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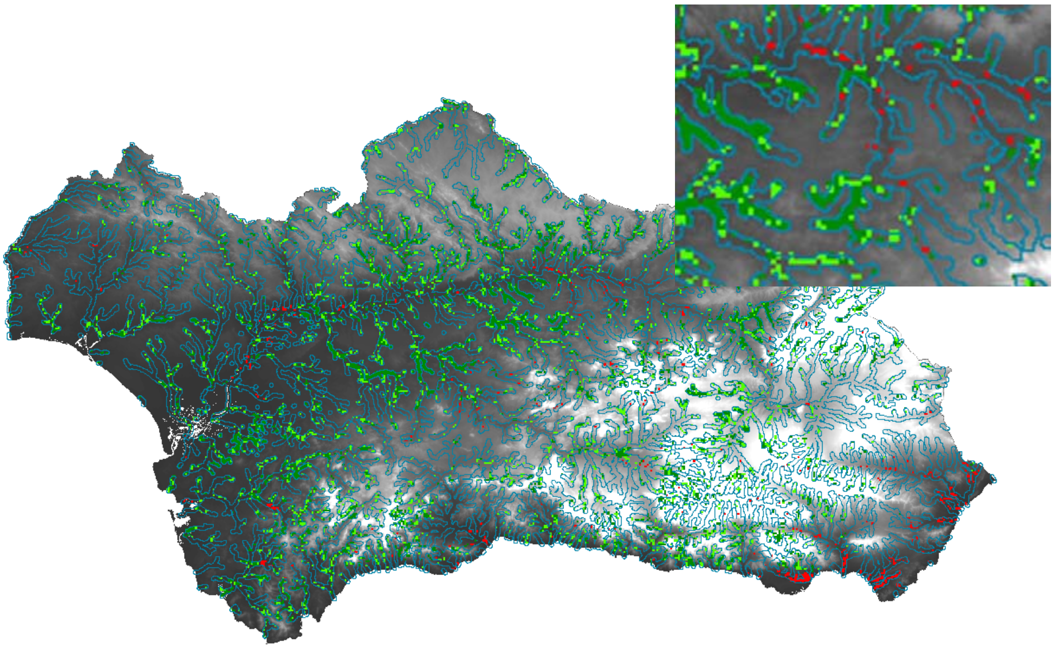

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Spatial Assessment of the Status of Riparian Zones and Related Effectiveness of Agri-Environmental Schemes in Andalusia, Spain

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I Summary and Main Findings

- The concise report -

The report introduces the concepts and results of a case study on riparian zones in Andalusia, Spain with focus on the assessment of actual environmental impact of Rural Development Agri-Environmental Measures (AEMs) by implementing spatial data and remote sensing based methods. 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.

EU policies and funding instruments such as the Common Agricultural and Regional Development Policies have a huge impact on the environment within Europe. In the past these were 'market' driven and in many cases the environmental impacts have been also negative, causing e.g. wetland loss and deterioration of water resources resulting from higher agricultural inputs across Europe. It is now widely recognized that human activities like urbanization, tourism, transport, and energy production have widely destroyed and damaged freshwater ecosystems effecting both water quality and quantity. The Water Framework Directive (WFD) aims to 'prevent further deterioration' and achieve good ecological and chemical status in all European waters by 2015 in an integrated river basin management context. The WFD focuses on sustainable development of water resources in establishing joint management of all waters in a catchment and promotes integration of water policy with other major EU policies like e.g. agriculture. The directive applies to all 27 Member States and candidate countries and to all those non-EU countries sharing river basins with the member states. It is the first EU directive that besides the chemical aspects also addresses ecological status such as flow regime, river continuity and abundance of aquatic organisms. The WFD considers rivers embedded in their ecosystems closely linked to their riparian areas and floodplains that will facilitate major restoration plans.

Riparian zones have been documented to exert multiple functions such as protecting soil, water and habitats and therefore are addressed in a number of EU policies. This case study looked into mapping the quality status of these riparian zones and examined how far AEMs could affect and improve their status. One of the scopes of the AEMs is promoting extensification. It has been shown that in case surrounding agricultural practices are extensified the status of the riparian system is better. Hence the implementation of AEMs could positively influence the status of the riparian zones. Four main assumptions were the driving forces of the work: (1) a positive relation between better riparian status and extensive land use based on documented sub-basin statistics for the Guadalquivir river basin. (2) Under AEMs like extensification an increase in the amount and vigour of the vegetation can be expected. (3) In a riparian buffer zone with favourable status more permanent vegetation cover can be expected than within zones in unfavourable status. (4) This information on permanent vegetation cover can be extracted from time series of remotely sensed vegetation indices.

Further, the present study suggests widening the concept of riparian zones into a larger riparian area including immediate surrounding land. This landscape element is capable of reducing erosion and surface runoff, limiting nutrient leaching through adapted land use as well as buffering dry land against floods and maintaining habitats of high nature conservation importance.

The riparian zones of the Guadalquivir river network have been mapped and analyzed by using three types of spatial data. (1) Time series of the Green Vegetation Fraction derived from the NOAA AVHRR satellite were used to calculate the permanent vegetation cover over the area during a sixteen year period (1989-2004). (2) A point database (PDRA) on riparian quality, derived from field surveillance and aerial photo interpretation. This database is based on the QBR (Qualitat del Bosc de Ribere) index that once computed gives the status of the riparian zone. Mostly forest but also shrubs and other low lying vegetation (except annuals) are considered. Cover structure (% of forest cover), cover quality (geomorphological type of the stream and number of native tree species), and naturalness (morphological changes due to agricultural activities) are taken into account to compute the index. The data was used for classifying the complete riparian network into ‘favourable’ and ‘unfavourable’ categories based on the low resolution satellite data. (3) GIS layers on the implementation of AEMs at farm level were utilized to assess their effect on the riparian status.

Using the CCM database a 1km buffer was calculated along the left and right river side of the Guadalquivir river basin. The 1 km buffer was used to represent the riparian-use zone and was classified into favourable and unfavourable status (figure 1.). For the classification a fuzzy nearest neighbour method was applied on the remotely sensed permanent vegetation fraction and was trained with the ground observation of the PDRA points. Thirty percent of the observations were selected randomly to train the classification excluding contrasting observations falling within the same 1km pixel to account for spatial autocorrelation. For the accuracy assessment of the results all points were included. In order to keep the Nearest Neighbour feature space as simple as possible, a principal component analysis was carried out on the sixteen remote sensing derived permanent vegetation fractions. The first three components explained ca. 90 % of the total variation and therefore these were used in the classification. Trend analysis was used to assess the direction and strength of the trend in the yearly permanent vegetation fraction data within the favourable and unfavourable riparian-used zones, both with and without AEMs (erosion measures in olive groves) applied. A linear function was fitted to the sixteen years seasonal permanent fraction because the curve analysis procedure exposed equal or lower significance of other functions.

The overall accuracy of the classification of the favourable and unfavourable riparian-used zone amounted to 89%. The fuzzy classification enabled the creation of a spatially continuous map of the status of the riparian-use zone thus no pixels were left unclassified. Frequency distribution of the classification

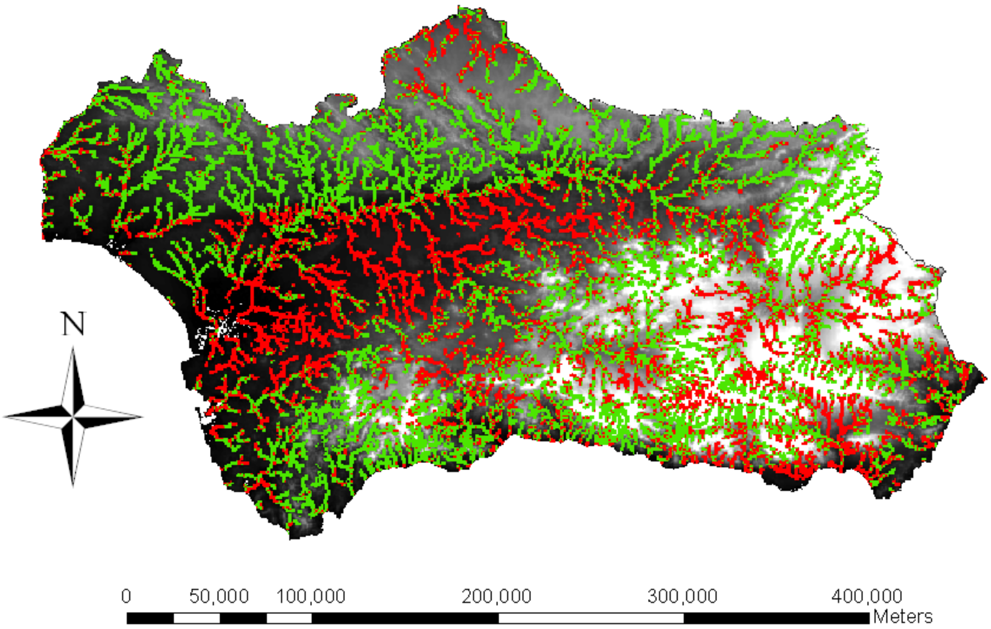


Figure 1: Classification of the favourable (green) and unfavourable (red) status of the riparian-use zone in Andalusia.

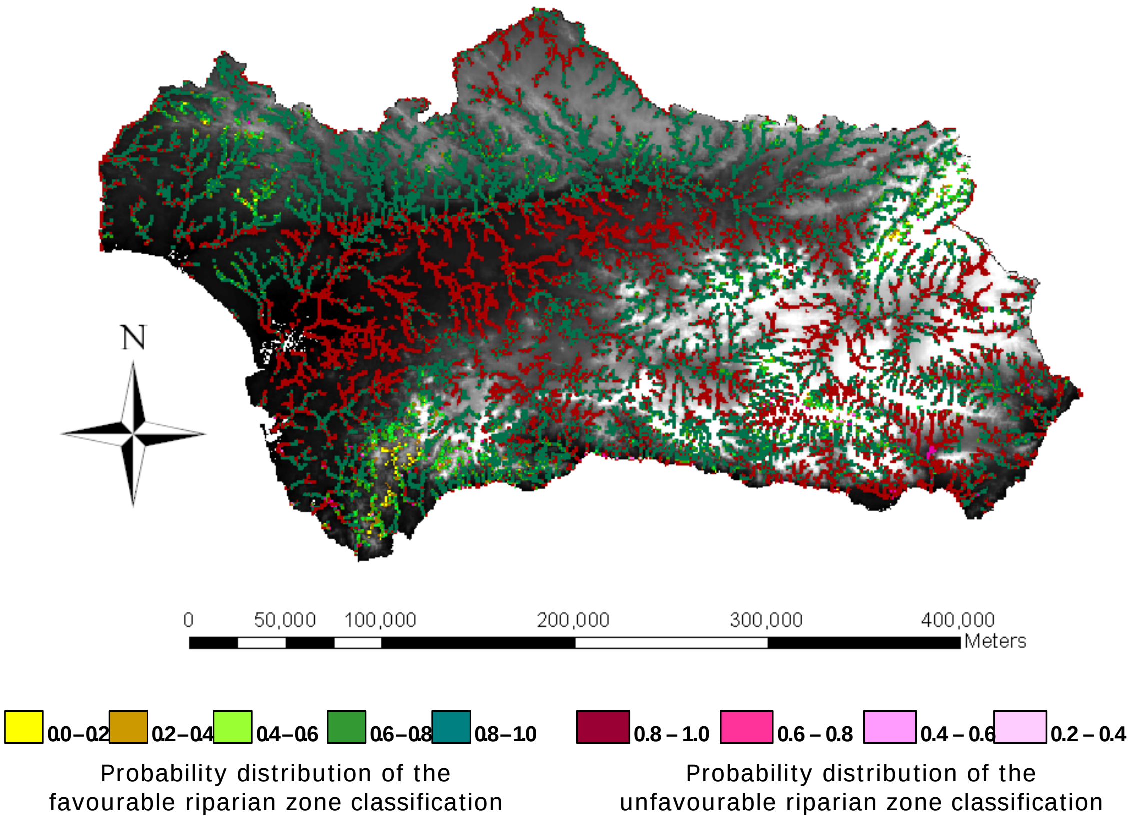
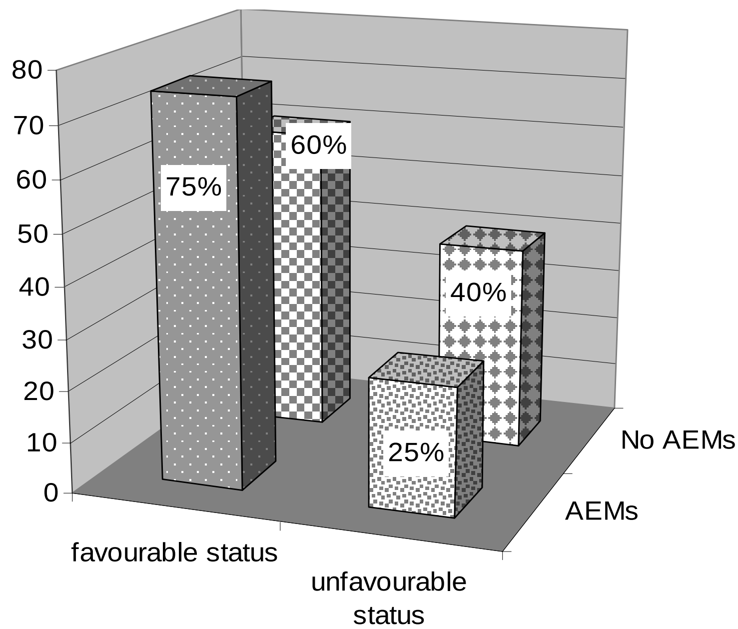


Figure 2: Probability of the riparian zone classification. For each pixel the probability of belonging to the finally assigned favourable or unfavourable categories is shown.

probability of the favourable and unfavourable categories was strongly skewed indicating that most of the pixels were classified into the respecting category with a very high probability. Ninety six percent of the pixels classified into the favourable category reached a probability of correct assignment between 0.8-1.0, another four percent was distributed in lower probability classes. Ninety five percent of the pixels classified into unfavourable riparian status reached a very high probability belonging to the interval of 0.8-1.0 while almost five percent of the pixels had a probability in the interval of 0.6-0.8. The lower probability of the classification of both the favourable and unfavourable riparian status occurred mostly in two areas: (1) Los Alcornocales south of Andalusia close to Gibraltar and (2) the Sierras de Castril y La Sagra, east Andalusia close to Murcia. The former area is mostly covered by evergreen oak, chestnut and other deciduous species while the latter with coniferous tree species. (figure 2.)

