Indicator** | **Measurement** |
| **17** | **Biodiversity: Population of farmland birds** | Trends of index of population of farmland birds |
| **18** | **Biodiversity: High Nature Value farmland areas** | UAA of High Nature Value Farmland areas |
| **19** | **Biodiversity: Tree species composition** | Distribution of species group by area of FOWL (% coniferous/% broadleaved/%mixed) |
| **20** | **Water quality: Gross Nutrient Balances** | Surplus of nitrogen in kg/ha<br>Surplus of phosphorus in kg/ha |
| **21** | **Water quality: Pollution by nitrates and pesticides** | Annual trends in the concentrations of nitrate in ground and surface waters<br>Annual trends in the concentrations of pesticides in ground and surface waters |
| **22** | **Soil: Areas at risk of soil erosion** | Areas at risk of soil erosion (classes of T/ha/year) |
| **23** | **Soil: Organic farming** | UAA under organic farming |
| **24** | **Climate change: Production of renewable energy from agriculture and forestry** | Production of renewable energy from agriculture (ktoe)<br>Production of renewable energy from forestry (ktoe) |
| **25** | **Climate change: UAA devoted to renewable energy** | UAA devoted to energy and biomass crops |
| **26** | **Climate change: GHG emissions from agriculture** | Agricultural emissions of GHG (ktoe) |

| CONTEXT RELATED BASELINE INDICATORS | | |
|---|---|---|
| AXIS 2, Improving the environment and the countryside through land management | | |
| | **Indicator** | **Measurement** |
| **7** | **Land Cover** | % area in agricultural / forest / natural / artificial |
| **8** | **LFA** | % UAA in non LFA / LFA mountain / other LFA / LFA with specific handicaps |
| **9** | **Areas of extensive agriculture** | % UAA for extensive arable crops<br>% UAA for extensive grazing |
| **10** | **Natura 2000 areas** | % territory under Natura 2000<br>% UAA under Natura 2000<br>% forest area under Natura 2000 |
| **11** | **Biodiversity: protected areas** | % FOWL protected to conserve biodiversity, landscapes and specific natural elements (MCPFE 4.9, classes 1.1, 1.2, 1.3 & 2) |
| **12** | **Development of forest area** | Average annual increase of forest and other wooded land areas |
| **13** | **Forest ecosystem health** | % trees / conifers / broadleaved in defoliation classes 2-4 |
| **14** | **Water Quality** | % territory designated as Nitrate Vulnerable Zone |
| **15** | **Water use** | % irrigated UAA |
| **16** | **Protective forests concerning primarily soil and water** | FOWL area managed primarily for soil & water protection (MCPFE 5.1 class 3.1) |

**Sources:**

- COUNCIL DECISION of 20 February 2006 on Community strategic guidelines for rural development (programming period 2007 to 2013) (2006/144/EC)
- European Union, DG Agriculture and Rural Development: Report 2006 on "RURAL DEVELOPMENT IN THE EUROPEAN UNION STATISTICAL AND ECONOMIC INFORMATION"

# 4. Framework and Scope of the work

In response to policy needs, the combined work on Agri-Environmental impact assessment will be focusing at developing an integrated framework for assessing the effectiveness of Agri-Environmental measures. The overall scope of this is to identify, assess and map actual environmental impacts of the Rural Development Agri-Environmental measures.

RDP evaluation reports often use policy uptake in terms of farm contracts and policy output in terms of budget spent per measure as basis not only for policy implementation success assessment, but also for environmental impact assessments. This leads to rather empirical assumptions. This manifests a clear need for more scientific base and evidence for the evaluation of Agri-Environmental measures.

It is obvious that due to the geographic and climate differences throughout the Union, Rural Development Plans will differ in tackling similar environmental problems, such as erosion, loss of habitat, pollution from agro-chemicals, etc. These phenomena vary in intensity and geo-physical character based on local circumstances. Hence there will be a need for a tailored array of methods. Furthermore, Rural development Planning inherently tackles scale differences. These range from EU level policy making to regional planning and local implementation. Although policy can handle scale differences quite easy, spatial assessment methods are more scale dependent and will need to include up- and downscaling options.

Network of pilot sites:

The assessment work answers to this complex situation by proposing developing and testing methods over a number of distributed pilot sites (Figure 1). Networking experience on evaluation of Rural Development Policies also responds to the growing conscience that due to its multi geo-topic nature, the RDP can only be evaluated by proper extrapolation of local impact assessments. Accommodating this need, the Rural, Water and Ecosystem Resources Unit of the IES, started to establish a network of pilot sites to collect circumstantial evidence on the environmental impact of Agri-Env measures, through the development and testing of methods and tools. The current core groups a number of initiatives for pilot studies realized through institutional or local efforts. The RWER unit coordinates the activities and the knowledge exchange.

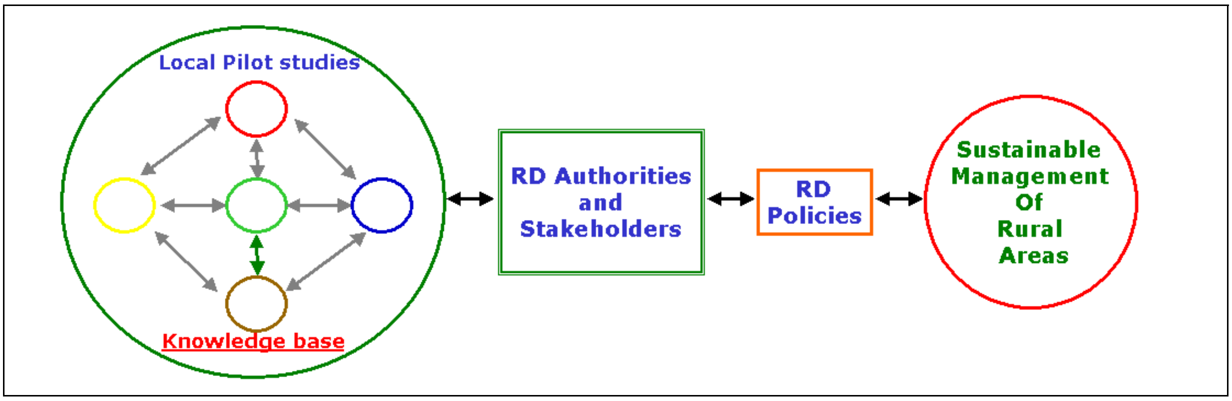



*Figure1: Linking pilot studies together with local stakeholders in support of environmental assessment of RDP Agri-Environmental measures.*

A first network meeting, held in November 2005 at the JRC, clarified strategic points related to the RDP:

- Firstly, environmental effectiveness should be ensured in addressing environmental problems related to agricultural land use, while increasing the economic efficiency, or reducing cost.
- Secondly, dissemination of lessons learned from existing projects, countries and regions should be improved.

To achieve these points, more rationale could be introduced into the schemes. Ex-ante and cause-effect analysis, measurable objectives, and increased understanding of the complexity of the rural development would contribute. It is clear that to realize all the above-mentioned goals, more systematic data is needed on measurable indicators in view of economic efficiency and environmental effectiveness assessment of the RD policy at the local level

Measure objectives can be set quite clear on the one hand (e.g. Farmland Bird Index) but key data is missing for quantitative impact assessment. On the other hand, more frequently, objectives could be better set if knowledge is gained on the quantification of impacts. Such quantification is related to the possibility to:

- Establish effective indicators
- Collect significant related data (baseline and monitoring)
- Establish functional relations between variables and/or indicators.

Pilot studies are therefore best suited to analyze the actual impact of a variety of similar measures that are each tailored to the specific conditions of certain areas. Work at local scale produces 'deep and narrow' methods and contributes to farm-scale knowledge on environmental effectiveness, including both on-site and off-site effects. But local studies are to be designed, not only to be comparable but also to be scalable to make them compatible for assessing the effectiveness of the RD policy objectives at wider region and EU scales. Therefore, resulting methods are to be adapted for extrapolation so interested users can apply them over other areas.
Work within the pilot study areas contributes to solve problems related to up-scaling from local to regional and EU scales. RDP measures are implemented locally, at farm

level. Impact at that scale needs to be aggregated in order to evaluate the contribution of the local and regional Agri-Environmental schemes to the National and EU wide set environmental priorities. This aggregation needs to be possible, on the one hand, within the pilot site towards assessing the local scheme objectives. On the other hand, aggregation needs to be envisaged throughout the various pilot sites, in view of compatibility to contribute to European scale indicators that are used to report on the Community environmental priorities. Furthermore, downscaling from the EU level to the local level, as well as from the pilot site level to the farm level, is needed for validation and to estimate how a global indicator reflects or can be used at local level.

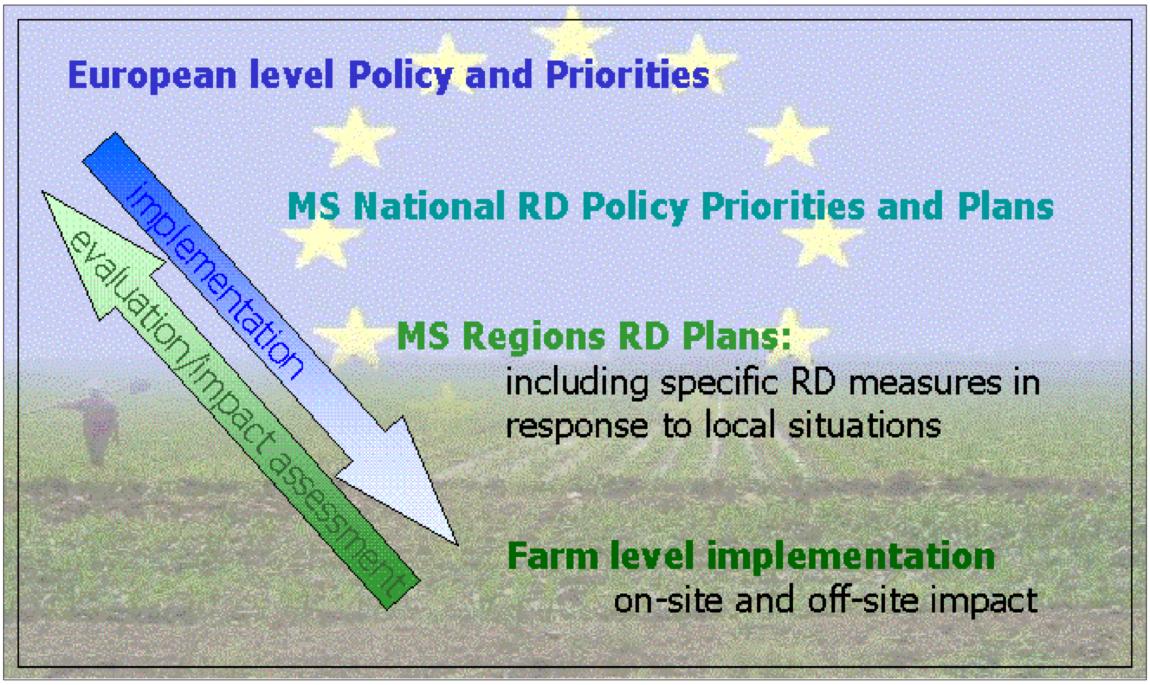



*Figure 2: scale issues related to implementation and evaluation of RDPs*

Ensuring the above described solutions through networking experience, a solid scientific and technical basis is to be provided. Hence, the RWER Unit has started to carry out studies on the development and testing of indicators in specific areas in Europe. Currently studies in the following pilot sites are operational:

- South Italy, Basilicata Region
- South Spain, Andalusia Region
- North East Poland, Bialostock Province
- South Central Turkey, Seyhan River basin

- Pilot River Basins working on agriculture impact and pressures on water resources, an activity under the WFD-CIS[5] coordinated by the Unit.

[5] DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000: Establishing a framework for Community action in the field of water policy

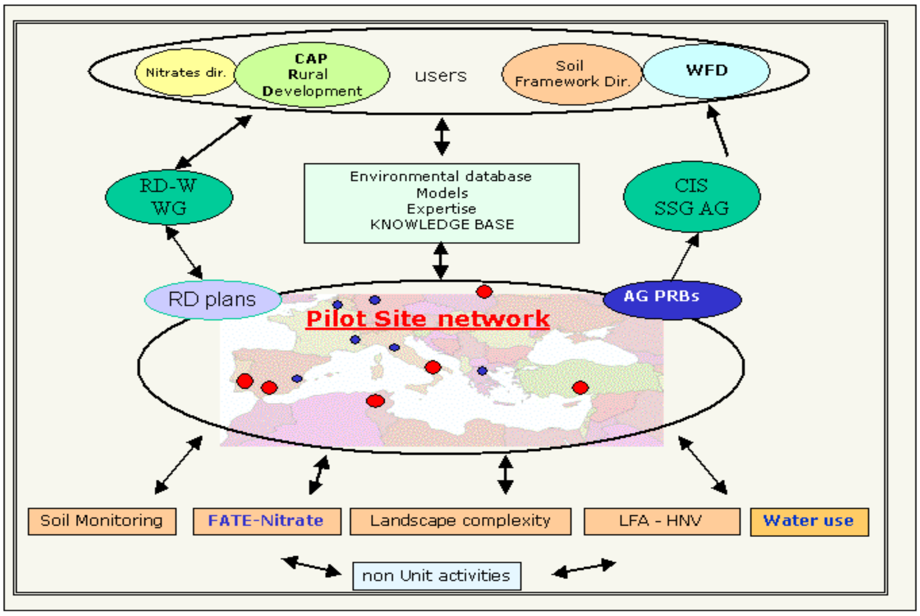



*Figure 3: Thematic network of pilot sites in relation to EU policies*

The effect of European Agri-Environmental schemes in conserving and promoting e.g. biodiversity has been investigated by Kleijn and Sutherland (2003). They found that studies were lacking from Mediterranean countries. They also stated that it was unlikely that results from other studies could be extrapolated to the southern European countries and therefore they stated the need for more research in the Mediterranean. Furthermore in support to various initiatives within the Mediterranean area, such as the European Neighbourhood Policy (ENP), Horizon 2020, WFD-Med EUWI Joint Process, the Unit's institutional work focuses precisely on a Mediterranean site for gaining insight and knowledge in the subject matter: the Andalusia Region in Spain, extended for some work to the west into the Alentejo Region of Portugal.

The intended result of the work in this phase will be a series of tested approaches that combine several spatial analysis methods which result in spatial maps indicating assessments of the actual impact of the agri-environmental measures related to one or more community priorities, in at least four geographic areas.

# 5. Driving Concepts

## 1. Main Rationale

Agri-Environmental Measures (AEM) within their specific objectives, such as e.g. extensification, erosion control or organic farming, directly address farming and land management practices. These have to be adopted by the 'contractor' of the measure.

Step I: Implementing these requested farming and land management practices is expected to influence, either separate or combined, certain environmental aspects. The planned change of these aspects is linked to the overall objective of the measure. The magnitude of that change will define the 'implementation success' of the measure.

Step II: The real impact in reference to the Community priorities, biodiversity, water quality and climate change, is then dependent on the relation of the changing environmental aspects and specific factors that can describe these community priorities. One of these factors is for example the increase of farmland birds diversity, related to biodiversity.


*Figure 4: Main Rationale for AEM impact assessment*

## 2. Step I

The environmental aspects aimed at by the measures, are e.g. presence of semi-natural permanent vegetation, including diversity in space and composition, soil and water quality, etc. Relations between implemented measures, along with their given set of agricultural practices, and the state and change of the environmental aspects will be indicative for the further impact assessment.

These thematic environmental aspects 'distilled' from the measures are the cornerstones to build the general analysis concepts that can be common to the pilot site studies. Moreover, they are the main drivers for designing the specific work further described in this document.


*Figure 5: Rationale for step I of the assessment framework*

Building theoretical relationships is being undertaken within the various sites indicated above. It is based mostly on compiled datasets resulting from monitoring activities or census sources. Table 1 illustrates that for some proposed approaches a number of key environmental datasets, that are expected to be strongly related or possibly influenced by the measure, can be assigned to the specific measures that are assessed. Local experience and further documented geo-physical relationships were gathered to build these links.

| Agri-environmental measures | Preliminary associated key datasets |
|---|---|
| Extensification<br>(measure #1 in Spain) | Intensive-extensive regime management<br>Livestock load<br>Crop production ratio<br>Environmental protected areas<br>Sensitive ecological areas |
| Erosion control in fragile environments<br>(measure #4 in Spain) | Erosion density<br>Geology and soil type<br>Slope<br>Number and type of agricultural practices (terraces, contour tillage, etc.) |
| Organic Farming<br>(measure # 1257/99 in the Basilicata Region in Italy) | Main crop distribution<br>Conventional agricultural practices per crop<br>Erosion potential<br>Water quality measurements |

*Table 1: Proposed links between datasets and Agri-env measures illustrate the relationship between the measure and environmental aspects that are expected to be influenced when implementing the measure.*

The next phase is to define the possible stresses/improvements of these environmental aspects that can be caused by the farming practices imposed by the measure.

Related to the identified potential stresses, the state and trends of the relevant environmental datasets can then be analyzed. This spatio-temporal analysis will consider periods before, during and after the implementation of the measures. Further comparison of derived spatio-temporal characteristics for areas with similar agri-geo-physical conditions, where measures are and are not implemented (paired analysis), will contribute to detecting environmental changes in view of establishing cause-effect relations. The analysis shall take into account also the changing socio-economic and climatic conditions as to be able to contribute 'residual' changes to AEM. It is therefore crucial to compile spatial information at significant scales on where AEM are implemented (figure 6 and 7).

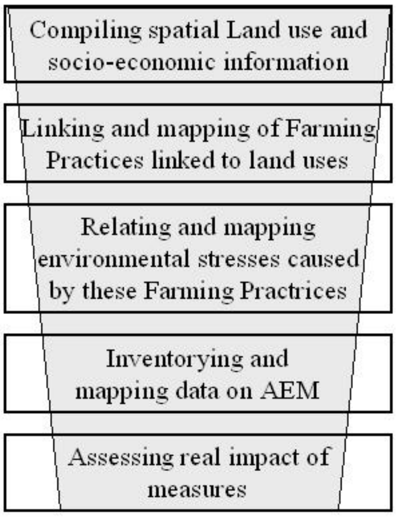



*Figure 6: Main proposed flow of impact assessment; Compiled from common aspects in the various on-going pilot studies.*

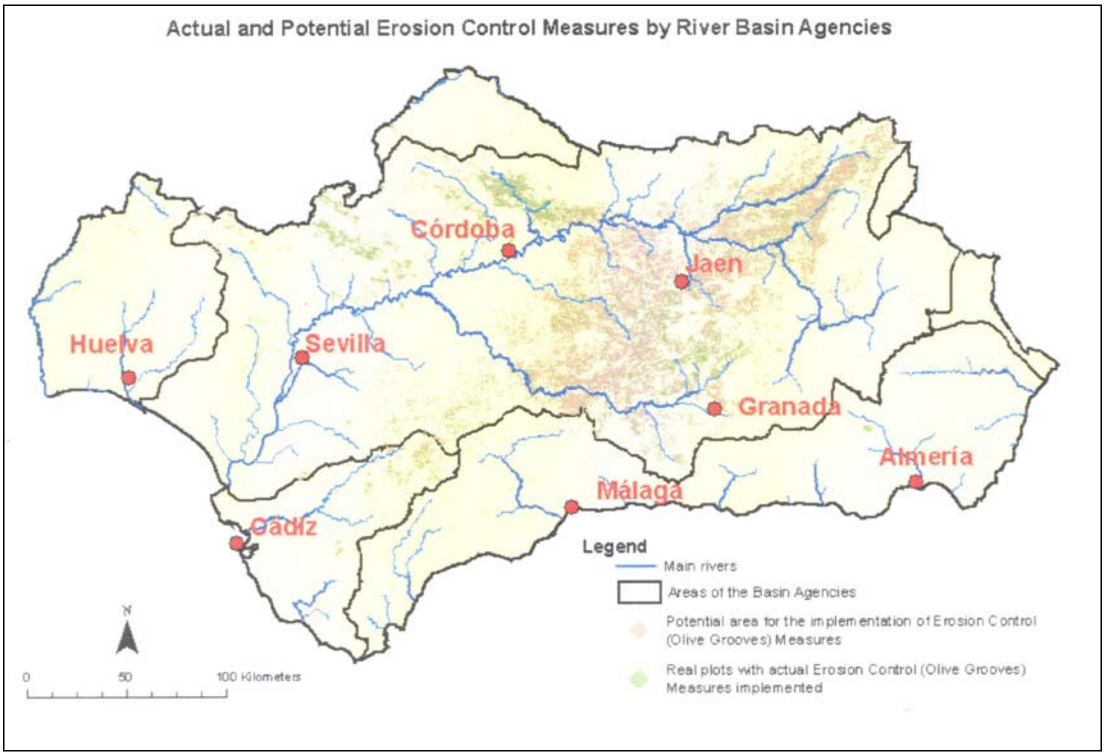



*Figure 7: Example of implementation of the erosion control measure in Andalusia in Spain. Source: Tecnoma Spain, 2006.*

## 3. Step II

The analysis of environmental datasets is expected to have led to identification of changes that are represented as variables in spatial layers that define crucial characteristics of areas where agri-environmental measures have been implemented, contrary to areas where measures have not been implemented. When considering the local scheme objectives and responding to the Community priorities, indicators will need to be compiled to describe their driving nature.

In case of e.g. biodiversity it will be necessary to define which aspects of biodiversity will be assessed, such as species richness, conservation values and suitability for restricted or indicative species (e.g Farmland Birds). Relevant associations will have to be build up to identify these aspects, e.g. in case of Farmland Birds, habitat structure and heterogeneity as well as forage indicators will need to be derived in combination with the characterisation resulting from step I. Naturally, it requires extensive knowledge of the area to define what is considered as a "changed" habitat and also knowledge of the species investigated. Most probably a significant change will be measured on a different scale when considering birds or e.g. carabids.

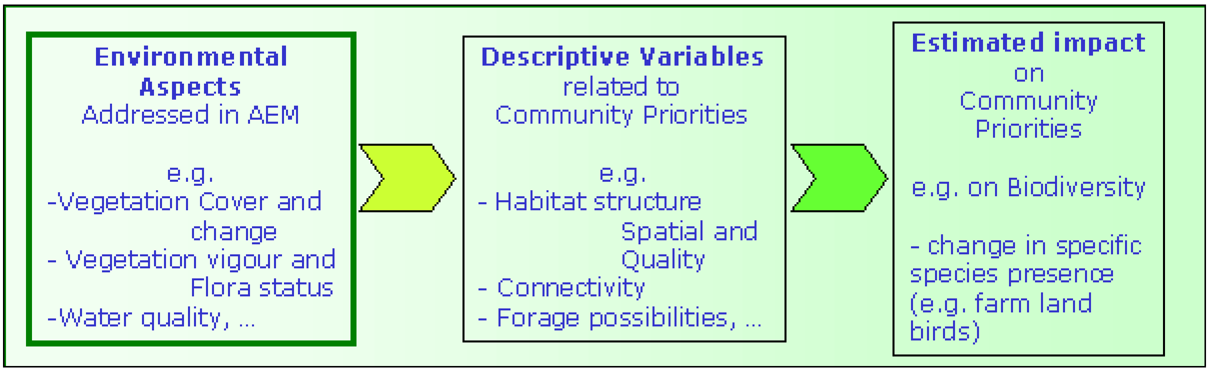



*Figure 8:* Rationale for step II of the assessment framework

# II. Complementary Spatial Dimensions for Impact Assessment

## 1. Strategy

In most cases, monitoring and census data are to be considered point observations that are, for our purposes, spatialized using adapted GIS based routines. Remote sensing based data, however, represents information on a spatial continuum. Moreover, remote sensing data offers means of measuring certain environmental aspects, such as land cover properties, at different spatial scales ranging form field to regional and global levels. Including remote sensing based information within the above discussed study approach, adds a very valuable spatial complement and allows to cover certain environmental aspects that otherwise cannot be included in such detail. Furthermore, remote sensing based data layers on land and/or landscape characteristics at the various spatial resolution, ranging for our work from 30m to 1km, are considered to be essential when having to deal with the different scales inherent to the planning and implementation of the Agri-Environmental schemes, as was illustrated in figure 2.