AEMs were implemented over 243 thousands hectares while around 3 million hectares remained without measures within the 1km riparian buffer in Andalusia. In both areas where AEMs were implemented and where no measures were applied a larger area can be found under favourable then under unfavourable status (figure 3.). However, in areas where measures were implemented 75% of the riparian-use area falls within the favourable class while only 25% of the area falls within the unfavourable one. Only 60% of the area is classified as favourable riparian status while as much as 40% is classified as unfavourable without AEMs. Expressed in terms of area, the ratio of favourable over unfavourable is 3 for areas where measure are implemented, whereas in areas without AEMs this ratio only accounts to 1.5. These results indicate that where measures are implemented (from 1998 onwards) most of the riparian-use zone presents a favourable status and that a proportionally larger area falls under favourable status under AEMs then without AEMs. However, these findings do not yet indicate a cause-effect link between the application of AEMs and their possible positive impact on the riparian status.



Ratio of favourable and unfavourable status under AEMs :

$$\frac{favourable}{unfavourable} = 3$$

Ratio of favourable and unfavourable status not under AEMs :

$$\frac{favourable}{unfavourable} = 1.5$$

Figure 3.: Distribution of AEMs within the favourable or unfavourable classified riparian-use zones

The temporal evolution of the total permanent vegetation fraction from 1989 till 2005 was studied in the following areas (figure 4.):

- favourable riparian-use zone with AEMs implemented
- favourable riparian-use zone without measures implemented
- unfavourable riparian-use zone with measures implemented
- unfavourable riparian-use zone without measures

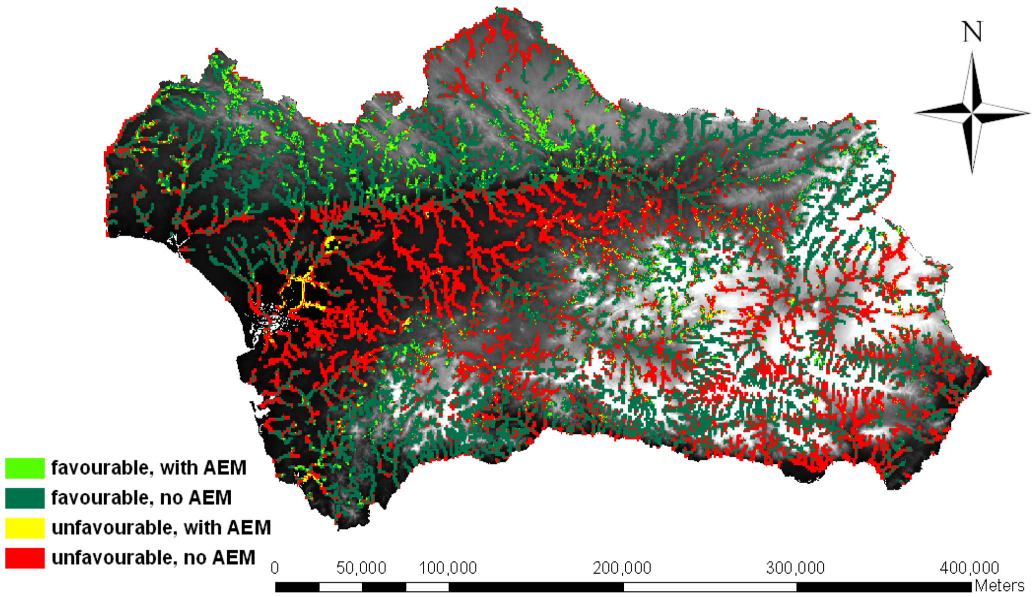


Figure 4.: classification of Andalusian riparian-use zones and distribution of AEMs

Favourable riparian status expressed higher amount of permanent fraction throughout the years then the unfavourable status both in areas where measures were implemented and in areas without the measures. Furthermore, favourable riparian areas where measures were implemented could be further distinguished from areas without measures based on the higher amount of permanent vegetation fraction. Similar was the situation in areas under unfavourable riparian status where the implementation of agri-environmental measures resulted in higher amount of permanent vegetation fraction throughout the years.

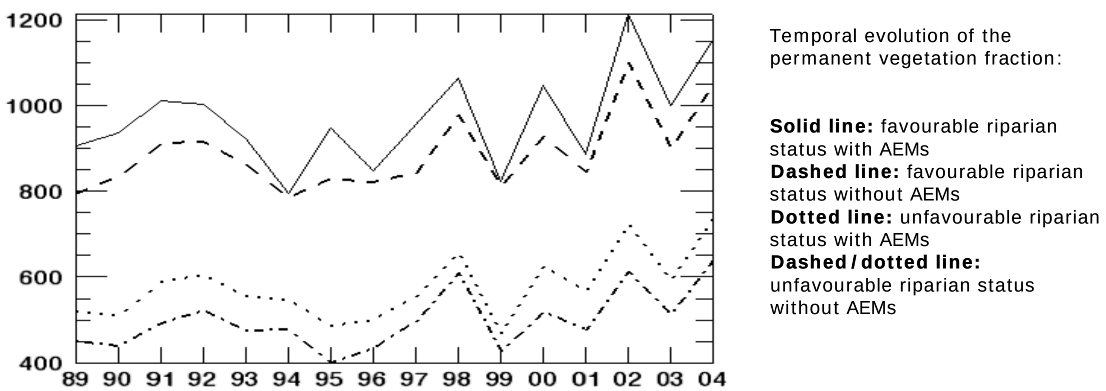


Figure 5.: Temporal evolution of the permanent vegetation fraction in riparian-use zones

These results show that we can monitor and distinguish areas with and without Agri-Environmental Measures based on the amount of permanent vegetation fraction derived from remote sensing time series images. However, the temporal evolution of the permanent vegetation fractions is similar (i.e. the shape of the time series curve) independently whether measures were implemented or not. At the start of the time series in 1989 the difference between the permanent fraction of areas with and without measures is comparable to that in 2004 both under the favourable and the unfavourable riparian status. At this point we cannot state if these areas differ in their permanent vegetation fraction because of implementation of agri environmental measures or if these measures were generally implemented in areas where vegetation were already in a healthier stage.

The mostly applied AEM is the erosion control measure in olive groves in both the favourable and unfavourable riparian-use zone in Andalusia. Therefore, the evolution of the permanent vegetation fraction was further analysed in the favourable and unfavourable riparian-use zone with and without AEMs applied, but spatially constrained to olives land cover (figure 6.). A linear trend analysis was run over these areas not including climatic variables (precipitation, minimum and maximum temperature) as these did not significantly explained the trend in the data (figure 7.).

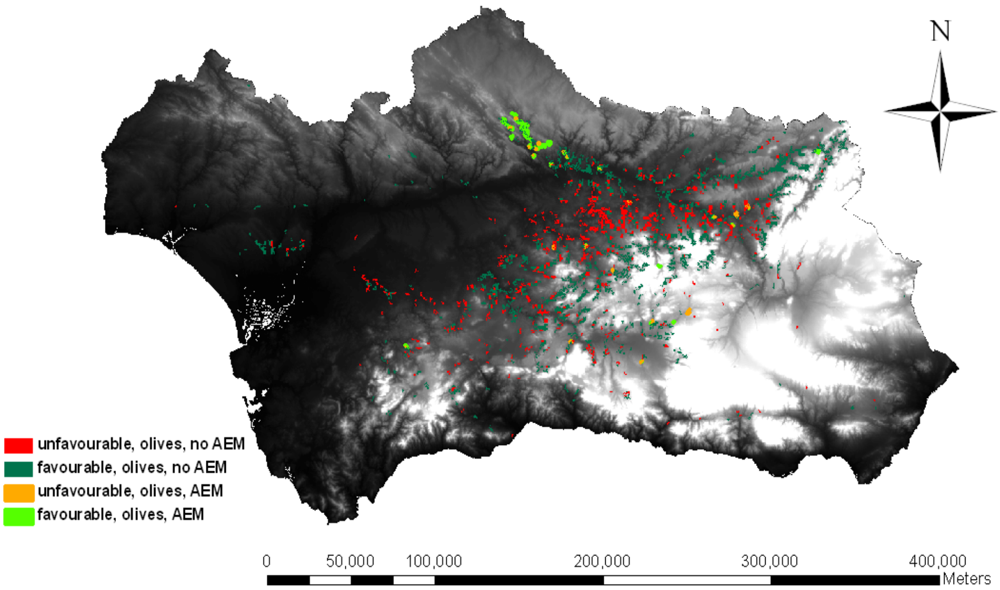


Figure 6.: Classified riparian-use zones and distribution of AEM-Erosion control in the Corine Land Cover based Olive areas

The favourable riparian-use zone where AEMs were implemented (full line) expressed the highest amount of permanent vegetation fraction with a positive and significant trend towards 2004 (R^2=0.263, $p < 0.042$). Without the implementation of AEMs the development of the permanent vegetation fraction (dashed line) was “flatter” without any clear trend in the data (R^2=0.198, $p < 0.084$). Also, in 1989 the amount of permanent vegetation in the favourable zone was comparable with and without AEMs but in 2004 clear differences could be observed between these areas. The favourable areas, where later the measures were implemented (full line) manifested higher values in 1989 probably due to the fact that farmers signed up those areas for measures where agricultural practices were already extensive (traditionally) with a lower income. Interesting is however the temporal evolution of the permanent vegetation fraction in the unfavourable riparian-use zone where AEMs were introduced (dotted line). These areas start up with very low permanent vegetation values in 1989 but in 2004 reach higher values then olive plantations in the favourable zone without agri-environmental measures (R^2=0.323, $p < 0.022$). This indicates that the natural riparian status alone does not explain healthier vegetation status (indicated by the higher amount of permanent vegetation on the area) and that the implementation of agri-environmental measures is most probably contributing to the vegetation to recover and to reach a healthier status.

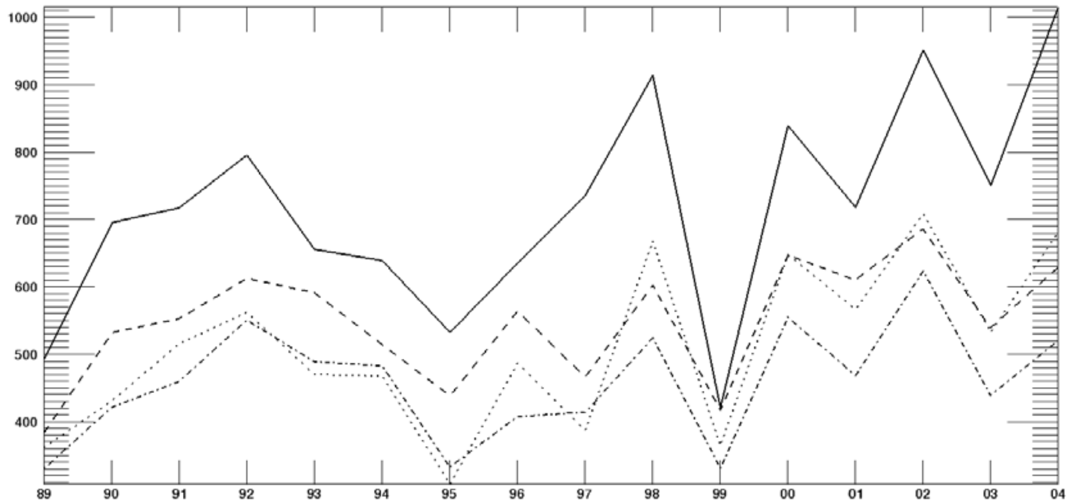


Figure 7.: Linear Trend Analysis of Permanent Vegetation Fractions in the classified riparian-use zones under AEM or not under AEM.