Within the Agri-Environmental measures there are a number of environmental aspects that are conditioned, expected to be improved, through the measure's associated agricultural practices that have an explicit spatial dimension. Therefore, investigation of options to complement the assessment approaches with remote sensing is considered a valid research direction. Our research proposal is established specifically to support, complement and increase the GIS and remote sensing capacities within the studies carried out currently in the network. It aims furthermore to fully link the statistical and spatial tools into operational approaches to be made accessible through a variety of toolboxes. It will focus on:

- The compilation of a Time Series digital dataset
- Spatial-temporal analysis to define cause-effect relationships
- Support to the development of user oriented methods and tools for the identification and assessment of environmental impacts of Rural Development Plans.

The data model and analysis work further described represent this remote sensing based work carried out in the RWER Unit's common pilot site, Andalusia.

At this stage, a preliminary scrutiny of the Agri-Environmental measures implemented in the Andalusia Region (Spanish Horizontal Programme) leads to the hypothesis that the state of land cover is an important environmental 'fil rouge' which change will have a direct impact on the Community priorities: Biodiversity, Water quality and Climate Change.

Establishing more detailed links between the farming practices and the elements defining the state of land cover provide theoretical assumptions on what should be affected or changed, and how. It is of course clear that this is a preliminary hypothesis formulation and more theoretical background and research will need to be incorporated to get these relations as exact as possible. As listed in Table 2, the state of land cover, addressed by the measures that can most possibly be observed through remote sensing based data, is related to:

a. Increase/decrease in permanent vegetation
b. Increase in vegetative field cover during the non agriculture active period

Overall, the questions to be explored in this part of the research include:

- What is the magnitude of total vegetation change per pixel over agricultural areas?
- What is the proportion of change attributed to shifts in vegetation activity compared to differences in the amount of vegetation activity?
- What are the trends of these changes, seasonality versus long lasting changes?
- How can the hotspots of change be identified?
- What are the real processes behind these hotspot changes? What proportion of these changes can be attributed to Agri-Environmental measures?
- What is the spatial distribution of these hotspot changes?

The further question relates to the actual impact of this land cover/landscape change:

- How can these changes be related to terrestrially observed measures of e.g. biodiversity or cause-effect models of e.g. land degradation?

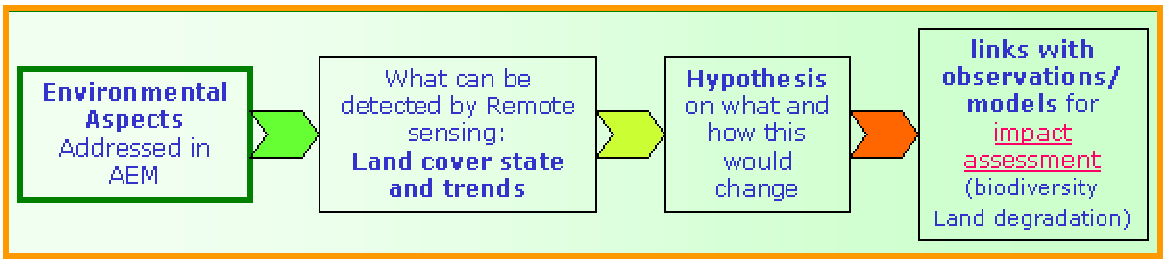



*Figure 9: Rationale for the complementary spatial assessments based on satellite data analysis*

*Table 2: Illustrating the links between an Agri-Environmental measure and environmental aspects in view of remote sensing based impact assessment (simplified)*

| **Measure 1. Extensification** | **Addressed agricultural management practices** | **Related environmental aspects** | **Hypothesis for Remote sensing based analysis** | **Remote sensing options** |
|---|---|---|---|---|
| **Beneficiaries** | | | | |
| 1.1.<br>Farms in areas where fallow land parcels have a Fallow Index > 10 and parcels on which the measure is applied were not subject to rotation of natural vegetation (and agriculture) | Agri-environmental fallow system:<br>a. No herbaceous cropping for 5 years on at least 1 ha<br>b. Maintain straw and weeds during at least 5 months<br>c. No use of phyto-sanitary products during the non cultivation period<br>d. Grazing or use of straw: max. 80% of what the local technical committee allows (i.e. limited grazing)<br>e. Prohibition of harvesting during the night to avoid death of birds | Vegetation cover<br><br>Vegetation cover<br><br>Less affected flora and fauna<br><br>Less affected fauna | More stable multi annual time biomass signal<br><br>NA<br><br>NA | A. Analysis of multi year phenological characteristics calculated from NDVI based vegetation abundance time curves and their cyclic patterns |
| 1.1.1. | f. Leave stubble on at least 50% of the surface | Vegetation cover<br>Soil condition (erosion control) | Idem<br>NA | Idem A. |
| 1.2.<br>Farms with parcels under rainfed herbaceous crop since 1992 (Parcels can be summed up) | Extensification for flora and fauna protection:<br>a. Use seeds free from phyto-sanitary products<br>b. Stubble can be ploughed in on a date decided by the local technical committee<br>c. Maintain hedges or islands of natural vegetation on at least 3% of the farm<br>d. Respect the local calendar for farming practices to keep straw and weeds in function of bird nesting<br>e. Increase the amount of seeds with 20% to account for loss due to birds | Less affected flora and fauna<br><br>Vegetation cover<br><br>Vegetation cover<br><br>Less affected flora and fauna<br><br>Less affected fauna | More permanent semi-natural vegetation cover | Idem A.<br><br>B. Multi annual analysis of NDVI based vegetation abundances looking at changes in magnitude and phase |
| 1.2.1. | f. Sowing of pulses | Less affected | | |

| | | | | |
|---|---|---|---|---|
| | on fallow lands to provide bird food, limited grazing allowed | flora and fauna<br><br>Vegetation cover | | Idem A. |
| 1.3.<br>Farms that have parcels under commitment for growing sunflower during at least 5 years | Agri-environmental intervention to crop rotation: adding sunflower:<br>a. Controlled grazing on stubble from previous cereals allowed<br>b. Use at least 3250kg seed<br>c. No mechanical or chemical weeding<br>d. Sunflower stubble has to be chopped and buried<br>e. Maintain existing field buffers for flora and fauna protection | Less affected flora<br><br>Vegetation Cover | | Idem B. |
| 1.4.<br>Farms on which min. 1ha will be taken out of production during at least 5 years | Withdrawal of productive agricultural land to create natural areas reserved for fauna and for conserving biodiversity:<br>a. Surface will be min. 1 ha of land under agriculture in the last 5 years<br>b. Carry out the required maintenance to control erosion, fires and degradation<br>c. No use of agrochemicals<br>d. Limited grazing allowed | Vegetation cover<br><br>Soil status (erosion and degradation control)<br><br>Less affected flora and fauna | | Idem b. |

Answering the above questions will need approaches that take into account various ways of analyses and data processing at different levels of details. Working at different spatial scales allows linking of different elements (e.g. clusters of patterns to meaningful land characteristics) that otherwise would not be possible. Specifically for biodiversity impact assessment a combination of a bottom-up (biodiversity impact) and top-down (measure impact on the land) approach is considered.

## *Conclusions*

The analysis will need to include:

a. Spatio-temporal characterisation of habitats and indicators for biodiversity impact assessment/modelling. This implies:

   + Time Series analysis of selected areas using high resolution satellite data in view of habitat characterisation
   + Linking to low resolution data for ‘extrapolation’ of the habitat level impact assessment to larger regions for synoptic overview.

b. Characterization of intensity and spatial patterns/variation of land cover, related to permanent vegetation and field cover, for paired analysis in view of determining the observable impact of the Agri-Environmental scheme on the land cover condition and ‘hot spots’. This implies:

   + Time series analysis of region wide low resolution satellite data producing characterisation layers
   + Linking to high resolution satellite series for calibration and understanding land cover dynamics processes at all scales

Access to available satellite data will ultimately determine the analysis techniques that can be applied, as an operational use of the result is a prerequisite. Chapter II.2. gives an overview of the available data, while Chapter II.3. illustrates in more detail the planned analysis. The work will be carried out as an ex-post analysis, considering the 2000-2006 Rural Development campaign. The developed analysis methods will offer also a basis for ex-ante evaluation for the 2007-2013 programming period.

The present document only aims to summarise the analysis strategy and the envisaged methods, along with some preliminary results. These are based on testing and applying of signal processing techniques and statistical methods for the analysis of time series remote sensing images. At the present stage of the research the high resolution data sets were not yet available, hence preliminary results could not be included in the current document.

It should be stressed again that the described remote sensing analysis aims at complementing the spatial aspects of impact assessment and that these approaches will need to be integrated with results from other coordinated studies.

# 2. Data Requirements

## 1. *Ancillary data sets:*

For the validation of the results obtained with remotely sensed data and for the model building purposes the following ancillary data will be required:

**Climate**

- Minimum, maximum and median temperature values are available for whole Spain, delivered in a 1km spatial resolution grid.
- Average rainfall values are also obtained. The data is averaged over a month and is available from 1970 to 2000.
- MARS (Monitoring Agriculture with Remote Sensing) Meteo data derived from global atmospheric model are available. The European MARS meteorological database holds daily measured climatic data for Europe (of a 50x50Km grid). MARS FOOD regularly receives daily, 10-daily and monthly outputs of the ECMWF (European Centre for Medium-Range Weather Forecast) atmospheric model. The Climate Quality Index of the European Environment Agency is based on the aridity index, which requires a harmonized way of computing evapotransipration, which at present differs among countries. In this respect FMA will be in charge of defining the most suitable algorithm(s) concerning evapotranspiration and the correct time frame, which depends on the available data and on the methodological approach adopted.

**Agriculture data**

- CAPRI (Common Agricultural Policy Regionalised Impact) model is available for crop area estimation in 1-km grids. The grid values are the area of the crop in 0.0001 km2 / km2 grid cell (hence, a value of 10000 means the area of the whole grid cell is covered with the respective crop).
- The ESCAPE (Expert System for Constraints to Agricultural Production in Europe) by INRA-Orléans might be used for the assessment of suitability of land units for cereals, maize, sugarbeet, potatoe, sunflower, rapeseed, vine-en oliveyard, pasture. The system is based on soil-related limitations, climate-related limitations (temperature) and -combined soil & climate related limitations (soil water availability).
- The global digital map of irrigated areas developed by the FAO in 2005 on the basis of cartographic information and FAO statistics might be used.
- IRENA indicators

**Geo-physical data**

- The European Soil Database (ESDB) Raster Archive contains raster (grid) data files with cell sizes of 10km x 10km for a large number of soil related parameters. These rasters are in the public domain access and allow expert users to use the data for instance to run soil, water and air related models.

- The Pan-European Soil Erosion Risk Assessment uses a process-based and spatially distributed model to quantify soil erosion by water and assess its risk across Europe. The conceptual basis of the PESERA model can also be extended to include estimates of tillage and wind erosion.
- The FAO/UNESCO Digital Soil Map of the World (DSMW) is Publicly available and might be used as input to the methodology.
- The Soil Profile Analytical Database of Europa (SPADBE) includes the following analytical results for the different soil horizons: texture (& particle size grades), organic matter content (C, N), structure, total nitrogen content, pH, calcium carbonate content, calcium sulphate content, electric conductivity, CEC and exchangeable bases, soil water retention, bulk density, root depth, groundwater level, and parent material.

**Land cover data**

- Corine (Co-ordination on Information of the Environment) Land Cover maps from 2000. Land cover database for the 25 EC Member States and other European countries: an inventory of land cover features for managing the environment, at an original scale of 1: 100 000, using 44 classes of the 3-level Corine nomenclature.
- The Corine Land Cover (CLC) Change database shows the changes between the CLC90 inventory and the CLC2000 inventory. The minimum mapping unit (MMU) of the change database was set to 5ha. Changes should refer to real evolution processes, and not to different interpretations of the same subject. The land cover changes database is necessary for the analysis of causes and consequences of natural and artificial processes, impact assessment, identification of trends, contribution to the maintenance of ecological balance and its consideration in decision-making processes.
- LUCAS (Land Use/Cover Area frame Survey) 2001 is an area frame statistical survey that aims at obtaining harmonized data at EU15 level (the 15 countries of the European Union before the 2004 enlargement) on land use, land cover (agricultural component) and environment.
- Land Cover Map of Andalusia for 1999 at 1:50000 scale and a draft land Cover Map for Andalusia at 1:25000 scale.