Full line: favourable riparian-use zones with AEMs;
Dashed line: favourable riparian-use zones zone without AEMs;
Dotted line: unfavourable riparian-use zones zone with AEMs;
Dash – dot: unfavourable riparian-use zones without AEMs.

The here proposed remote sensing approach based on vegetation phenology indicators allows to create a spatially explicit map of the status of the riparian-use zones. Successful use of low resolution data offers the possibility for spatially continuous maps at regional to global scales. The riparian-use zone classification can be a direct input for the River Basin Management Plans as required under the Water Framework Directive (WFD). Confirmation of the association of extensive agricultural land use with better riparian system status as monitored through remote sensing vegetation phenology indicators is a step forward to spatially address riparian-use zone management and targeting of Agri-Environmental and water protection measures. Furthermore the results indicate the possibility of assessing the effectiveness of AEMs on erosion control in olive areas in southern Spain. Further work is needed to open more of this potential for systematic assessment of AEMs impact on these environmental aspects. Linkages with other datasets, such as riparian or farmland birds or nutrient use and losses, are expected to contribute to the impact assessment of AEM schemes related to the Community priorities on biodiversity and water quality.

Based on the assumption of better status of the riparian-use zones in case of higher remotely sensed permanent vegetation fraction, decision making can be facilitated by maps where areas with a significant positive trend is represented. Below, the favourable riparian-use zones are shown under erosion control measures in olives (light green) and without these measures (dark green) that exhibited a significant positive trend. Both because of the favourable status and of the significant positive trend in the permanent vegetation fraction these areas are expected to become or persist as biodiversity hot-spots. The unfavourable riparian-use zone that exhibited a positive trend in the permanent vegetation fraction is displayed with red. These areas, although classified as unfavourable, have a potential to become biodiversity hot spots because of the positive trend in the permanent vegetation cover. All together, these areas provide valuable habitats to flora and fauna species or protect water quality and regulate stream temperature. They may stabilise stream banks and reduce soil erosion and sediment input. Furthermore, they could provide a source of cover for fish from predators and solar radiation and may provide organisms and leaf litter which become the primary nutrient source that drives the aquatic ecosystem.

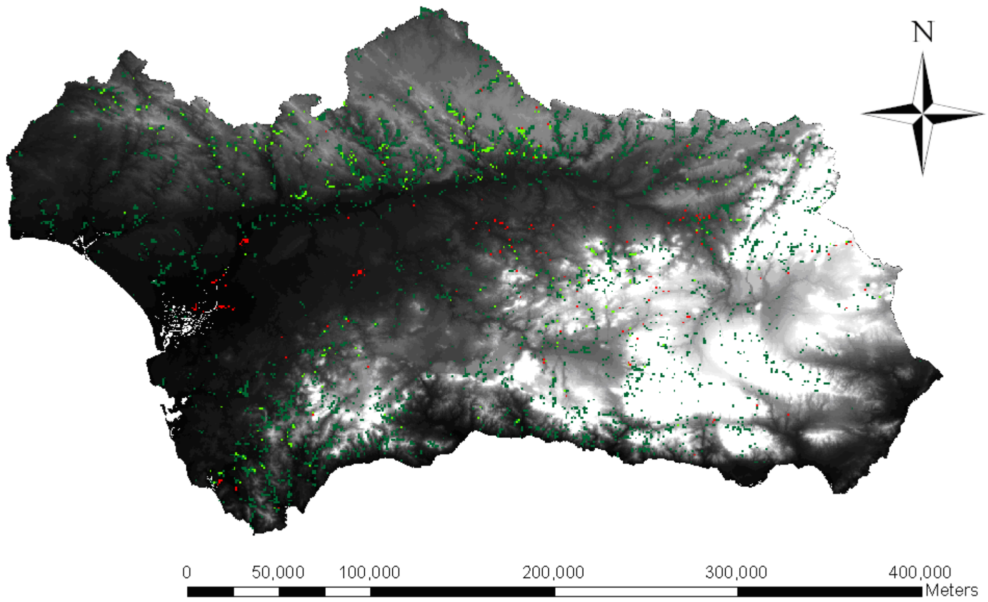


Figure 8.: Potential biodiversity hotspots in Andalusia with respect of AEMs:

light green: significant positive trends in the permanent vegetation fraction in the favourable riparian-use zone with AEMs
dark green: significant positive trends in the permanent vegetation fraction in the favourable riparian-use zone without AEMs
red: significant positive trends in the permanent vegetation fraction in the unfavourable riparian-use zone with AEMs

The Figure below presents significant positive and negative trends of the permanent vegetation fraction in the favourable and unfavourable riparian zone independently of Agri-Environmental Measures applied. Based on the assumption of better status of the riparian zone in case of positive trend of the permanent vegetation green is assigned to possible biodiversity hotspots (light green, favourable zone) and to riparian areas with the potential to become one (dark green, unfavourable zone). Orange and red areas (negative trends in the favourable and unfavourable riparian zones, respectively) represent surfaces in danger of disappearing habitats.

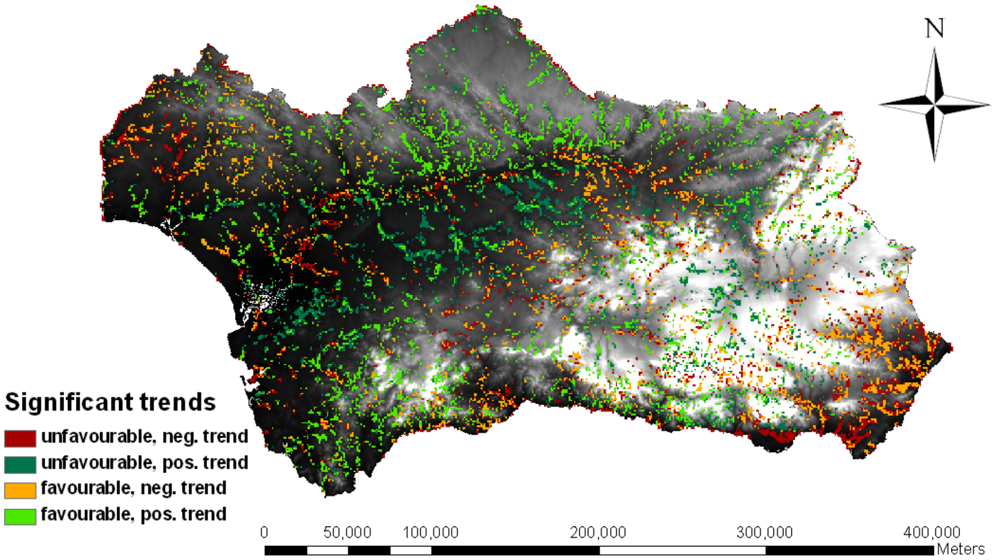


Figure 9.: Potential biodiversity hotspots in Andalusia regardless of AEMs:

Light green: significant positive trends in the permanent vegetation fraction in the favourable riparian-use zone
Dark green: significant positive trends in the permanent vegetation fraction in the unfavourable riparian-use zone
Orange: Areas with significant negative trends are in danger – within favourable riparian-use zones
Red: Areas with significant negative trends are in danger – within unfavourable riparian-use zones

II Detailed Study Report

1 Introduction

Some Definitions of Riparian zones

The present day riparian concept and its derivative terms (riparian, riparial, riparious) all come from the Latin Riparius, which itself derives from the Latin Ripa (Pl. Ripae) meaning bank or shore, as of a stream or river. The original meaning has been largely retained through subsequent history, i.e., pertaining to the terrestrial, moist soil zone immediately landward of aquatic wetlands, other freshwater bodies, both perennial and intermittent watercourses, and many estuaries. Despite numerous attempts, no single purely descriptive definition embracing riparian systems—that is, one that attempts to define by listing all the different types of riparian phenomena—has proven successful. It is useful to recognize that the term "riparian" is an adjective. The term, once defined, can thus usefully modify a multitude of other well-accepted terms (Warner et al., 1984).

Riparian: pertaining to the banks and other adjacent terrestrial (as opposed to aquatic) environs of freshwater bodies, watercourses, estuaries, and surface-emergent aquifers (springs, seeps, oases), whose transported freshwaters provide soil moisture sufficiently in excess of that otherwise available through local precipitation to potentially support the growth of mesic vegetation.

Definitions are also depending on the use of the zones and the objectives for which the definition is to be used. Ecological, managerial or legal aspects consider different characteristics of these zones. Landform definitions refer purely to morphological features, vegetation based definitions were experienced rather local and impractical, while legislative definitions are mostly based on fixed widths resulting in a not useful rigid frame. Once the riparian functions have been identified the management strategies and regulations can be identified. Functional definitions seem appropriate to attain program goals. Riparian land according to this approach is defined as:

‘Any land which adjoins, directly influences, or is influenced by a body of water’ (http://www.rivers.gov.au/acrobat/riprap11.pdf).

This definition reflects the processes and interactions that take place between the landscape and the river. As there is no single law of nature that defines the width legal rules can provide a pragmatic solution.

Riparian zones are widely recognized as functional buffer areas adjacent to flowing fresh water forming a transition zone between the water course and the surrounding dry land. They exert a variety of functions ranging from physical capacities to stabilize the river banks and prevent erosion, shielding the water from possible pollution by e.g. pesticide drift. They act as nutrient sinks and therefore have a potential to decrease pressures from agriculture on water resources. Furthermore they create specific biodiversity habitats and esthetic landscape elements. These functions translate in geo-physical, social and economic values. Therefore the choice of definition is generally dependent on the situation or management objectives and the person or group making the definition. Considering the further economic and social values of the riparian zones, riparian issues could be dealt with considering larger spatial and functional boundaries. Meyer (1981) identifies three progressively larger areas:

1) The riparian system, defined as the area adjacent to flowing fresh water, with its moist soils and associated biota and environment;
2) The riparian-use zone, where the riparian system and man interact and where riparian and non-riparian systems may interrelate with each other;
3) The area of riparian influence, where "products" of the riparian-use zone (often water) are exported to impact on other ecological, social, and economic systems.

Although these concepts are hardly discussed or applied up to now, the current case study promotes the concept of 'riparian-use zone' and offers a basis for further investigation on its practical use.

Furthermore, for the present study the concept of 'favourable' and 'unfavourable' functioning of the riparian-use zone was introduced as a classifier, based on the role of the riparian eco-system.

The role of riparian eco-systems

Studies of riparian habitats indicate that they are important to ecosystem integrity and functions across landscapes (Sands 1977, Johnson and McCormick 1979, Katibah 1984, Johnson et al. 1985, Faber 2003). Riparian zones often have higher species richness then their surroundings mostly due to the heterogeneous environment created by flooding, sediment deposition and lateral channel migration (Naiman et al., 1993). Forested riparian corridors, even relatively narrow ones of a few hundred meters, support a rich diversity of breeding birds and the quality and extent of these woodlands will dictate the species which can be found there (http://www.dnr.state.oh.us/dnap/rivbirds/default.htm). These areas provide important breeding and over wintering grounds, migration stopover areas, and corridors for dispersal. The loss of riparian habitats was assumed to be the most important cause of population decline among landbird species in western North America (DeSate and George, 1994).

Sediment and sediment-associated pollutants, such as phosphorus, bacteria, and some pesticides, move to surface waters almost exclusively by surface runoff. When surface runoff is sufficiently slowed, sediment will settle out. Most nitrogen from agricultural fields move quickly into the soil and nitrate is very mobile in the soil. Any nitrate not used by the crop or the soil organisms continues to move through the soil and into the shallow ground water below the soil surface. To remove nitrate from groundwater before it reaches surface water, the groundwater must enter a zone where plant roots are or have been active. These plant roots may either absorb the nitrate for use in plant growth or, more importantly, provide an energy source for bacteria that convert nitrate-nitrogen to harmless nitrogen gas. This process, denitrification, occurs almost exclusively in water-saturated zones where abundant organic matter is present. Riparian forest stripes, but also grasses, shrubs or other vegetation growing along streams reduce nitrogen under most conditions. Furthermore, woody vegetation provides food and cover for wildlife, helps lower water temperatures by shading the waterbody, contributes energy sources to aquatic community, protects streambanks and slows out-of-bank flood flows.

Riparian zones also fight erosion in two ways: the leaf canopy breaks the force of rainfall before it impacts the ground, and tree roots hold the soil together even better than grass. Trees protect both the quantity and quality of the water itself. Overhanging canopy reduces water loss from solar radiation and wind. Shade keeps the stream cooler which allows the water to hold more dissolved oxygen. Modifications to rivers combined with intensified agriculture, urban development and changes to agricultural drainage and run-off and water abstraction have cause decline in these ecosystems. Most rivers in Europe have been subject to drainage of riparian habitats to provide agricultural land. Such modifications have led to widespread losses of aquatic habitats and biodiversity with thousands of small lakes ponds and stems lost entirely to drainage for agricultural land.

Water quality is also influenced by the physical management of rivers and the wider hydrological environment of a river basin. Canalisation, dam building, river bank management and other changes to the hydrological flow can disrupt natural habitats such as bank side vegetation and destroy pebble riffles where salmon and other fish spawn. They also change seasonal flow patterns that are vital to many species, as well as the connectivity between habitats, a very important factor for the functioning of aquatic ecosystems and for the development of the different life stages of aquatic organisms. There is an increased awareness of the conservation importance of riverine and wetland habitats and their role on buffering dry land against floods. In traditional farming systems often flooded riverine and lake-shore habitats offered valuable habitats for many rare species. Recreating and restoring these habitats is one of the challenges for nature conservation actions and as such important wetland areas are given strong protection through the birds and habitats directives.

Many aspects conditioning the role or degree of favourable functioning of the riparian eco-system are related to the type, state, amount and permanence of vegetative cover. Considering these functions over the wider riparian-use zone, the following concept was formulated:

Landcover and land use changes due to alteration of agricultural practices may have different impacts on the status and functioning of the riparian-use zone considering the various combinations of land use intensity and status of the riparian vegetation (Figure 10). Intensive land use coupled with healthy riparian-system vegetation is assumed to be a ‘favourable’ riparian-use zone as its buffering capacity would be maintained. Extensive land use within the riparian-use zone would also create a ‘favourable’ functioning status both with good and bad status of the riparian vegetation. In the former case the riparian zone will approximate a natural status while in the latter case the negative impact of the agriculture is expected to be reduced due to the extensive land use. In case the intensive land management is coupled with bad riparian vegetation status the riparian-use zone is assumed to be in an ‘unfavourable’ functioning status due to pressure from agriculture, intensive management and higher inputs, combined with a reduced buffering capacity.

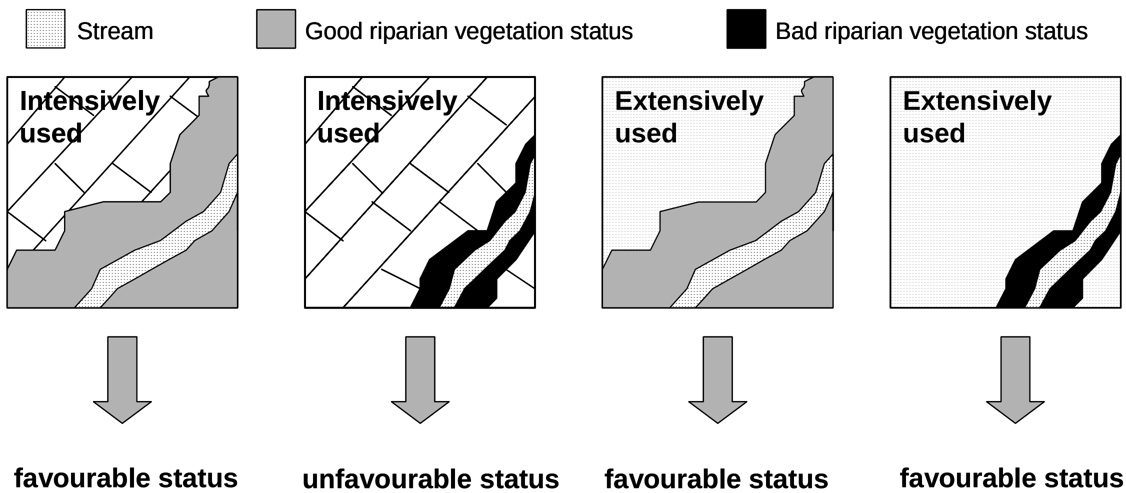


Figure 10: Schematic presentation of favourable and unfavourable functioning of riparian use zones.

Riparian in EU policies

In 2000, Europe adopted the Water Framework Directive (WFD) to bring together and integrate work on water resource management. The directive's second principle is to restore every river, lake, groundwater, wetland and other water body across the Community to a 'good status' by 2015. This includes a good ecological and chemical status for surface waters and a good chemical and quantitative status for groundwater. It requires managing the river basin so that the quality and quantity of water does not affect the ecological services of any specific water body (EEA, 2005). Thus, any abstraction has to maintain ecologically sustainable flows in rivers and preserve groundwater reserves. Discharges and land-based activities have to be restricted to a level of pollution that does not affect the expected biology of the water. In particular, the directive means that new measures will have to be taken to control the agricultural sector so as to manage both its diffuse pollution sources and its abstractions of water for irrigation

Article 4 of the WFD defines a long-term sustainable water management based on a high level of protection of the aquatic environment and introduces the principle of preventing any further deterioration of status. The classification scheme for the status includes five categories: high, good, moderate, poor, and bad, the objective being the achievement of good status for all surface waters by 2015. The harmonization of the understanding of good status across all member states will be done through the intercalibration exercise that also ensures consistency with the definition of the Directive. Intercalibration takes into account the functioning and structure of aquatic ecosystems and the level at which human activities influence them. The benchmark or reference condition is the high status that reflects no or very low human pressure and the other categories will be assessed as the deviation from this (i.e. good status means slight deviation from the high status). The assessment of the status of surface waters concerns chemical and ecological quality, the latter including biological and hydromorphological elements. One important morphological element for the assessment is the structure and condition of the riparian zone.

One component of the WFD deals with groundwater bodies to achieve good quantitative and chemical status by 2005. Groundwater has an important role in the riparian zone through the maintenance of wetlands and river flows and as a buffer in dry periods. Since groundwater moves slowly the impact of anthropogenic activities may last for a long time, which will be reflected in the quality of surface waters as these receive continuous discharge of inflowing groundwater. Furthermore the quality of the associated aquatic ecosystems and directly dependent terrestrial ecosystems like that of the riparian zone will also be influenced. Around one third of the European groundwater bodies exceed the nitrate guideline values due to pollution from domestic, agricultural and industrial sources. The directive obliges member states to classify groundwater bodies according to the impacts of human activities and to establish registers of protected areas for habitats and species within each river basin. Furthermore, a groundwater monitoring network and a river basin management plan has to be established, the latter including a summary of pressures and impacts of human activities on groundwater status. Monitoring results have to be presented in a map by the member states for which spatially explicit analysis of the riparian status is indispensable.

The assessment of the impact of the implementation of the EU policies on the status or change of the riparian zones has not been systematically undertaken within Europe. Related to the Rural Development Programme (RDP) under the Common Agriculture Policy, the European Commission needs a basis of understanding of actual and potential impact of rural development plans. Local, as well as European decision makers need adapted methods to assess environmental outputs, outcomes and impact of their policy for continued improved policy design and land and river basin planning. Monitoring and census data are considered point observations, eventually repeated through time. Spatial interpolation of such data is not always straightforward and in many cases can best be done if some information on a spatial continuum is used. The EU Scientific and Technical Report (Cherlet and Ivits, 2007) introduces thereto strategies for implementing environmental spatial based methods related to assessing environmental effectiveness of RDPs. Here we report on the use of these concepts and strategies for a case study on the riparian zones in Andalusia, Spain.

Agri-Environmental Indicators and biodiversity

Agri-Environmental Measures (AEMs) within their specific objectives, such as e.g. extensification, erosion control or organic farming, directly address farming and land management practices. Although information concerning the impact of agriculture on natural resources exists at a national and EU level, much of it is based on estimates and macro-modelling rather then the aggregation of local information. While detailed information of farming practices helps to understand the process driving the sustainability of agriculture, the sheer diversity of farming practices and local conditions are difficult to capture at an aggregate level (COM(2000) 20). For this reason it is important to develop indicators that capture the key trends in farming activities as e.g. intensification-extensification at a range of geographical levels in order to identify both broad national trends as well as localised practices. Indicators have to reflect site-specific features and programme criteria in order to be meaningful: this way they accurately capture the state of the environment and the effects of local farming activities. Furthermore, they have to reflect regional differences in economic structure and differences in natural conditions.

The basis for an agri-environmental indicator framework is provided by the Driving force-Pressure-State-Impact-Response model of the European Environment Agency. The current *state* of the agricultural environment indicates undesirable changes that need to be ameliorated and its change over time indicates desirable states which should be preserved. The farming *pressure(s)* have to be identified, the *impact* of which have caused the changes and the present state of the agricultural environment. Such pressures on the water resources have been described and prioritized by the Pilot River Basin Group on Agriculture of the WFD and some indicators for assessment have been proposed (Cherlet, 2007). The pressures and processes are linked to the *driving forces* in the economy that are influenced by agricultural policy. Finally, indicators are needed to monitor if agri-environmental measures have the desired effect, i.e. the *response* to the impact. Although many indicators have been developed on the EU level there is a gap in the existence of operational indicators for landscapes, global habitat stock, biodiversity and landscape diversity.

Europe's biodiversity has been shaped by agriculture since the last glaciations therefore the continuation of traditional methods of land management is essential to species survival in these areas. It has been estimated that 50% of all species in Europe depend on agricultural habitats. Semi natural areas like the dehesas (grasslands with scattered oak trees, typical in parts of Iberia see Figure 11) are home to many of Europe's most valued species. The two key trends leading to the loss and fragmentation of semi-natural habitats in agriculture in Europe are the intensification of agriculture and the abandonment of farmland. Abandonment generally reduces the diverse extensive agricultural habitats and often leaves behind a simplified ecosystem that will be populated by fast growing intensive species. The intensification of agriculture over the past half-century has caused profound changes to the traditional agri-ecological landscapes and the species that live in them.

Figure 11: Typical dehesa landscape in North-West Andalucian mountains *(source Eva Ivits)*.

Intensification of agriculture causes physical, chemical, and biological changes to the landscape. These are:

- Abandoned terraces on hillsides
- Degraded hedgerows
- Small heterogeneous fields converted into large monocultures
- Drained wetland, disappearance of small streams
- Lost crop rotations
- Pastures converted into arable land
- Woodlands converted into agriculture

In November 2005, at the summit to celebrate the 10th Anniversary of the Euro-Mediterranean process, the partners committed to endorse a feasible timetable to de-pollute the Mediterranean Sea by 2020. Following-up on this commitment from all of the Euro-Mediterranean Partners the European Commission launched the Horizon 2020 initiative that aims to tackle the top sources of Mediterranean pollution by the year 2020. The highest number of plant and animal species in Europe is hosted in the Mediterranean basin, which has been identified by Conservation International as one of the world's 34 biodiversity hot spots. The EU had committed itself to halt the loss of biodiversity by 2010 and began a review of its biodiversity strategy in 2003. It was found that many species remained threatened in Europe, many have seen their populations drop dramatically in recent years. The reason for this is the relatively low rate of implementation of both the strategy and the action plans in the Member States. Policies to ensure the preservation of ecosystems in Europe require different approaches then in other parts of the world. Classical conservation methods such as the creation of national parks, can protect only a fraction of the continent's biodiversity – broader support for the social and economic systems is needed to sustain species, habitats and ecosystems.

Driving concepts of the study

In order to assess the effects of agri-environmental measures on agricultural ecosystems the following concepts were considered that drove the analysis and methodological development.

1. **Nature protection and biodiversity:** The Water Framework Directive (adopted in October 2000), the prime legislative instrument for protection of the water environment in Europe, lists among others the riparian zones as primary importance. Lagoons, estuaries, riparian forests, grazed wet meadows and farm pounds are vital for a wide range of biodiversity. However, intensified agriculture coupled with drainage, surface run-off and water abstraction have caused a massive decline in these ecosystems. In north and western Europe 60% of wetlands have disappeared during the 20th century, which declines continues especially that the traditional uses of wetlands are being abandoned throughout Europe (The European Environment, State and Outlook). There is an increasing awareness on the importance of riparian zone seen as a landscape element capable of high buffer capacity in surface runoff and nutrient leaching as well as buffering dry land against floods and as habitats of high nature conservation importance.

2. **Extensive agriculture -> natural riparian status:** In the Guadalquivir river basin the riparian status shows a direct relation with the extent and degree of intensity of agricultural management along the river (Cherlet, 2007). When looking at the sub-basin level in the Guadalquivir, the areas with low riparian status are in the intensive agricultural areas. The first report of the Pilot River Basin (PRB) analysed the agricultural pressure on habitat loss and physical modification of wetlands. The study identified agricultural land reclamation and management intensity responsible for significant pressures by reducing floodplain and wetlands and affecting the undisturbed conditions of the riparian zones. In short it was shown that the condition of the riparian zone gets worse with more intense agricultural activities. In general, habitat loss and physical modifications imply negative changes in hydrology, erosion and biodiversity but the PRB report also stated that more cause-effect analysis is needed at all relevant

scales to establish the direct link. Furthermore, the report showed more negative effect of cereal cultivation on the riparian zone then olives plantations. It was assumed that olives plantations could be used for the improvement of the buffering capacity of the riparian zone in case farmers keep the undergrowth undisturbed on the surface. An intensive olive plantation with large proportion of bare soil surface will be able to buffer less surface runoff and nutrient leaching of agricultural pollutants or reduce riverside soil erosion then an integrated olive plantation with permanent undergrowth left on the surface (Figure 12).