**Socio-economic data**

Socio-economic data will be drawn from the GISCO database containing information on administrative areas and other regional subdivisions. The data contains information on demography, economy, transport, industry, unemployment, agriculture, finance and labor. Data related to demography and socio-economic activities are collected on the commune or ward level. Administrative data are available on the NUTS0-3 level and will be incorporated in the research. Infrastructure data on roads, settlements of the GISCO database will be important for biodiversity research. Socio-economic indicators of the Irena project will also be used.

## 2. Remote Sensing data

Over the last two decades, remotely sensed data has offered means of measuring vegetation properties at regional to global scales. Of particular significance has been the availability of Time Series of remote sensing images extending over many years.

### 1. NOAA AVHRR based Green Vegetation Fraction

In interpreting multi-temporal information from time series data, it is usual to calculate “vegetation indices” defined as ratios of radiances in different bands. Currently the longest back-dating time series of biophysical variables like the NDVI are provided by the AVHRR (Advanced Very High Resolution Radiometer) sensor on board of the NOAA (National Oceanic and Atmospheric Administration) satellite. The mostly used vegetation index is the NDVI (Normalised Difference Vegetation Index), a measure of the amount of active photosynthetic biomass, correlated with biophysical parameters such as green leaf biomass, fraction of green vegetation cover, leaf area index, total dry matter accumulation and annual net primary productivity (Asrar et al., 1985, Justice et al., 1985, Myneni et al., 1995, Prince, 1991, Sellers, 1985, Tucker, 1979, Tucker et al., 1985).

One problem with the NDVI index is the contamination of the vegetation signal with noise due to clouds, aerosols, water vapour, and background soil radiation (Lu et al., 2003). Noise due to soil background influences the detection of sparse vegetation cover resulting in NDVI values up to 0.3 for non vegetated areas (Stellmes et al., 2002). Most importantly, pseudo-vegetation fractions are minimized due to the spectral response of the background material (Hostert et al., 2003). Especially in the Mediterranean area this problem hinders the usefulness of NDVI as indicator of vegetation cover.
In order to overcome this problem a spectral mixture analysis (SMA) strategy was developed in the framework of the EU funded research project MEDALUS, to derive green vegetation fraction (GVF) from the AVHRR data. The method is based on the inverse relationship between the vegetation index NDVI and the land surface temperature. It acts on the assumption that vegetation cover should predominantly control the position of an AVHRR land surface pixel within the feature space spanned up by NDVI and surface temperature.

The yearly varying GVF values could be used for a classification of habitat heterogeneity, where a heterogeneous habitat is defined if it did not persist to stay the same through the time period used. Kerr et al. (2001) were already successful in linking habitat heterogeneity to butterfly species richness as measured from Spot Vegetation data.

### 2. SeaWiFS based FAPAR – vegetation state parameter

The purpose of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Project of the NASA is to provide quantitative data on global ocean bio-optical properties to the Earth science community. FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) is an indicator of the state and productivity of vegetation and has been recognized as a fundamental surface parameter for environmental studies. FAPAR represents the fraction of the solar energy that is absorbed by vegetation and therefore plays an important role during the plant photosynthetic process.

The Global Environmental Monitoring (GEM) unit of the Institute developed the FAPAR product for Environment and Sustainability in the Joint Research Centre on a 1km spatial resolution. It can be used either as a high-performance indicator of the presence and state of the vegetation cover, or as a quantitative estimate of one of the main factors controlling its productivity. Time series of the FAPAR product can be used to document the spatial variability and temporal evolution of the vegetation cover over large areas and long periods of time, and in particular monitor the seasonal and inter-annual changes that have occurred. However, the FAPAR time series data only go back to the year 1998, thus long term time series analysis and assessing significant changes in the vegetation phonologies are only possible with restrictions. However, the developed methodology will be tested on the FAPAR data on a dekad basis.

The MODIS (Moderate Resolution Imaging Spectroradiometer) instrument provides high radiometric sensitivity (12 bit) in 36 spectral bands on 250m spatial resolution.
MERIS, the Medium-spectral Resolution Imaging Spectrometer has fifteen spectral bands and provides a spatial resolution 260x300m. However, these systems are only operational from 2002 on, therefore are not appropriate for time series analysis where long term changes in the vegetation phenology are of interest.

## 3. SPOT VGT based NDVI

The SPOT VEGETATION program is conceived to allow daily monitoring of terrestrial vegetation cover through remote sensing at regional to global scales. The first satellite component (VEGETATION1) of the programme was launched onboard SPOT4 in 1998 while the second instrument was launched onboard SPOT5 in 2002. The instruments deliver measurements specifically tailored to monitor land surface parameters with a frequency of about one day and a medium spatial resolution of 1km. The instrument provides measurements in the visible and short wave infrared domains. The overall objectives of the "VEGETATION" system are to provide accurate measurements of basic characteristics of vegetation canopies on an operational basis, involving both regional and global scales experiments.

The VEGETATION system will provide long term basic measurements adapted to biosphere studies and opportunities for scale integration are provided by the combination with the main SPOT instruments (HRVIR) which allow high spatial resolution for detailed modelling activities or multilevel sampling procedures. However, long term time series analysis of past phenological and land cover changes will only be possible in the future because of the relatively short archive database. Nevertheless, the future importance of the system in European research is well understood and the methodological study will include the SPOT VEGETATION data on a dekad bases as well.

### 4. Landsat ETM

Since the early 70s, for over 34 years the Landsat program has collected spectral information from Earth's surface, creating a historical archive unmatched in quality, detail, coverage, and length. From 1972 on seven Landsat satellite was launched, although the sixth failed to reach the orbit and was never operational. The Landsat 5 Thematic Mapper instrument is operation from 1984 onwards supplying seven bands in the visible, infrared and thermal infrared spectrum. The Enhanced Thematic Mapper Plus (ETM+) instrument of the Landsat 7 includes additional features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment, and large area mapping than its design forebears. These features are a panchromatic band with 15m spatial resolution on-board, full aperture, 5% absolute radiometric calibration a thermal IR channel with 60m spatial resolution and an on-board data recorder. The high spatial resolution of the visible and infrared channels (30m) makes the two satellites especially appropriate for land surface studies. For the present research Landsat 5 and 7 satellite images will be acquired for the ten years period of 1995-2005. Depending on the financial constraints two to three images will be acquired from selected test areas in Andalusia.

# 3. Analysis Methods

## *1. Introduction*

High resolution remote sensing data will be applied for the assessments of the agricultural landscape structure and to provide the link between the environmental changes induced by Agri-Environment measures and their effects on e.g. farmland biodiversity. Such links will be established through compiling of objective relevant indicators derived from time series analysis and other image analysis.

Low resolution satellite data is to be used for the distinct spatial characterisation of areas where Agri-Environmental measures have been applied and areas where they have not been applied. Long time series analysis will be undertaken to derive a number of indicative variables characterising crucial environmental aspects and their changes.

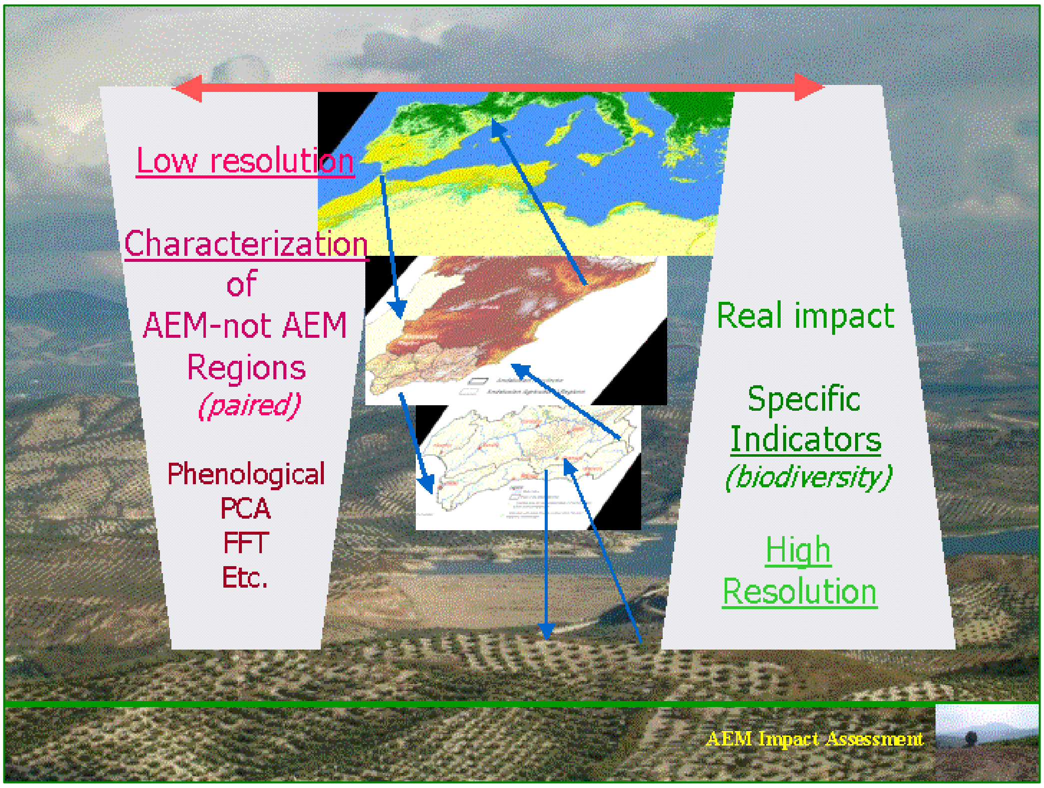



*Figure 10: Combined use of high and low resolution satellite data*

Several methods have been applied in the recent years to analyse time series of satellite images for vegetation studies:

- Traditional methods extract trend and seasonal components e.g. to identify the different greening rhythms of trees and grassland in a mixed woodland landscape (Roderick et al., 1999).
- Principal Component Analysis (PCA) has been used extensively to map vegetation types and changes (Benedetti et al., 1994, Lambin and Strahler, 1993, Townshend et al., 1987). Eastman and Fulk (1993) identified seasonal trends using PCA.
- Studies of interannual vegetation variability were performed using wavelet decomposition by e.g. Li and Kafatos (2000).
- Azzali and Menenti (2000) used the Fast Fourier Transform (FFT) to decompose NDVI time series into a set of periodic components and related their amplitudes and phases to aridity and vegetation types.
- Another method for the analysis of time series data is the generation of indices that break down the curve into measures of the timing and magnitude of signal response. These phenological metrics decompose the curve into a set of statistics reducing the curve to its parts within an individual cycle. Time series of NDVI, for instance, has been analysed to generate a set of metrics that summarise the phenology of vegetation (Lloyd, 1990, Reed et al., 1994), predict end of season biomass (Diallo et al., 1991, Prince, 19991), or assess landscape degradation (Holm et al., 2003).

A comprehensive set of reference studies, concerning the use of time series analysis in agricultural areas, is missing. Nevertheless, Hill and Donald (2003) demonstrated relationships between agricultural productivity and phenological metrics. The above described spatial indicators derived from time series data will be validated by means of high resolution images.

# 2. *Spatio-temporal characterisation of habitats and indicators for biodiversity impact assessment/modelling*

### a. Biodiversity specific

The effect of the CAP Agri-Environmental measures on biodiversity is not explicitly known up to now, especially in semi-natural areas that have become increasingly fragmented and isolated. Kleijn and Sutherland (2003) for instance thoroughly reviewed the effectiveness of European Agri-Environment schemes in conserving and promoting biodiversity and stated that there was a lack of research examining whether the schemes were effective at all. On the other hand, for specific areas and cases the effects of land management and policy measures on species diversity are well understood. It is also recognized that the maintenance of biodiversity requires spatial considerations. Hence, understanding the consequences of habitat change, and developing effective strategies to maintain biodiversity in disturbed landscapes, is a major challenge to scientists, land managers and policy makers (Bennett, 1998).

It is the explicit way in which the spatial arrangements of habitats within agricultural areas are considered that gives spatial sciences an important role in biodiversity research. Because the habitat of any species is usually not distributed homogeneously in nature, a species may occur as a set of local populations, each occupying a patch separated from other patches by areas of unsuitable habitats (Ricklefs and Miller, 2000). Since these local populations are assumed to be small, landscape phenomena like fragmentation and human intervention have important effect on population dynamics or even on extinction. Fragmentation related to e.g. intensive agricultural practices and human driven expansion has precisely been identified as the major reason for the decline of many endangered species. One of the challenges in conservation efforts is to understand the dynamics of spatially structured populations (Ricklefs and Miller, 2000).

To be effective, research concerning the success of agri-environmental measures must combine several disciplines such as geo-physical analysis, population genetics, population and community ecology, landscape ecology, forestry and further integrate scientific skills with applied management and policy. Moreover, efforts still need to be focused on the development and application of spatial technologies such as remote sensing and Geographic Information Systems (GIS) to correctly address the spatial dimensions.

The EC Fifth Framework Program research project "BioAssess" showed that diversity measures of birds, butterflies, lichens, plants, ground beetles, soil macrofauna and springtails responded markedly to land use in terms of abundance, diversity, and species composition. The BioAssess project developed methods to quantify the impact of land use change and environmental policies on biodiversity utilising remote sensing derived landscape indices and field samples of biodiversity. The project responded to the defined need of the EC to quantify the impact of policies on the decline of biodiversity. Several landscape indices were shown to be potentially useful indicators of the richness of single taxa. Among others, total core area, patch richness, and landscape evenness were shown to correlate well with species richness. Below (Figure 11) is an example of spatial modelling of Erithacus Rubecula (Robin) presence-absence data in an intensive agricultural area with landscape indices derived from Landsat images.

The characterisation of habitat structure through landscape indices requires high resolution images while the relationship between biological diversity and e.g. Net Primary Productivity can be assessed through time series of large area extent satellite images. These are, up to date, only available on a low spatial resolution so that future work will concentrate on up- and downscaling between high and low resolution spatial information. The method will allow us to detect areas that undergo important and consistent alteration of vegetation cover and status that can be identified to be the result of the implementation of AEM. Periods before and after implementation of AEM will be considered. It is essential to detect the areas that undergo substantial change but it is even more important to differentiate between the different types of processes underlying these, where the link of low and high resolution images will play a major role.

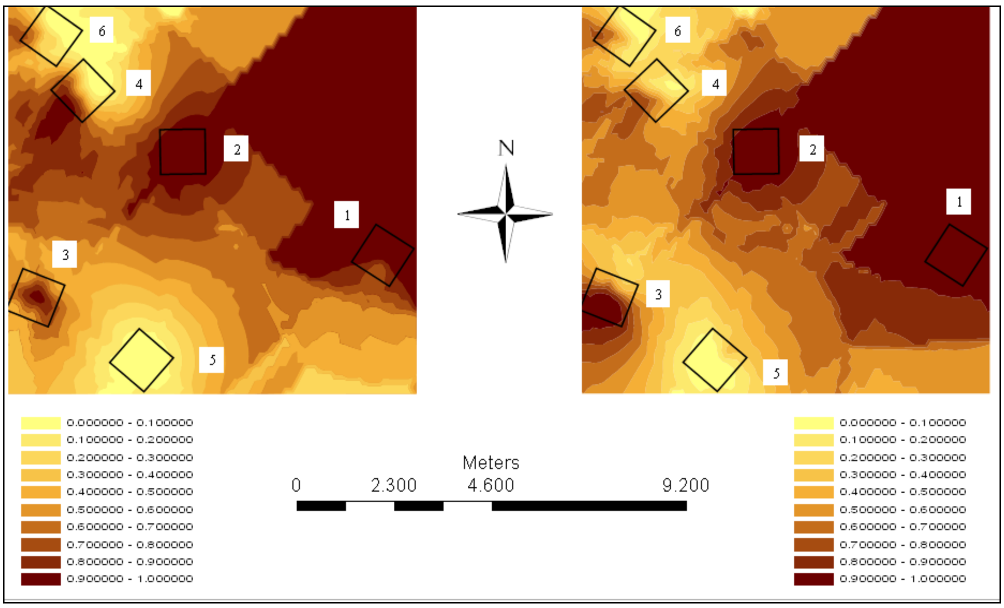



*Figure 11: Kriging prediction surface of observed (left) and predicted values (right) of Robin (Erithacus rubecula) presence-absence in areas potentially affected by AEM based on high resolution remote sensing data.*

### b. High resolution data processing

There are a number of indicators developed by the European Environmental Agency (EEA) for the measurement of biodiversity. Many of these indicators are difficult or are much too expensive respectively too time consuming to assess on a regular basis without remote sensing. Just to mention some out of the comprehensive number of indicators are forest area in hectares (ha), changes of area per year in ha, classification between forest and other wooded land, forest types, spatial pattern of forest cover, fragmentation, regeneration, landscape structure respectively pattern. As land use increases in intensity and extent in many parts of the world, we must begin to understand the role of landscape pattern in preserving, altering, or eliminating biological communities (Miller et al., 1997). High resolution remote sensing images allow identifying landscape structure through patterns of interconnected patches and are widely available nowadays. Numerous national and international projects have been initiated, which applied satellite remote sensing for derivation of landscape indices, quantitative measures of landscape structure. Many papers and publications address the relationship between landscape phenomena measured by remote sensing and species diversity. The role of remote sensing in landscape ecological studies seems to be well understood in the international scientific platform and European research projects.

Segmentation of remote sensing data becomes especially important in case of high-resolution images where it is more likely that a neighbouring pixel belongs to the same land cover class as the pixel under consideration (Blaschke et al, 2000). Besides that, the high spatial-resolution of advanced sensors increases the spectral within-field variability and therefore might decrease the classification accuracy of traditional methods on per pixel basis (Schiewe et al., 2001). Furthermore, information important for the understanding of remote sensing data is often not included in single pixels but in image objects and in the mutual relationship between them. Beyond the pure spectral information, image-objects are characterised by a number of additional features such as texture and neighbourhood information, which can hardly be exploited using pixel-based approaches (Hoffman and Van der Vegt, 2001). With image objects, meaningful statistic and texture calculation becomes possible, increased uncorrelated feature space using shape (e.g. length, number of edges, etc.) can be produced, and the close relation between real-world objects and image objects can be utilised (Benz et al., 2004). Object-based processing does not only consider contextual information but also information about the shape of and the spatial relations between the image regions. This is also advantageous for biodiversity studies on landscape level and regional level, which is based on the delineation of basic units like habitats or ecotypes. Even so it is well known that sharp borderlines and homogenous units seldom reflect reality, it seems to be the only feasible way to come up with a practical approach for land cover as well as landscape diversity characterisation.

A landscape patch is a relatively discrete spatial pattern which may vary in size, internal homogeneity, and discreteness and is the basic structural and functional unit of the landscape (Forman and Godron, 1986). The motivation to develop techniques for the extraction of image objects stems from the fact, that most image data exhibit characteristic texture which is neglected in traditional classifications (Blaschke and Strobl, 2001). Image segmentation is a method of defining discrete objects or classes of objects in an image (Ryherd and Woodcock, 1996). Segmentation can be done on hierarchical scales, where a semantic net is built between the different levels and their objects (Figure 12). This allows the development of a hierarchical classification scheme where the delineated objects can be further categorised into finer classes. Since the user can define the scale, which influences the detail of objects, this method is very useful for landscape ecological analysis aiming at biodiversity studies.

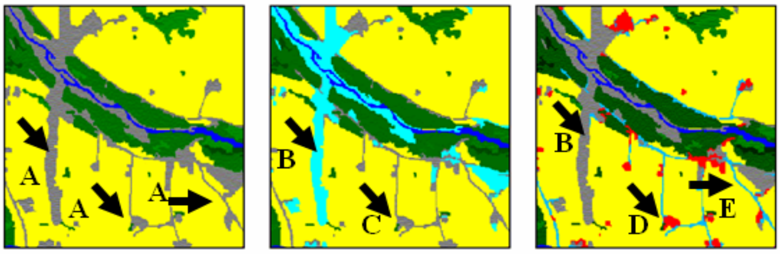



*Figure 12: Hierarchic segmentation with eCognition, orthophoto subset; left: level1 segmentation, A=artificial surface; middle: supporting level, A is divided into open soil (B) and human surface (C); right: level2 segmentation, C is divided into houses (D) and streets (E).*

Landscape patches identified from satellite images serve as basis when calculating landscape indices of fragmentation, connectivity or anthropogenic influence. For the calculation of landscape indices image processing techniques are required that produce homogeneous objects and well defined object edges. Segmentation is the technique, which groups pixels into homogeneous entities where original reflectance values are replaced with one value. These homogeneous landscape objects reduce the "salt and pepper effect" of pixel-based methods, and will facilitate the assessment of landscape scale effects of Agri-Environmental measures. For instance, the salt and pepper effect might lead to overestimating connectivity of landscape elements, e.g. of forest patches within an intensive agricultural area as shown below in an example from Switzerland (Figure 13). The application of object-oriented techniques will increase the confidence of assessing the effect of Agri-Environmental measures on the connectivity in intensive agriculture landscapes.

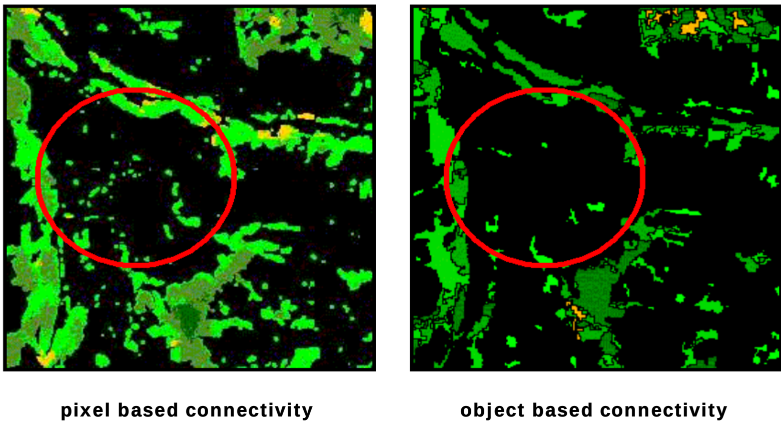



*Figure 13: Connectivity of forest habitats within an intensive agricultural area, pixel-based (left) and object-based (right) classification. Red circle indicates critical area, green objects represent forest.*

# 3. Characterization of intensity and spatial patterns and variation of land cover

## a. Trend analysis

The detection of spatial trend patterns is an important issue in long-term environmental studies (Udenhofer, 2006). Trend analysis of the 17 year GVF time series, considering periods before and after implementation of agri-environmental measures, is expected to provide indications on spatial patterns and intensity of changes in the vegetation cover. Excluding influencing phenomena, such as meteorological variations, these observed changes could then be attributed as direct environmental effect of these measures that address agricultural management practices related to increase in permanent vegetation.

A trend is characterized by its functional form, direction and magnitude and should be interpreted with respect to its statistical significance (Widmann and Schär, 1997). Most time series patterns can be described in two terms of two basic classes of components: trend and seasonality. The former represents a systematic linear or nonlinear component that changes over time and does not repeat within the time range captured by our data. The seasonal component on the other hand repeats itself in systematic intervals over time. These two components can coexist in the data, e.g. when the time series has a positive trend and the values repeat itself seasonally. The GVF data exhibits strong seasonality with high values in the summer months and low values in the winter periods. When modelling the time series data the seasonality has to be taken into account otherwise the model would not explain the seasonal variation and as a result the error would be autocorrelated. One possibility is the seasonal decomposition technique, which separates the total variation in the time series data into seasonal factors, trend and cyclical factors, unexplained variation (error) and the seasonally adjusted series. The seasonally adjusted series is the original series with the seasonal components removed i.e. a combination of the trend/cyclic and error components. This might enter the time series trend models as the dependent variable. Below (Figure 14) is an example of the seasonally adjusted series (right) of the original GVF data over the rainfed areas (left).