3. **Natural riparian status associated to remotely sensed permanent vegetation fraction:** The phenological development of the vegetation cover can be monitored through a yearly vegetation index (see chapter on data requirements further below) with a typically low value at the beginning of the season, high values at the maximum vegetation cover and another minimum where the end of the growing season is reached. The permanent vegetation fraction is calculated as the time integral (area under the curve for each year) defined between the two minima. Following the above introduced concept on degree of favourable functioning of the riparian-use zone, the assumption for the present study was that the better status of the riparian-use zone can be correlated to an increased permanent fraction of the vegetation cover extracted from time series of remotely sensed images. The permanent fraction of vegetation cover represents the amount of vegetation/biomass in a year that is permanently on the surface. On one hand, trees of the riparian vegetation zone permanently cover the area even if their seasonal development shows a cyclic behaviour. On the other hand, where agri-environmental measures are introduced the undergrowth is left on the area (e.g. olive plantations, see Figure 1), which is assumed to increase the remotely sensed vegetation signal and thus the calculated permanent vegetation fraction.

Figure 12: integrated olive plantation with the undergrowth left on the surface (left) and intensive olive plantation with a bare soil surface (right) *(Source Eva Ivits)*.

Many studies have been made on practically each of the specific characteristics of the riparian zones. Nonetheless very few attempts have been made to either uniformly classify the quality status of the riparian zones or to systematically map this status at regional or European scales. In this study low resolution satellite data is to be used for the distinct spatial characterisation and classification of the wider riparian-use zones according to the degree of favourable or unfavourable riparian functioning (hereafter indicated shortly as 'riparian – favourable or unfavourable – status'). The classification will be based on field data collected on the area of the Guadalquivir river basin. For the characterisation long time series analysis will be undertaken to derive a number of indicative variables. The favourable and unfavourable riparian status will be linked to agri-environmental measures practiced in the riparian zones in order to deduce information on their effects on the environment. The basis for this linkage is the assumption that extensification practices will increase the status of the riparian vegetation zones.

2 Data

2.1 Field data

2.1.1 Riparian Status

The "Plan Director de Riberas de Andalucía" (PDRA) is an initiative of the Junta de Andalucia showing the present situation in the riparian areas in Andalusia, taking into account different hydraulic and hydrologic regimes. The study was carried out in 2003 by the Consejería de Medio Ambiente in order to characterise and evaluate the actual state of the Andalusian rivers. The quality of the riparian zone and its components included the assessment of river channels, vegetation cover, naturalness and diversity. It relied on the QBR (Qualitat del Bosc de Ribera) index (Narcis Prat, Universidad Central de Barcelona and Antoni Munne, Agencia Catalana del Agua) by means of collected data from two sampling networks. The first is the hydrologic network dataset and the second is a point dataset with information regarding the land use for the right and left riversides and the quality of the riverside vegetation. The land uses at the riversides are indicated by the main land use and they are classified as forest (high, medium and low cover), green areas, crops, urban, scattered urban area, industry, infrastructure and fallow. The quality of the riverside vegetation has been assessed by means of two methods:

- for 6192 points remote sensing techniques have been used
- and for 691 points a field based methodology was carried out.

The QBR index considers the entire area of the riparian zone where the main channel and the riparian area is differentiated. The main channel is the zone up to the bankfull stage that is flooded at least every two years while the riparian area is the surface from the bankfull stage until the area flooded at least once every 100 years. Four major characteristics of the riparian zone are evaluated whereby the QBR index is a summation of the scores given to these, varying between 0 and 100. The evaluated characteristics are:

- Total riparian cover
- Cover structure
- Cover quality
- Channel alteration

The method for calculation of the scores is published elsewhere (http://geographyfieldwork.com/Riparian%20quality%20QBR%20index.htm), in the following only the main characteristics of the QBR index are described.

1. Total riparian cover

For the calculation of the total cover all plants except annuals are measured on both river banks considering also the connectivity between the terrestrial forest ecosystems. Unpaved roads and paths of less then 4 meters width are not considered as fragmentation elements. The vegetation cover is classified into four categories and scored accordingly and receives plus scores according to their connectivity level. Highest scores arise if the vegetation cover is above 80% and if the connectivity between the riparian area and the woodland is total.

2. Riparian cover structure

The riparian cover structure is defined as the percentage of tree cover, but if trees are absent also shrubs and other low lying vegetation are considered on both river banks. Shrubs below the forest cover and the presence of helophytes increase the score value while linear structures like a plantation and fragmented patches decrease the value. Highest score will arise if the tree cover is over 75% and of at least 50% of the channel has helophytes. This measure aims to evaluate the structural composition of the vegetation thus can be considered as a habitat indicator important for the diversity of the flora and fauna in the riparian zone.

3. Cover quality

The cover quality of the riparian zone is assessed based on the number of native tree species and the geomorphological type of the stream according to their shape and slope. Higher quality score is given if the trees build up a tunnel structure or if the vegetation is arranged in a gallery like composition. Gallery is defined as a succession of different species from the bankfull stage to the upper riparian area. Man made buildings and the presence of hard structures in which the vegetation cannot root decrease the score while geomorphological structures such as islands will increase the score. Highest scores are given if the number of native tree species is > 3 and if the tree community is continuous at least 3m wide along the river and covers at least 75% of the riparian area.

4. Naturalness of the river channel

The naturalness of the river channel is assessed based on morphological changes occurring in the alluvial terraces. For instance, channel reduction due to agricultural activities or the elimination of river meanders and the linearization of the river bank will lower the score. Most negative scores will arise from concrete structures along the length of the riparian habitats. Highest naturalness scores are given to areas where the river channel is completely unmodified (see Figure 13 below).

Riparian vegetation under good status and good diversity level.

Riparian zone under natural status and high level of diversity.

Figure 13: Good and natural riparian status. *(Source Tecnoma)*

The final PDRA dataset consisted of 6883 points in the Guadalquivir river basin along both river sides. For the present study the two extreme classes were selected and further investigated by means of spatial data and methods: the bad and the natural classes (Figure 14).

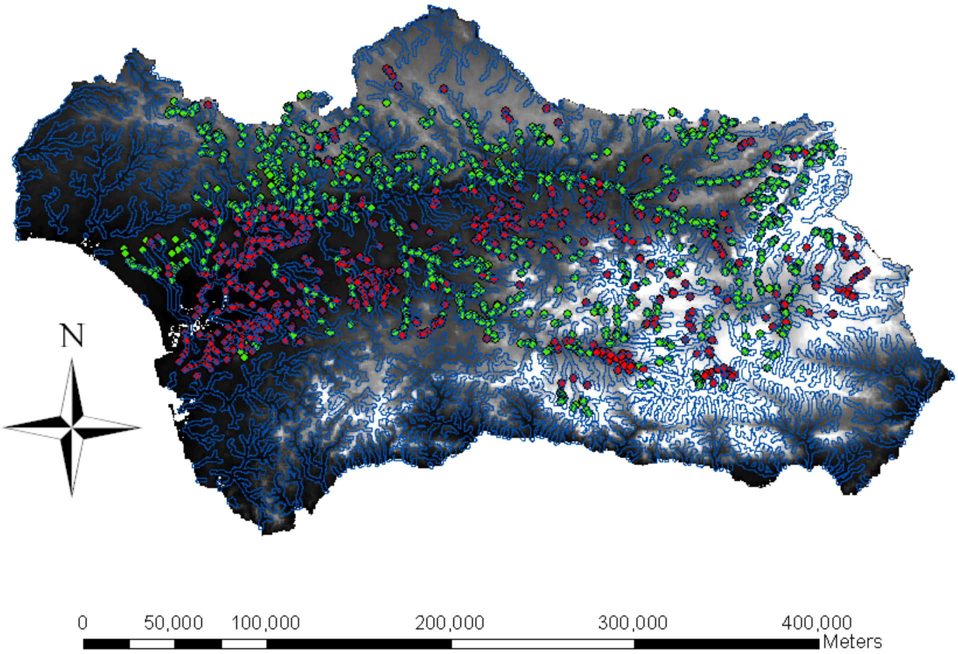


Figure 14: Distribution of the natural (green) and bad (red) riparian status field observation in the Guadalquivir river basin. In the background: the DEM model of Andalusia derived from SRTM data.

2.1.2 Parcel data on Agri-Environmental Measures

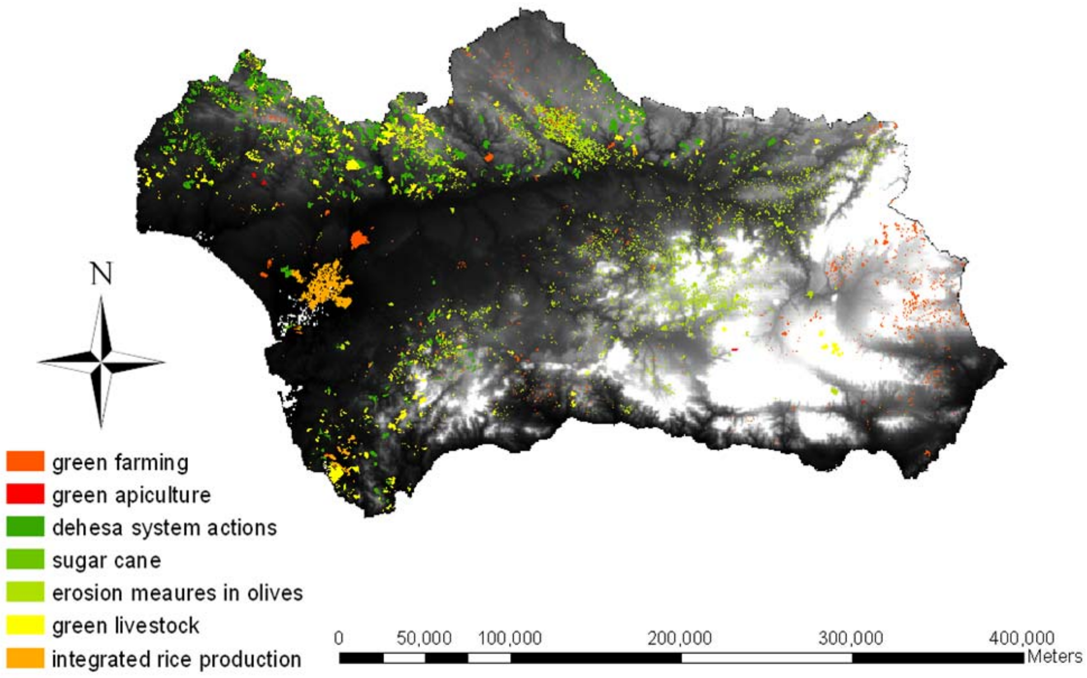


Figure 15: Distribution of Agri-Environmental Measures in Andalusia.

For a long time, farmers were the unique responsible for the restoration of the riparian vegetation and for protecting the river banks in Andalusia. For centuries farmer have strengthened the development of selected species which were useful for cattle feeding (poplar), tillage tools (ash, elm) fibres (wicker), medicine (*Equisetum*) or of hunting interest. Farmers have also protected irrigation structures from floods and the farm lands from the erosion. Due to new materials and the socioeconomic changes, this traditional management has been lost. Now, administrative bodies are the main responsible for the conservation and restoration of the river banks. Agri-Environmental Measures (AEMs) are based on the development of agricultural production methods compatible with the environment and are based on five major lines: water, soil, natural hazards, biodiversity and landscape. The measures that are related to habitat and morphologic alterations are: 1) Green farming agriculture, 2) Erosion control in olive groves, 3) Actions in dehesa systems, and 4) Rice integrated production. With the three first measures the green cover has a significant answer, having better status those areas where a measure has been applied respect to those areas where non has been applied (Cherlet, 2007). The location of the measures applied were collected and spatialised by the company Tecnoma (Figure 15).

2.2 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. 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.

3 Analysis Methods

3.1 Classification

Fuzzy Classification attempts to handle the mixed-pixel problem by employing the fuzzy logic concept. In this, a given entity (i.e. a pixel) might have partial membership to more then one category (Lillesand and Kiefer, 2000). Fuzzy logic was introduced by Lofti Zadeh in the 1960’s (see e.g. Zadeh et al, 1975). Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth values between "completely true" and "completely false". In traditional classification techniques, every pixel belongs to only one class, which is why these techniques are also called “hard classifiers”. In these methods it is assumed, that the defined classes in the image close each other out (de Kok, 2001). In fuzzy or “soft classification” however, a membership grade is assigned to the classified pixel (or objects in case of segmentation), such as:

$$f_{class,obj} = \left[\mu_{class1}(obj), \mu_{class2}(obj), ..., \mu_{classn}(obj)\right]$$

where:

μ = membership grade
n = dimension of the membership (Benz et al., 2004).

Thus, one pixel (or object) may belong to forest with 70% membership, to meadow with 20% membership, and to urban areas with 10% membership. Hard classifiers would only give the information, which membership degree is the highest, whereas the tuple of memberships contains all information about the overall reliability, stability, and class mixture (Benz et al., 2004).

As an example of fuzzy set consider the description of water landcover class based on the vegetation index feature. In case of three fuzzy sets *dark*, *grey*, and *bright* the fuzzy rule would be: **“if”** the value *x* of vegetation index is the member of fuzzy set *dark* **“then”** the image object is assigned to water. This is illustrated in Figure 16. If the value of vegetation index of an object is 0.17, then the object belongs to the fuzzy set dark with a fuzzy membership of 0.5. On the other hand, the value of 0.17 results in a fuzzy membership of only 0.2 in the fuzzy set *medium* thus the object is rather *dark* as *medium*, i.e. belongs to the class water.