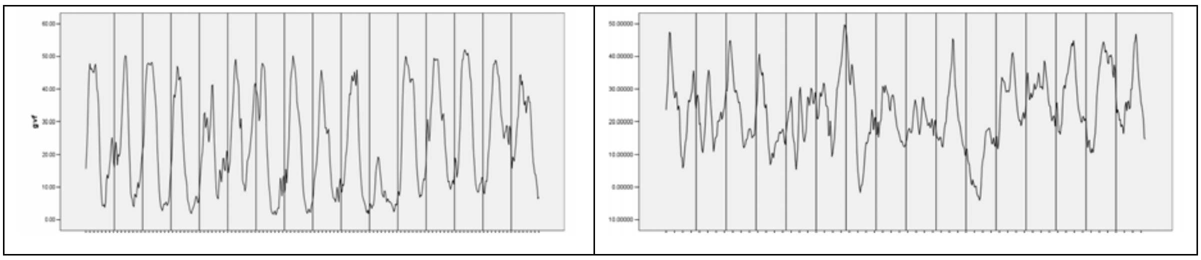
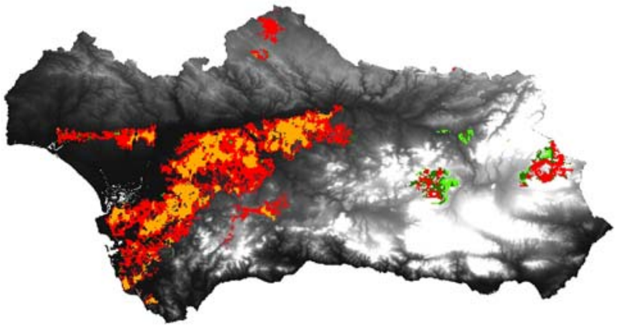


*Figure 14: seasonally adjusted series (right) of the original GVF data over the rainfed areas (left).*

In order to assess direction, strength, and significance in the time series data a linear function can be fitted. If there is a clear nonlinear component the data has to be transferred to remove nonlinearity. Below (Figure 15) is an example of trend analysis over rainfed areas in the periods of 1989-1999 and 2000-2004. The positive and negative trend values were ordered into two classes.

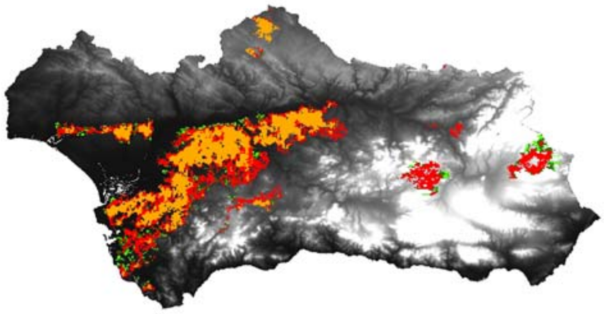


Trend analysis of GVF data within the period 1989-1999

Classes of the positive and negative trend changes

| Trend class | Change value | Change color |
|---|---|---|
| positive trend | | |
| Class +2 | x> 0.5 | |
| Class +1 | 0<x< 0.5 | |
| negative trend | | |
| Class -1 | 0>x>-0 | |
| Class -2 | x<-2 | |

*Figure 15a: trend analysis over rain-fed areas in the period of 1989-1999*



Trend analysis of GVF data within the period 2000-2004

Classes of the positive and negative trend changes

| Trend class | Change value | Change color |
|---|---|---|
| positive trend | | |
| Class +2 | x> 0.5 | |
| Class +1 | 0<x< 0.5 | |
| negative trend | | |
| Class -1 | 0>x>-0 | |
| Class -2 | x<-2 | |

*Figure 15b: trend analysis over rain-fed areas in the period of 2000-2004*

## b. Phenological Indices

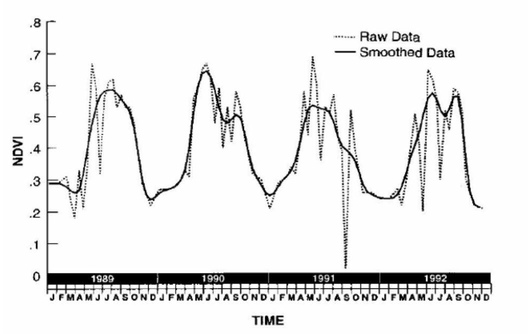
The quantification of phenological processes is very important for understanding ecosystems and ecological development. Phenological processes are determined by the length of the growing season, frost damage, timing and duration of pests and diseases, water fluxes, nutrient budgets, carbon sequestration and food availability. All these factors together determine population growth and influence species-species interactions (competition, predation, reproduction) and species distribution. The timing and progression of plant development may also provide information to help making inferences about the condition of plants and their environment.

For our work, the hypothesis is that changes in land cover and use, resulting from the AEM (see chapter I.1.), can be deducted from spatio-temporal analysis of phenological indices calculated from the satellite based time series data. Comparison of such results over areas where measures are applied and where not will be determine a proper characterisation of impact.

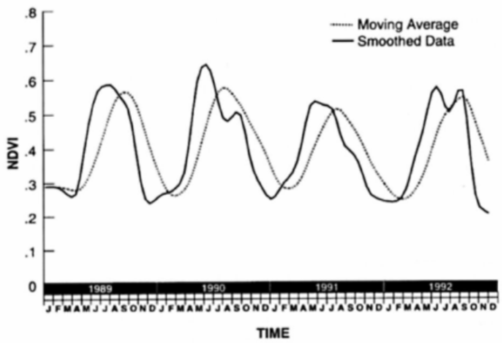
Already in the late eighties Goward et al. (1987) demonstrated that the time integral of the NDVI (area under the curve) over an annual period produced a measure related to net primary productivity values of different biomes. Based on the similarity with the GVF data (similar but enhanced information on vegetation phenology and state) it is straightforward to assume that the latter will also perform comparably well for quantifying changes in state of land cover as expressed in the hypothesis in chapter I.1.

After the method of Reed et al. (1994) initially five phenological indices were calculated from the time series of the Green Vegetation Fraction image. In a later phase of the project the calculation of other indices and the application of the FAPAR data are also foreseen. These metrics may not necessarily correspond directly to conventional ground-based phenological events but provide indicators of ecosystem dynamics and a measurable change in ecosystem characteristics.

The GVF time series data was smoothed using a 5 interval running median filter followed by the calculation of two forward and backward lagging curves, by means of a moving average algorithm. The crossings of the original curve in the upwards direction and the forward lag define the time period when the GVF curve is significantly higher then its minimum value (Figure 16), thus potentially the start of the growing season. Similarly, the cross point of the original curve and the curve lagging behind will be significant as the end of the season. The period of the lag should correspond approximately to the length of the non-growing season for the environment in question (Reed et al. 1994). For this reason, stratification will be carried out to provide climate, morphological and latitude adapted average non growing periods by means of field data like crop calendars, yearly sowing-harvest patterns, weather data or the farm systems approach. Initially the following metrics are calculated, but a more exhaustive set will be created in the later phase: (1) start of growing season, (2) end of growing season, (3) length of growing season, (4) time integral, and (5) intensity of the season.



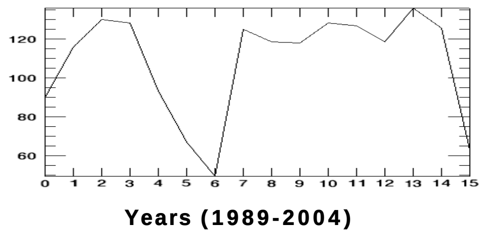
Running median smoothing of the time-series data (after Reed et. al, 1987)



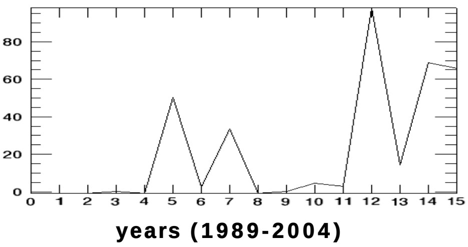
Forward lag created by a moving average algorithm: crossing of the original and the lagged data define the start of the growing season

*Figure16: Running median smoothing and the mowing average lag of the time-series data*

The pattern of length of growing season shows a high degree of spatial variation for the years 1989-2004 and for the rainfed and olives areas Years 1991, 2000, and 2002 stand out as a good year over the rainfed area (see Figure 17) while the year 1995 brought few green vegetation. This year was exceptionally dry that is consistent with the dependency of green vegetation on precipitation events over the rainfed area. This year was also very poor for the test area in olive plantation while exceptionally long season was observed here in 2001. The observed differences in the spatial pattern of the growing season throughout the years (when adjusted to climatic factors) might be highly indicative on the effect of Agri-Environmental measures and on the state of the environment and on biodiversity.




Length of growing season in the rainfed area in Andalusia




Length of growing season in the olives plantation in Andalusia

*Figure 17: Running median smoothing and the mowing average lag of the time-series data*

## c. Principal Component Analysis

The principal components analysis is a multivariate statistical technique which is often used for data-compression, for change detection and for long sequence time series evaluation., The intrinsic value of the Principal Component analysis is, for the AEM impact assessment, in the potential to highlight spatial patterns related to different behaviour and intensity of change of environmental aspects.

The Principal Component transformation is a direct outcome of the high correlation that exists between dates for regions that are relatively constant and the low correlation associated with regions that are quite different with time (Richards, 1984). The mathematical basis for the technique suggests that the first principal component will indicate the typical values over a series while successive components represent change in order of magnitude (Eastman, 1993). From the second principal component on the transformation will provide information on the major changes occurring within the series and can be used to isolate areas for more specific scrutiny. The reason for this is the assumption that the major portion of the variance of a time series data is associated with correlated, i.e. constant land cover types, which will be summarized in the first component. Regions of localized change will be enhanced in the higher principal components. Standardised Principal Component Analysis is based on the correlation matrix which is derived from the covariance matrix by dividing the values with their standard deviation. The standardisation is intended to minimize the undue influence of other extraneous factors like atmospheric interference (aerosols and water vapour) or changes in surface illumination conditions. This procedure has been found to be very useful in the analysis of time series data sets where the interest is in the identification of phenomena or signals that propagate over time, like the green vegetation fraction signals.

In the present study the standardised principal component technique is applied on the time series of the GVF data. One reason for mapping change in phenology could be for instance screening areas where the habitat structure persisted over time. High habitat heterogeneity that persisted over a long time period was showed to have a correlation with species richness potentially through higher speciation rates (Kerr, 2001). Only those principal components images are selected, which explain more then 90% of the total variation in the dataset. These images are then visually inspected for a distinct spatial pattern, and those where mostly noise dominates are excluded from the further analysis. The component loadings of the single principal components are plotted against the single bands in order to understand the connection between the extracted components and the seasonality of the data. The loadings take up values between -1 and 1 and can be interpreted as a correlation measure. In the GVF time series the first 12 components explained over 90% of the total variation. These 12 images can be considered to represent the seasonal and change components of the 16 years GVF time series data.

The interest of the present study lies in examining the change patterns i.e. the atypical components in the time series data. Component 2 is computed from the residuals after the variance accounted for by component 1 are removed. The second component accounts for 11% variation in the 16 years time series. High PC2 values show high peaks in the non-growing seasons i.e. in the winter months and low values in the growing seasons i.e. in the summer months (Figure 18). From 2000 on a shift can be observed: high PC2 values occur in the summer months (not shown). Very high PC2 values occur in non-irrigated herbaceous crops and in agro forestry areas in the north of Andalusia in the province of Cordoba (dotted white circle 1). Also in the southern region in the province of Cadiz continuous grassland and herbaceous crops exhibit high pixel values in the second component (dashed white circle). Very low PC2 values occur in rice fields and in other irrigated herbaceous crops areas in the province of Sevilla (dotted black circle). In the Granada region the Sierra Nevada Mountains and other grassland/scrubs/rock surfaces exhibits very low PC2 values (dashed black circle. Moderate values are observable in annual crops. So, high PC2 values indicate areas where there is generally a lot of / or at least there is vegetation throughout the non-growing season: agro forestry, annual crops, non-irrigated arable land and pastures. The latter category can be considered as natural vegetation.