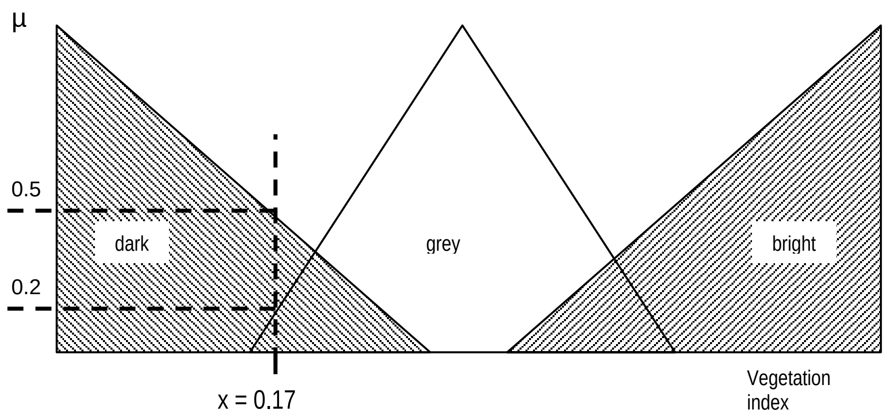


Figure 16: Fuzzy set theory for the description of water land cover class in the feature "Vegetation index".

The1 km buffer representing the riparian-use zone was classified into favourable and unfavourable status. For the classification a fuzzy nearest neighbour method was applied on the remotely sensed permanent vegetation fraction and was trained with the ground observation of the PDRA points. Thirty percent of the observations were selected randomly to train the classification excluding contrasting observations falling within the same 1km pixel, as apparent changes over relative short distances were covered by nearby observations. This way the biasing effect of spatial autocorrelation was accounted for. For the accuracy assessment of the results all points were included. In order to keep the Nearest Neighbour feature space as simple as possible, a principal component analysis was carried out on the sixteen total permanent fractions. The first three components explained ca. 90 % of the total variation and therefore these were used in the classification.

3.2 Phenology derived from remote sensing time series

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

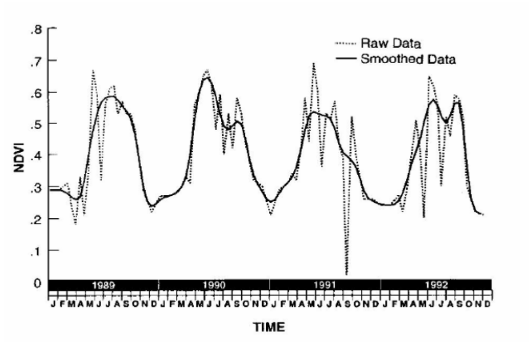
- Traditional methods extract trend and seasonal components e.g. to identify the different greening rhythms of trees and grassland in a mixed woodland landscape (Roderick et al., 1999).
- Principal Component Analysis (PCA) has been used extensively to map vegetation types and changes (Benedetti et al., 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).

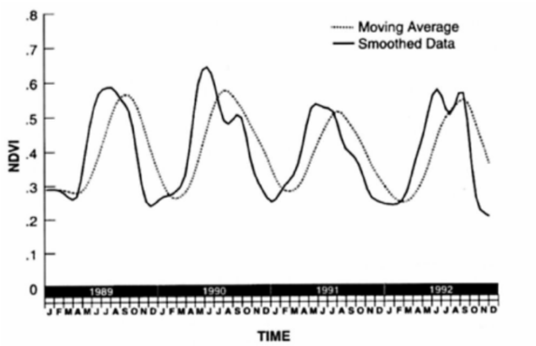
A comprehensive set of reference studies, concerning the use of time series analysis in agricultural areas, is missing. Nevertheless, Hill and Donald (2003) demonstrated relationships between agricultural productivity and phenological metrics. The above described spatial indicators derived from time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

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. 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.

After the method of Reed et al. (1994) 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 17), 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 the present study and for the follow up European wide application however this method seemed too arbitrary and therefore another solution was searched for, that defines the lag from the data itself but not in a subjective manner. After several test runs, the method applying 1 standard deviation from the bary centre of the integral surface for defining the lag distance seemed the most appropriate and was used for the calculation of the moving average curve.



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

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

The permanent vegetation fraction was defined via two methods:

- The Total Permanent Fraction will be the area under the vegetation curve defined by the two absolute minima on the curve (MIN in Figure 18).
- The Seasonal Permanent Fraction will be the area under the vegetation curve defined by the start of season (SOS) and end of season (EOS) points derived by the forward and backward lagged moving averages.

Using the field data on riparian status, spectral libraries of the two permanent fractions were created and were investigated as to how well they separate areas with natural from areas with bad status. The 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.

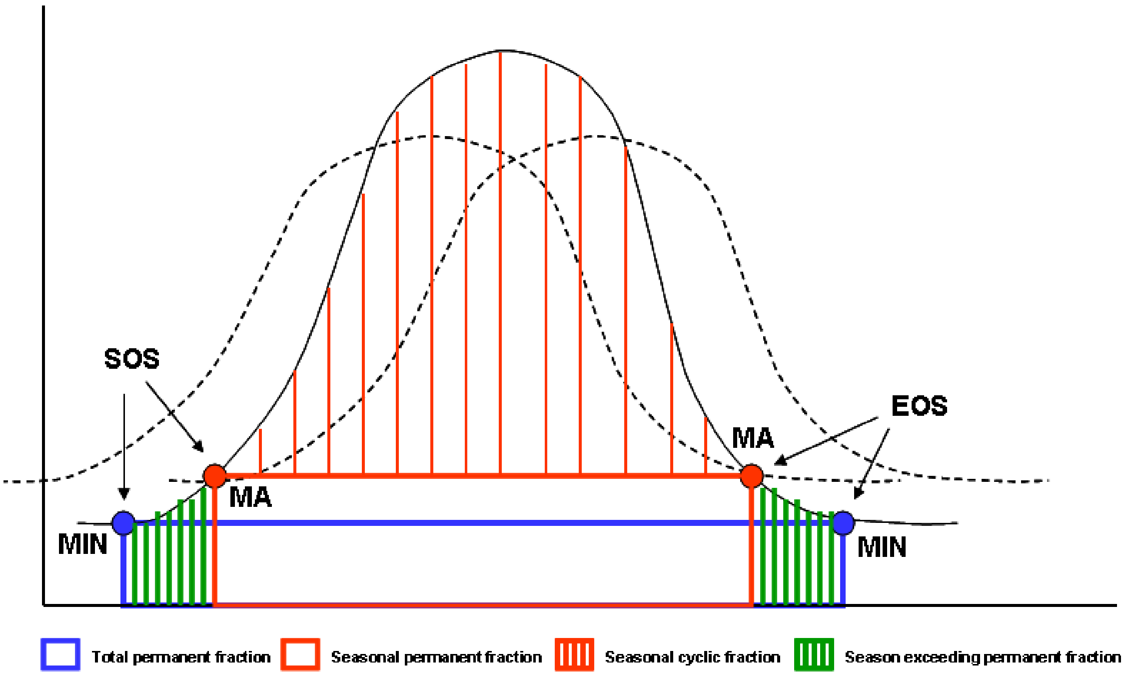


Figure 18: Description of the permanent and cyclic fractions under the time series curve of one year.

In order to monitor the effect of agri-environmental measures and especially that of extensification by means of remotely sensed vegetation indices the following assumptions were made:

- In case of extensification of agricultural practices the amount of permanent vegetation cover should also increase on the area where this measure was introduced.
- In case the amount of vegetation that permanently covers the area increases it will be possible to monitor by means of remote sensing.
- The permanent vegetation fraction can be calculated from remotely sensed vegetation indices as the area under the curve defined by the start and the end of the season.
- The amount of permanent vegetation fraction in the riparian-use area will be correlated to its natural and bad status and therefore can be used as indicator of agricultural extensification and eventually as an indication of the effect of a certain agri-environmental measure.

3.3 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.

3.4 Discriminant analysis

Discriminant analysis was used to further explore the capacity of the vegetation fractions in differentiating the riparian zone in favourable and unfavourable status. The method is equivalent to an F-test of an ANOVA that states whether the designed groups are significantly different from each other with respect to the mean of a particular variable. As a measure of how well the computed discriminant function can differentiate between the groups the eigenvalue, the canonical correlation coefficient and the Wilks' Lambda statistic was used. The eigenvalue is computed as the quotient of the sum of squared variances between the groups and the sum of squared variances within the groups. High values, i.e. when the variance between the groups is much higher then the variance within the groups, indicate good discriminative power of the variable. The canonical correlation coefficient measures the strength of the relation between the discriminant function and the defined groups. It is defined as:

$$canonical\_correlation = \sqrt{\frac{eigenvalue}{1 + eigenvalue}}$$

thus measures the part of the variance between the groups compared to the total variance. The higher the value the better is the explanatory power of the discriminant model and the better the separation between the groups. It is normalised between 0 and 1 thus gives a better basis for comparison then the eigenvalue. Wilks' lambda is a goodness of fit measure, which is computed as the quotient of the sum of squared within group variances to the total sum of squared variances. It is an inverse measure, i.e. smaller values indicate higher separability. Wilks' Lambda can be transformed into a probabilistic variable so that it allows a statistical test with a Chi square distribution. The null hypothesis states that the defined groups are not significantly different while the alternative hypothesis states that there is a statistically significant difference between the groups.

3.5 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 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.

In the present study trend analysis was used to assess the direction and strength of the trend in the seasonal permanent fraction data derived from GVF for each year. A linear function was fitted to the sixteen years seasonal permanent fraction because the curve analysis procedure exposed equal or lower significance of other functions like logarithmic, inverse, quadratic, cubic etc. The Durbin-Watson statistic and the plot of the partial autocorrelation function (PACF) of the non-standardised model residuals were used to check existence of autocorrelation in the data. The Durbin-Watson statistic tests the null hypothesis that the residuals from an ordinary least-squares regression are not autocorrelated against the alternative that the residuals follow a first-order autoregression process (AR1). The regression models assume that the residuals are uncorrelated. If a non-periodic function, such as a straight line, is fitted to periodic time series data, the errors have a periodic form and are positively correlated over time; these deviations are said to be "autocorrelated'' or "serially correlated”. Autocorrelated deviations may also indicate that the form (shape) of the function being fitted is inappropriate for the data values (e.g., a linear equation fitted to quadratic data). A value of 2 indicates that there appears to be no autocorrelation in the data. Small values of the statistic indicate that successive error terms are, on average, close in value to one another and thus positively correlated. Large test statistic values on the other hand indicate that the successive errors are, on average, much different and thus negatively correlated.

Durbin and Watson established upper and lower bounds for the critical values. Typically, tabulated bounds are used to test the hypothesis of zero autocorrelation against the alternative of positive first-order autocorrelation, since positive autocorrelation is seen much more frequently in practice than negative autocorrelation. If the observed value of the test statistic is less than the tabulated lower bound, then you should reject the null hypothesis of non-autocorrelated errors in favor of the hypothesis of positive first-order autocorrelation. If the observed test statistic value (d) is greater than 2, the null hypothesis against the alternative hypothesis of negative first-order autocorrelation has to be tested. To do this, the quantity 4-d has to be computed and compared with the tabulated values of dL and dU. If the test statistic value were greater than dU, the null hypothesis will not be rejected. The sample partial autocorrelation at lag *L* is simply the correlation between the two sets of residuals obtained from regressing the elements y_t and y_{t-L} on the set of intervening values y_1, y_2,...,y_{t-L+1}. It measures the dependence between y_t and y_{t-L} after the effect of the intervening values has been removed thus at lag $\boldsymbol{k}$ it is the autocorrelation between $\boldsymbol{X_t}$ and $\boldsymbol{X_{t-k}}$ that is not accounted for by lags 1 through $\boldsymbol{k-1}$. Autoregressive processes exhibit spikes in the PACF plots where the number of spikes equals the order of the autoregressive process in the time series data.

4 Results

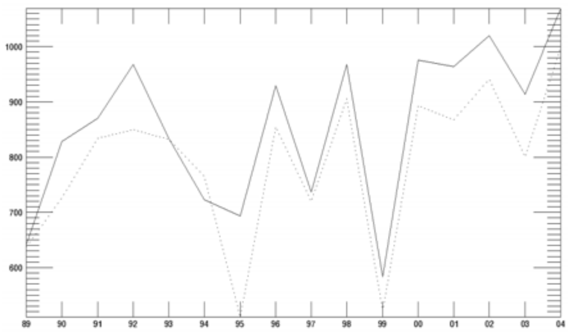
4.1 Classification of the favourable and unfavourable riparian status.