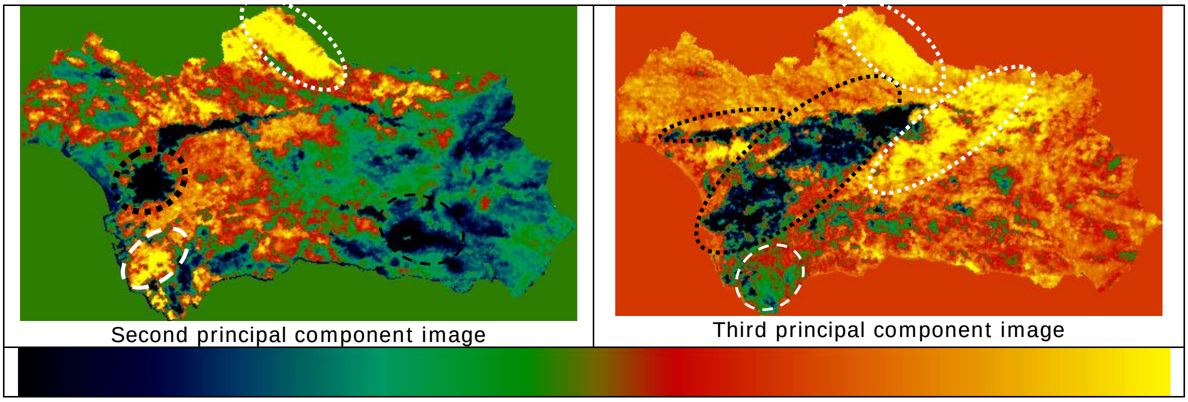



*Figure 18: First and second Principal component image of the GVF time series data*

The third principal component amounted to about 4% of the total variation and is a residual pattern calculated after the variance accounted for by components 1 and 2 has been removed. Winter months correlate positively and moderately with high PC3 values, except the years 1994, 2001, 2003 (not shown). Especially 2001 exhibits very low values, both absolutely and within the months. The spatial pattern of component three shows distinct negative anomalies in non-irrigated arable land across the provinces Cadiz and Seville (dotted black circle). Very strong positive anomalies can be observed in olive groves in the province Jaen (white dotted circle) and agro forestry areas in Cordoba (white dashed circle). In the northern part of Cordoba non-irrigated arable land areas are pinpointed with both high and low values in the third principal component. The reason for this might lie in management practices or in the application of Agri-Environmental measures. For this analysis field data of the applied measures are inevitable. Moderate to no anomalies can be observed in broadleaved forest, natural grassland and Screlophyllous vegetation land cover types south of Andalusia, the province of Cadiz (dashed white circle).

## d. Fourier Analysis

The Fourier Analysis contributes to the impact assessment as it allows to analyse the cyclic character of e.g. land cover changeability. Hence, it can facilitate interpretation of other analysis results by indicating outlier situations and variability or steadiness of observed environmental changes.

Fourier Analysis is based on the concept that real world signals can be approximated by a sum of sinusoids, each at a different frequency. The more sinusoids included in the sum, the better the approximation (Figure19). The frequency of each sinusoid in the series is an integer multiple of the frequency of the signal being approximated. These are referred to as the harmonics of the original waveform. Each of the harmonic frequencies is defined by a magnitude (amplitude) and a phase. The phase indicates how to shift the harmonic before adding it to the sum. The phase information can be difficult to interpret and its use is restricted to a few specialized applications for instance where the yearly shift in the magnitude of the green vegetation fraction is of interest.

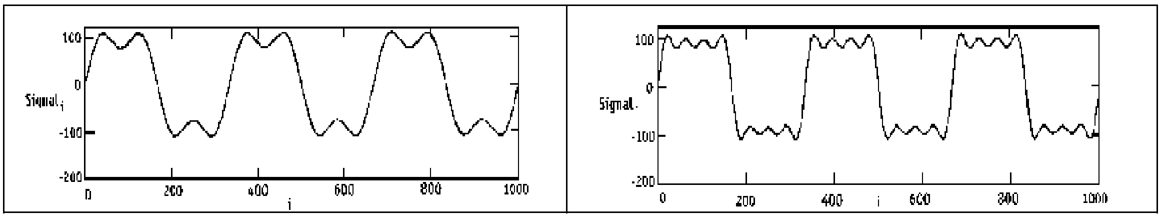



*Figure19: Real world signals approximated by sinusoids*

Amplitude values for periods of twelve and six months are closely related to agro-biological phenomena, such as the growth of vegetation in response to the annual patterns in temperature and rainfall. The amplitude (magnitude) at one year period measures the maximum total variability of the NDVI values, or total biomass activity, over one year, from the minimum to the maximum NDVI values. The phase value at one year period is the time lag between the maximum NDVI and the beginning of the series (first dekad in January). For the period of six months the amplitude is a measure of the variability of NDVI within half a year. The two sided power spectrum of the series is estimated by the periodogram method derived from the Fourier transform. The amplitude of the periodogram for each period Tk is computed as the fraction of the variance of the series. that is explained by the given period. The phase term is also recovered from the discrete Fourier transform of the series The arctangent function returns values of phase which has for each Fourier frequency the range [-pi, pi]. Thus the full range is 2pi radians, the perimeter of the unit circle. Addressing the annual cycle in dekads data the range [-pi, pi] corresponds to the range of 36 dekads in a year, from January to December. By the following transformation the phase spectrum is obtained in degrees.

$$P(\lambda)_{\deg} = \frac{180}{\pi} P(\lambda)_{rad}$$

The windowed Fourier Transform (WFT) uses a sliding rectangular window of length T that moves along the time-series with the sampling rate of $\Delta t$ and a total length $T = N\Delta t$. For each window the FFT derives the Fourier frequencies $T^{-1}$ to $(2\Delta t)^{-1}$. The length of the window is selected such that the basic cyclic components of interest are represented by these frequencies. For instance, the development of the annual cycle's amplitude in monthly temperature data can be assessed by selecting *T* as any integer multiple of 12.

Short-lived high frequency components, such as abrupt changes in vegetation cover caused by wildfires, drought-induced stress, deforestation and crop harvesting causes rather short-lived high-frequency impulses in the signal. Here, good time localization is needed that is guaranteed if a comparable small window size is used. Respecting the 16 years time series, 16 magnitude and phase values can be calculated. With trend analysis techniques a linear trend model can be fitted on these values and positive respectively negative changes throughout the time series can be calculated. Below, Figure 20 shows positive (green) and negative (red) trends of the phase (left) and the magnitude (right) measures within non irrigated arable land areas in the period 1989-2004. Trends were calculated as the regression coefficient b of the linear trend model.

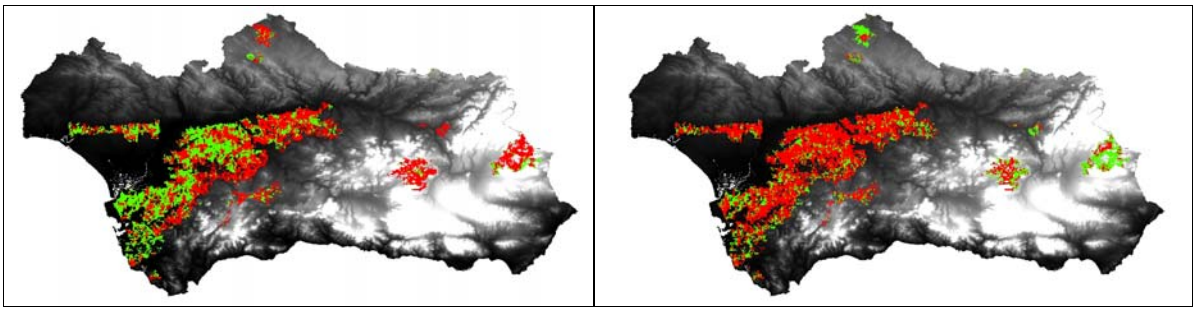


*Figure 20: positive (green) and negative (red) trends in the phase (left) and magnitude (right) values throughout the period 1989-2004.*

## e. ARIMA Modelling to explain the pattern in the GVF data with independent variables

In order to assign observed changes of environmental and landscape aspects, as resulting from above indicated analysis, to Agri-Environmental measures, the importance and dependency of other influencing phenomena has to be understood and/or isolated, in space and time, from the data series itself. Hence, the purpose of the ARIMA modelling of the GVF time series data is, on the one hand, to understand the internal structure of the data and, on the other hand, to explain the structure of the data against independent environmental variables such as meteorology, soil quality and socio economic variables.

For modelling the GVF time series data the ARIMA (Autoregressive Integrated Moving Average) technique was used. The identification of possible autoregressive or moving average processes requires the examination of the autocorrelation (ACF) and partial autocorrelation functions (PACF) of the GVF series. When testing for autocorrelations in the data it is important to look at lags that are multiples of the periodicity in the data, since these lags will reflect seasonal effects. If the ACF of the time series is not completely stationary, differencing is necessary to stabilize the series which is one of the statistical requirements of the ARIMA models. Following the theoretical guidelines describing ACF and PACF patterns in statistical handbooks, the GVF series (over the rainfed area) exhibits an AR rather then a MA process. In the case of the rainfed area an AR process of order two was defined

After defining the structure of the ARIMA model, three independent variables (precipitation, maximum and minimum temperature) were included in the model in order to account for their explanatory power in the GVF data. The ACF and PACF of the model residuals indicated that the residuals of the ARIMA model were random, thus the model successfully accounted for the seasonal factors in the time series and that no essential components have been omitted. The table below exhibits the parameter estimates from the ARIMA model defined above. Both the first and second order autoregressive parameters are significant on the 5% confidence level, indicating that the fitted model is correct. Precipitation and maximum temperature observed at simultaneous time periods do not explain the development of green vegetation fraction along the time series. However, lagged versions of the variable precipitation up to the order four significantly explain the variance in the GVF data. This means, that the development of the green vegetation can be attributed to precipitation events up to four months before the time period under consideration. Maximum temperature in the area does not exhibit an explanatory power but the lagged versions of the variable (lagged two and three months behind) become significant on the 5% level. In case of the minimum temperature in the area, already the time synchronized variable demonstrated a significant explanatory power in the development of green vegetation cover on the 0,019 significance level.

The lagged versions of the minimum temperature over the rainfed area also demonstrated to have significant effect up to a lag of three months. On the other hand, despite their significance the estimated values of these variables indicate that their contribution to the model is very low (see the “Estimates” column in Table3 below). That indicates that other independent variables not investigated here might give better explanatory values for the development of the green vegetation fraction over rainfed areas. Furthermore, the climatic data used here were sampled on a 5 by 5 km grid while the green vegetation fraction was derived from the 1km spatial resolution NOAH AVHRR data. Future work concerns the application of climatic data sampled on a 1km grid as well as the usage of socio-economic explanatory variables and the investigation of the effect of Agri-Environmental measures.

*Table 3: Parameter estimates of the ARIMA model*

| | | Estimates | Std Error | t | Approx Sig |
|---|---|---|---|---|---|
| Non-Seasonal Lags | AR1 | .818 | .104 | 7.839 | .000 |
| | AR2 | -.242 | .112 | -2.171 | .032 |
| Regression Coefficients | prnfd | -2.7E-005 | .000 | -.132 | .895 |
| | tmaxrnfd | .009 | .007 | 1.323 | .189 |
| | tminrnfd | -.019 | .008 | -2.380 | .019 |
| | LAGS(prnfd,1) | .000 | .000 | 1.918 | .058 |
| | LAGS(prnfd,2) | .001 | .000 | 5.235 | .000 |
| | LAGS(prnfd,3) | .001 | .000 | 3.452 | .001 |
| | LAGS(prnfd,4) | .001 | .000 | 2.582 | .011 |
| | LAGS(prnfd,5) | .000 | .000 | -.876 | .383 |
| | LAGS(tmaxrnfd,1) | .010 | .007 | 1.530 | .129 |
| | LAGS(tmaxrnfd,2) | .030 | .006 | 4.846 | .000 |
| | LAGS(tmaxrnfd,3) | .014 | .006 | 2.134 | .035 |
| | LAGS(tmaxrnfd,4) | .002 | .007 | .290 | .772 |
| | LAGS(tmaxrnfd,5) | -.005 | .006 | -.786 | .434 |
| | LAGS(tminrnfd,1) | -.027 | .008 | -3.322 | .001 |
| | LAGS(tminrnfd,2) | -.042 | .008 | -5.518 | .000 |
| | LAGS(tminrnfd,3) | -.018 | .009 | -2.129 | .036 |
| | LAGS(tminrnfd,4) | -.011 | .010 | -1.100 | .274 |
| | LAGS(tminrnfd,5) | -.001 | .008 | -.175 | .861 |

Melard's algorithm was used for estimation.