Figure 19 displays spectral libraries of the seasonal cyclic, seasonal permanent, total cyclic and the total permanent fractions over the favourable (full line) and the unfavourable (dashed line) riparian areas. After visual interpretation of the graphs, the permanent fractions better separate the natural and the bad riparian statuses then the cyclic fractions. Furthermore, the total permanent fraction exhibits much higher differences between the favourable and the unfavourable riparian status then the seasonal permanent fraction. The very dry year of 1999 does not seem to effect the total permanent fraction as much as in case of the other indicators where this year clearly exhibit a very low value compared to the rest of the series. The least successful separation between the natural and bad riparian status arise from the seasonal cyclic vegetation fraction image. In case of the permanent fractions the curves follow very similar pattern over the favourable and unfavourable status. The cyclic fractions on the other hand show different developments especially in the year 1995. Here the riparian areas in the bad status experienced very low cyclic vegetation values while in areas under natural status the cyclic fraction of the vegetation

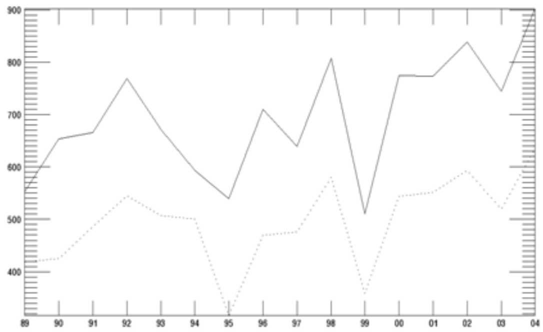
Discriminant analysis of the ***seasonal cyclic fraction*** data over the olives areas is presented in Figure 20. The eigenvalue of 0.058 indicates that the variance between the groups is only 0.06 times higher then the variance within the groups. Thus, the explanatory power of the discriminant model is very low. This is also reflected in the canonical correlation coefficient that shows a low relation between the two groups of the riparian status and the computed discriminant function. The Wilks' lambda is insignificant thus indicates that using the seasonal cyclic fraction no differentiation can be made between the natural and bad riparian status.

The ***seasonal permanent fraction*** data gives better separation of the natural and bad riparian status areas (Figure 21). The eigenvalue shows that the variance between the two groups is higher then the variance within the groups and the canonical correlation coefficient jumped to 0.721. This indicates that the discriminant model using the seasonal permanent fraction can well separate natural from bad riparian status. Wilks' lambda is highly significant on the 0.000% level indicating that the seasonal permanent fraction can significantly separate the two riparian areas.

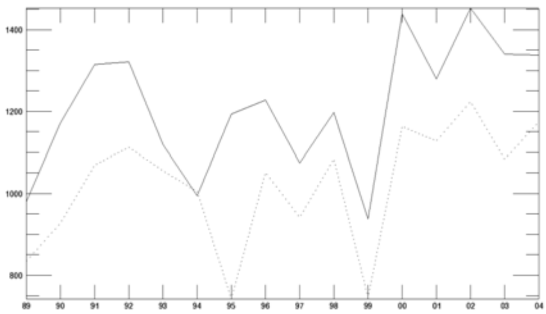
The discriminative power of the ***total cyclic fraction*** is between that of the seasonal fractions: it is better then the seasonal cyclic but worse then the seasonal permanent fraction (Figure 22). The eigenvalue indicates that the between group variance is less then half of the within group variance thus, although the model can explain some differences between the groups the separation is not satisfactory. The canonical correlation coefficient also shows only a modest relationship between the two groups and the computed discriminant function. Wilks' lambda is significant on the 0.001 % level thus even though the separability between the groups is modest the results are trustworthy.



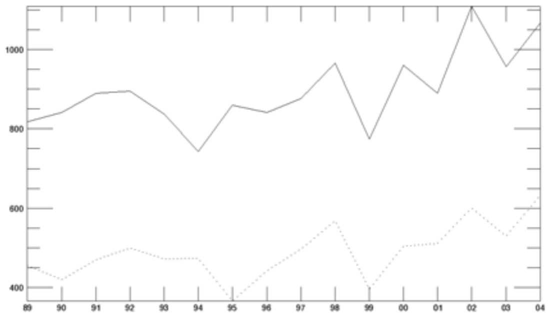
Seasonal cyclic vegetation fraction



Seasonal permanent vegetation fraction



Total cyclic vegetation fraction



Total permanent vegetation fraction

Figure 19: Spectral libraries of the total and seasonal permanent fractions over the natural (solid line) and the bad (dotted line) riparian areas.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.058[a]	100.0	100.0	.234

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.945	1.668	1	.197

Figure 20: Discriminant analysis of the natural and bad riparian status using the seasonal cyclic fraction data.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.081[a]	100.0	100.0	.721

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.481	21.617	1	.000

Figure 21: Discriminant analysis of the natural and bad riparian status using the seasonal permanent fraction data.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.413[a]	100.0	100.0	.541

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.708	10.204	1	.001

Figure 22: Discriminant analysis of the natural and bad riparian status using the total cyclic fraction data.

The ***total permanent fraction*** data reached the best separability between the riparian areas under natural and bad status (Figure 23). The eigenvalue is the highest with 6.021 meaning that the variance between the riparian status groups is six times higher then the variance within the riparian groups. The canonical correlation coefficient shows a very strong relationship between the defined groups and the computed discriminant function. Wilks' lambda is highly significant on the 0.000 level and the value itself indicates highest separability between the natural and bad riparian status.

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.021[a]	100.0	100.0	.926

a. First 1 canonical discriminant functions were used in the analysis.

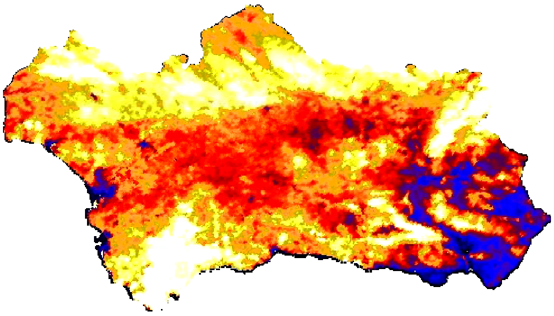
Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.142	57.493	1	.000

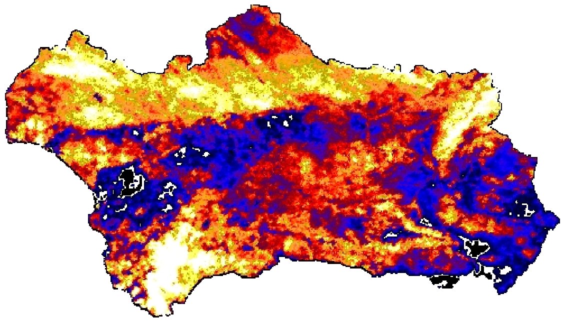
Figure 23: Discriminant analysis of the natural and bad riparian status using the total permanent fraction data.

Based on the discriminant analysis results the total permanent fraction was used for the classification of the favourable and unfavourable riparian-use zones based on ground observations of the natural and bad riparian status. For training the Nearest Neighbour classifier of the favourable and unfavourable classes, samples lying 1 standard deviation from the mean of the natural and bad riparian status sample population were selected, respectively. For accuracy assessment of the classification all the observations were used. In order to keep the Nearest Neighbour feature space as simple as possible, a principal component analysis was carried out on the sixteen total permanent fractions. The first three components explained ca. 90 % of the total variation and therefore these were used in the classification (Figure 24). Additionally, the first principal component of the sixteen years GVF data (576 images) was calculated and used in the Nearest Neighbour feature space to facilitate the classification. This component described 68% of the total variation and was included to account for seasonal changes throughout the years (see Figure 24).

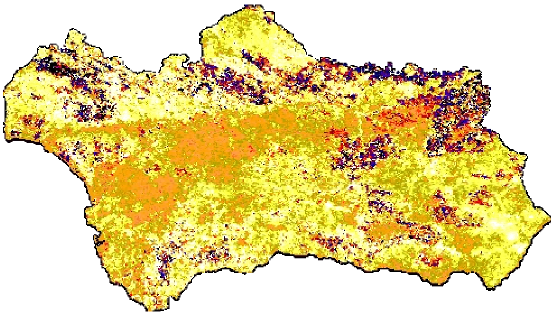
The overall accuracy of the classification, which is the total number of test pixels correctly classified divided by the total number of pixels, amounted to 89% (Figure 25). The overall accuracy includes overall errors of omission (exclusion) without regards to class membership. It disregards errors due to commission entirely and as such represents an overally optimistic estimate of classification accuracy. The accuracies of individual categories can be calculated by dividing the number of correctly classified pixels in each category by either the total number of pixels in the corresponding row or column. Commission errors (non-diagonal row elements in the error matrix) are represented by pixels that were improperly included in one category while omission errors (non-diagonal column elements in the error matrix) are represented by pixels that were improperly excluded from a category. The Producer's accuracy neglects errors of commission but accounts for errors of omission. For class A it is the number of correctly classified pixels in



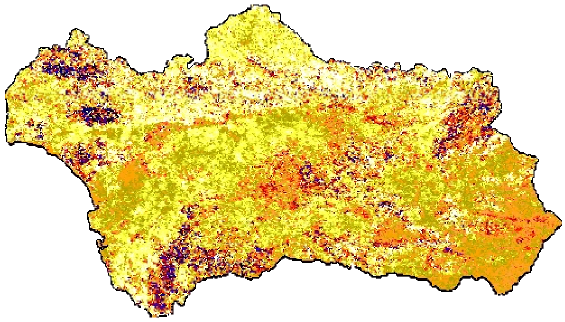
1st Principal Component of the GVF data



1st Principal Component of the total permanent fraction



2nd Principal Component of the total permanent fraction



3rd Principal component of the total permanent fraction

Color range of the GVF and total permanent fraction values
left: low values; right: high values

Figure 24: Images used for the classification of natural and bad riparian status

class A divided by the number of training pixels used for that category (the column total). This figure indicates how well *training set pixels* of the given category are classified. The natural riparian status reached a Producer's accuracy of 88% while the bad status that of 90%. Thus, only 12 and 10 % of the pixels were improperly excluded from the natural and the bad riparian categories, respectively. The User's accuracy is a measure of commission error and indicates the probability that a pixel classified into a given category actually represents that category on the ground. It is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). The User's accuracy accounts for 92 and 85 % for the natural and bad riparian status classes, respectively. Thus the probability that a pixel classified into the natural category actually represents natural riparian status on the ground is higher then those for the bad riparian status category.

User \ Referenc...	natural	very bad	Sum
Confusion Matrix			
natural	791	65	856
very bad	110	617	727
unclassified	0	0	0
Sum	901	682	
Accuracy			
Producer	0.8779	0.9047	
User	0.924	0.8487	
Hellden	0.9004	0.8758	
Short	0.8188	0.779	
KIA Per Class	0.7342	0.8237	
Totals			
Overall Accuracy	**0.8895**		
KIA	**0.7764**		

Figure 25: Error matrix and accuracy assessment of the classification of the favourable and unfavourable riparian status based on the total permanent fractions over the sixteen years.

The Kappa Index of Agreement (KIA) coefficient measures the proportion of agreement after chance agreements have been removed from considerations. In contrast to the overall accuracy the Kappa coefficient takes also non-diagonal elements in the error matrix into account. The Kappa coefficient belongs to the family of bivariate agreement coefficients, in the form:

$$Agreement = 1 - \frac{observed\_disagreement}{\exp ected\_disagreement}$$

These agreements, like the Kappa coefficient, are zero for chance agreement, one for perfect agreement, and negative for less than chance agreement. A Kappa of zero occurs when the agreement between classified data and verification data equals chance agreement (Fenstermaker, 1991) The 0.77 Kappa coefficient in the above example means that the accuracy of the classification is 77% better then the accuracy that would result from a random assignment.