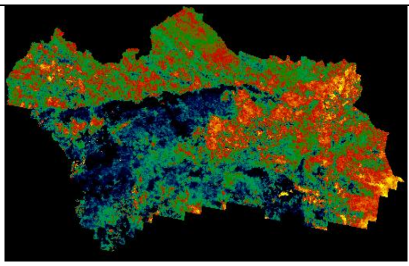
Parameter estimates of the ARIMA model

prnfd: precipitation above the rainfed area
tmaxrnfd: maximum temperature above the rainfed area
tminrnfd: minimum temperature above the rainfed area

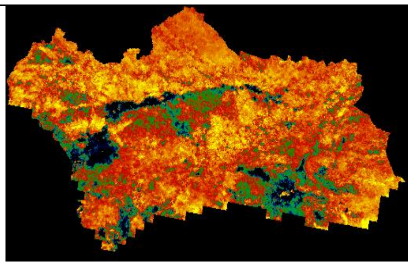
With the newly developed software TimeStats from the University of Trier, Department of Remote Sensing (Udelhoven, 2006) it is possible to run the ARIMA model described above on a pixel by pixel basis rather then on values averaged over a selected test area. This facilitates the interpretation of vegetation processes, as green vegetation fraction values over the smallest possible spatial unit of a remote sensing image are used.

The ARIMA model above suggested an autoregressive seasonal and non-seasonal regression process of order two. In order to account for the realistic time lags between the amount of green vegetation and the meteorological variables precipitation, minimum and maximum temperature over the whole Andalusia region, a time lag of four was selected in the present analysis. Precipitation reached a maximum Pearson’s correlation coefficient of 0.36 and a minimum of -0.45 over the whole region. Lagged versions of this variable up to four months reached maximum correlation values of only 0.49 (lag of three months). This indicates that over the Andalusia region, precipitation with a time lag of four months can only explain up to 40% in the development of the vegetation as measured by the Green Vegetation Fraction image. However, the spatial distribution of the Person’s correlation coefficient indicates that these values appear in many regions of Andalusia over a large territory.

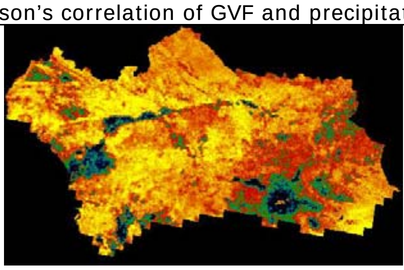
Maximum temperatures measured over Andalusia exhibited higher positive and negative correlation values up to 0,92 and -0.80, respectively (not shown). Highest correlation values were achieved from the time synchronized temperature values but also time lagged versions of the variable exhibited high positive and negative correlations. Minimum temperature behaved similarly. The above observed spatial pattern of the Pearson’s correlations and their significance has to be explained based on the land use map received from partners in Andalusia and based on knowledge about the vegetation cover.



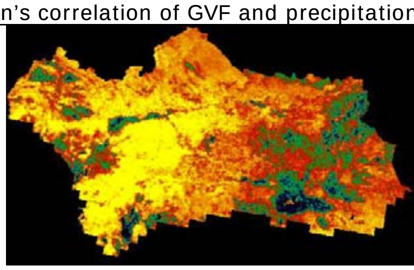
Person's correlation of GVF and precipitation



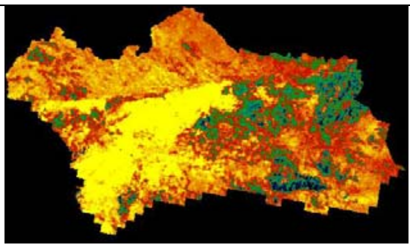
Person's correlation of GVF and precipitation, lag1



Person's correlation of GVF and precipitation, lag2



Person's correlation of GVF and precipitation, lag3



Person's correlation of GVF and precipitation, lag4

scale of the color table: dark blue indicates lowest values, yellow indicates highest values

*Figure 21: Person correlations from a linear regression model of GVF with lagged precipitation series.*

The spatial pattern and its interpretation might be useful for:

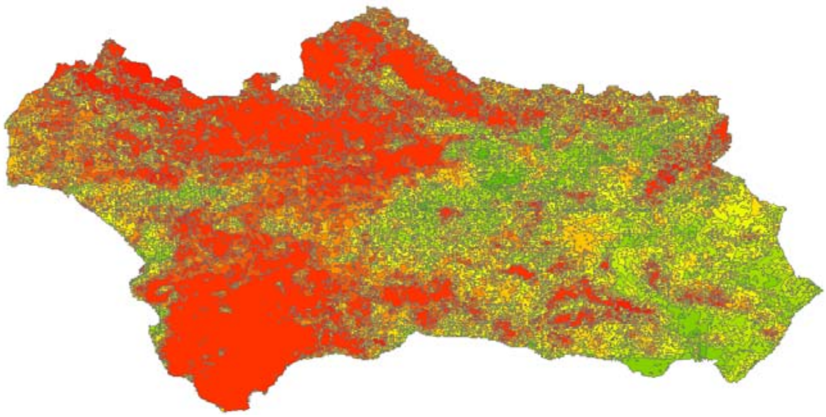
- Developing a strategy for the stratification of vegetation cover / climate dependent vegetation zones. The GVF images stratified according to these zones might be used as input for the calculation of phenological indices and for other signal processing techniques as the Principal Component Analysis or Fourier and wavelet analysis techniques.

- The strata might be useful for the decision if the pattern observed in the GVF data has to be normalised for climatic variables and if yes over which areas. Pixels, where no negative or positive correlations were measured between the GVF image and the meteorological data might be left unchanged.

The spatio-temporal analysis of these various datasets will yield a set of characteristics that will then be compared over areas where Agri-Environmental measures were applied and over areas where no specific measures were applied. Through other models and/or proposed indicators, these results will be further linked to assess the actual environmental impacts in terms biodiversity, water quality and climate change.

# 4. Development of spatial indicators for biodiversity and rural development policy

Unsupervised or supervised classification of the agricultural zone based on temporal and spatial pattern of the phenological metrics could reveal a set of classes that are characterised by differences in overall magnitude and response in particular years. Textural images of the phenological indices might also give useful indicators on the state and change of the phenology and thus might serve as input for the biodiversity study. Considering the time integrated GVF (TIGVF) metrics for example, when averaged over all years the classes might be defined by increasing value of TIGVF with relatively similar spatial variability, but classes with similar average TIGVF are differentiated by degree of variability in temporal values. The classes with their mix of different magnitudes and interannual variation in the time integrated GVF data could identify distinct interactions between landscape characteristics and production response, i.e the mix of crops and pastures and the climatic-induced patterns of production. Hill et al. (2003) for example calculated the average values of the other phenological metrics for each time integrated NDVI classes revealing both the major factors responsible for the TINDVI response and the limits and benefits of particular metrics. They identified a set of zones which could be readily related to land use and climatic characteristics. The same authors found evidence of the relationship of TINDVI data to agricultural productivity, depending on the extent to which crop or total agricultural production are directly reduced by rainfall deficiency.



Color range: green = cold spots, i.e. polygons with lower then average values near each other; yellow= moderate sized core area; red = hot-spots, i.e. polygons with higher then average values near each other

*Figure 22: Calculation of the Ord-Getis GI statistic over Andalusia for the definition of hotspots*

A map of vegetation functioning and its change strata can be developed. This characterisation of the variability of vegetation functioning will serve as basis for the further analysis. On one hand, the derived functional classes will serve as habitat maps, classified both within areas under Agri-Environment agreements and areas without applied measures. The derivation of e.g. landscape indices on the basis of this map will quantify e.g the fragmentation and connectivity of the habitats and also will document the changes of these processes. Core Area of the habitats can be calculated, which has been used extensively as biodiversity indicator especially for e.g. bird species known to rely on edge habitats. Bailey at al. (2004) on the other hand calculated the Simpson's diversity index to measure the heterogeneity of NDVI classes and correlated the diversity values with observed bird and butterfly species richness values. But simply the classification and the definition of temporal development of e.g. grassland area might be useful to predict the probability of finding certain bird species (Herkert 1994; Vickery et al. 1994). Another interesting aspect might be the calculation of spatial clusters of statistically significant high or low values used to identify spatial "hot spots" or "cold spots" e.g. with the Ord-Getis GI statistic (see Figure 22). This indicates the extent to which a location is surrounded by a cluster of high or low values. It shows areas where higher-than-average values "hot spots" tend to be found near each other or where lower-then-average values "cold spots" tend to be found near each other. With such analyses hot spots or areas with high vegetation vigour through the years could be found and assuming this as a measure of net primary productivity linkages with biodiversity data could be established.

# III. Outlook

In the Common Framework for Rural Development Policy evaluation schemes and strategic monitoring of the Community and national Agri-Environmental strategies for the period 2007-2013, Regulation (EC) No 1698/2005, DG AGRI included a number of indicators for the RDP Axis 2: Improving the Environment and the Country Side through land Management. Many of these are based on the IRENA indicator proposals. These indicators will allow aggregation of outputs, results and impacts at EU level and help assess progress in achieving Community priorities.

The results of the IRENA Assessment Report and Mid-Term RPD evaluation report (Agra CEAS 2006) produced for the EU, however indicate that methods applied for compilation of the indicator data can still be improved. This illustrates again the need for the development of further indicators for the assessment of the environmental impacts of rural development strategies. The current research proposed in this report is expected to contribute to the insight in the process of indicator compilation and to improve on the aggregation options. Remotely sensed time series of vegetation phenological change, indication on landscape/land use alteration or alteration of crop patterns is expected to provide important linkage to the statistical analysis of sampled biodiversity data, in response to one of the Community priorities.

The EEA briefing on environmental integration in EU agricultural policy (2006) also states the need for better targeting of Agri-Environmental schemes in regions of highest biodiversity concern to ensure that farmland habitats in the Natura 2000 network are appropriately managed. Proper impact assessment also contribute to better targeting of measures, once the cause-effect relations are identified.

Further work will focus on:

- further improvement of the tested remote sensing signal processing methods for the monitoring of permanent vegetation cover, its changes and its importance as Agri-Environmental indicators.

- testing of other advanced methods, e.g. the Fourier analysis and wavelet analysis methods for the quantification of change in time series curves.

- the production of a change map over the selected target areas “rainfed” over the Andalusia region.

- the establishment of a spatial database in Andalusia attributing areas with and without applied Agri-Environmental measures.

- the collection of existing biodiversity data, partly sampled in past EU competitive projects and partly being sampled in ongoing initiatives. These data are of outmost importance in order to draw statistically significant conclusions about the environmental impacts of Agri-Environmental measures. First contact to possible future partners have already been made.

- the application of Spot Vegetation data

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**Abstract**

The report introduces the concepts and strategies for implementing spatial based methods for the assessment of actual environmental impact of Rural Development agri-environmental measures. The objective of the research work is to propose an array of possibilities to identify, assess and to map the impact of the Rural Development schemes related to the Community environmental priorities in contribution to the EC defined evaluation indicators. The work is to be carried out in several pilot sites complemented by specific research adding to the spatial dimensions of the impact assessment.

Experiences are being linked and made available through the establishment of a technical Pilot Site Network. Specific research results will be reported separately.

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