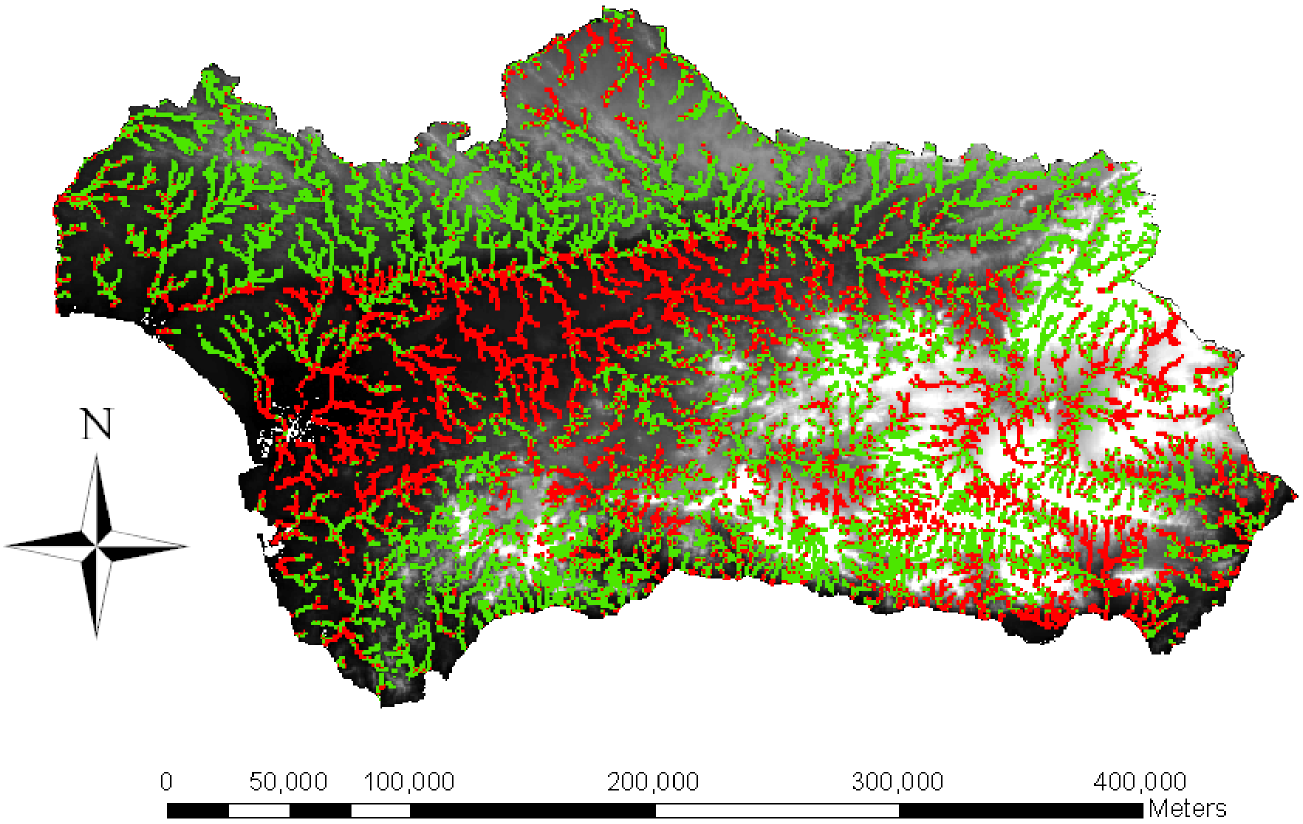


Figure 26: Classification of favourable (green) and unfavourable (red) riparian-use zones in Andalusia.

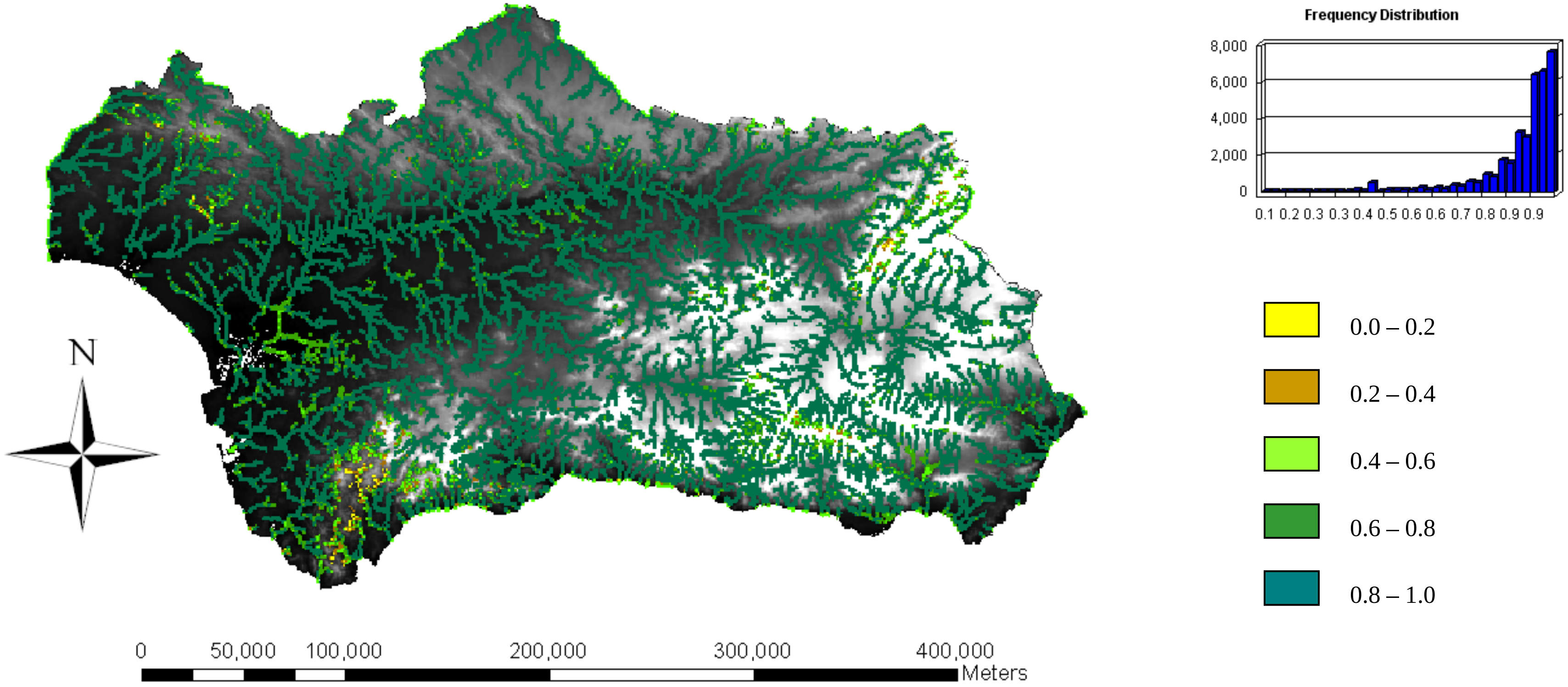


Figure 27: Probability that the riparian zone in Andalusia belongs to the favourable status. Each pixels probability of belonging to the natural riparian zone class is shown independently whether the pixel was classified as natural riparian status or not.

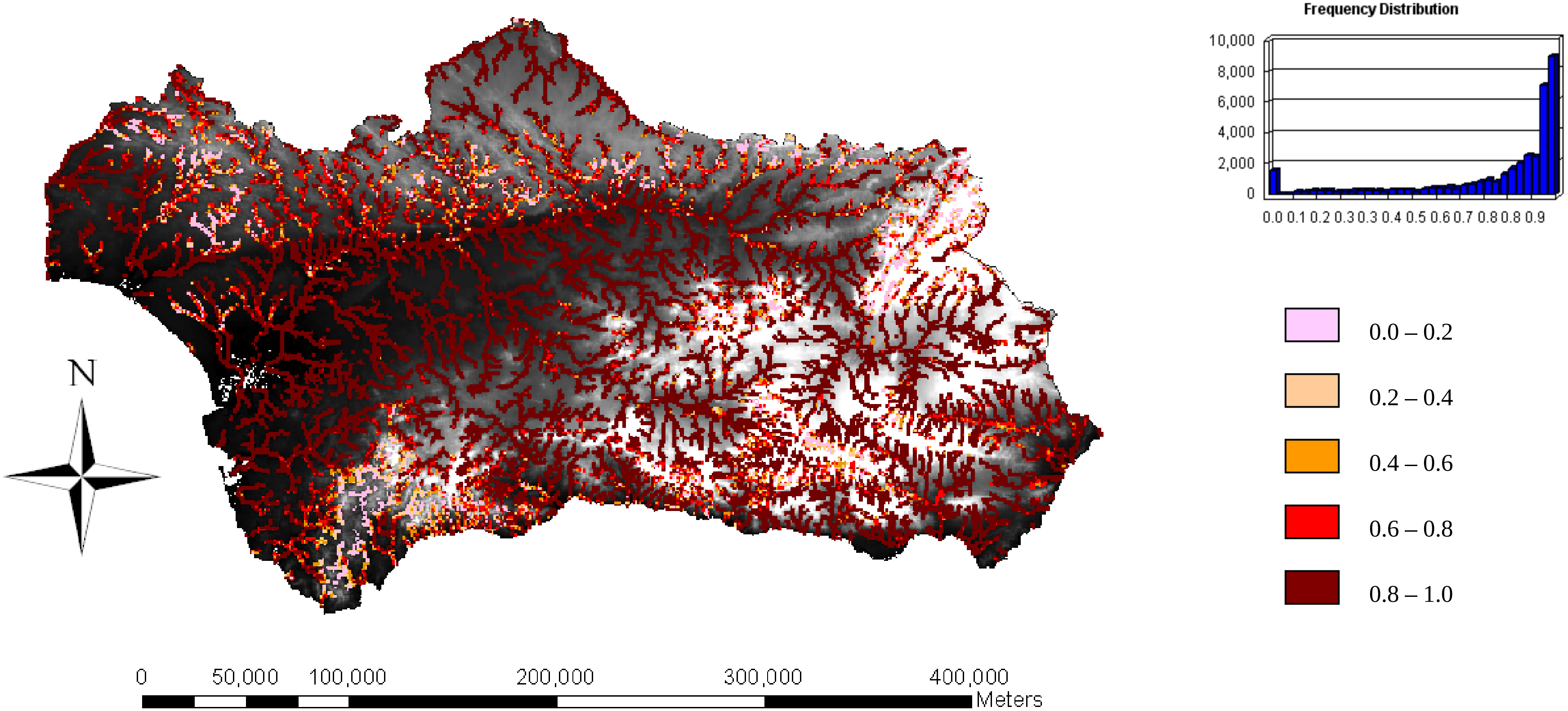
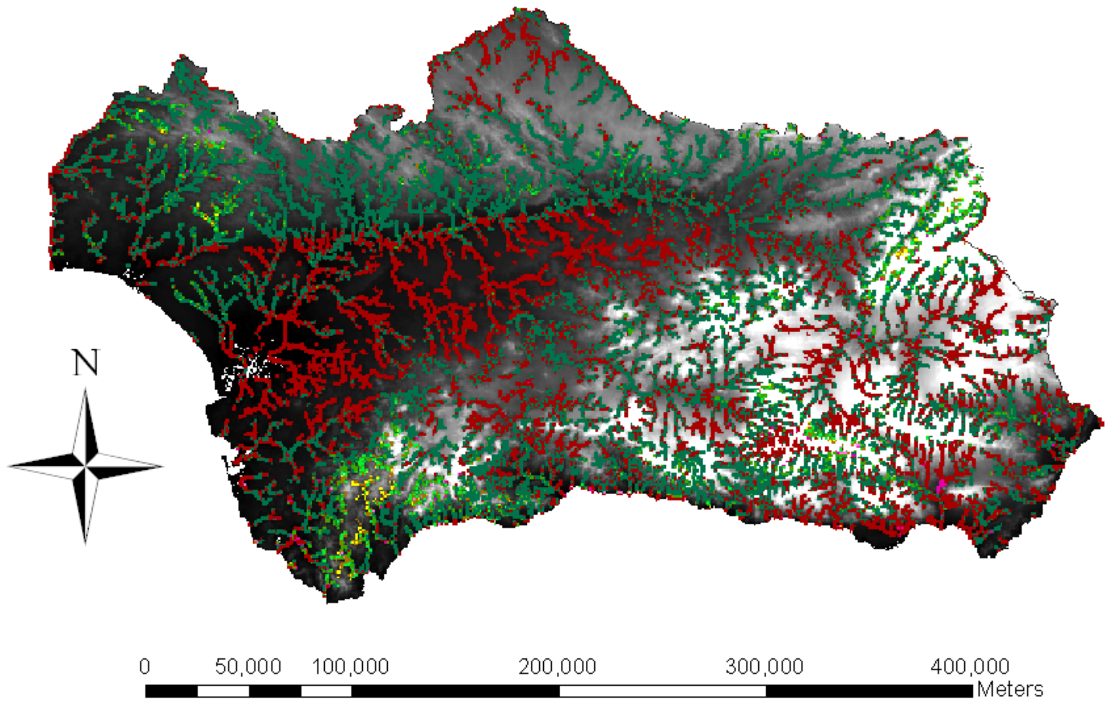
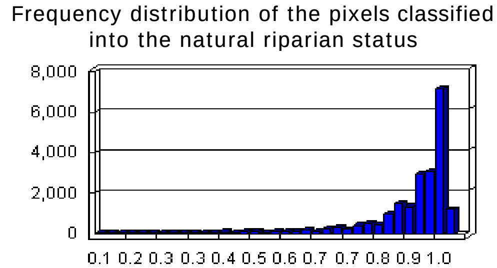
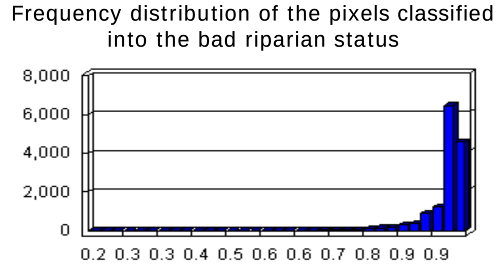


Figure 28: Probability that the riparian zone in Andalusia belongs to the unfavourable status. Each pixels probability of belonging to the bad class is shown independently whether the pixel was classified as bad riparian status or not.







Probability classes of the natural riparian zone classification

0.0 – 0.2 **0.2 – 0.4** **0.4 – 0.6** **0.6 – 0.8** **0.8 – 1.0**

Probability classes of the bad riparian zone classification

0.8 – 1.0 **0.6 – 0.8** **0.4 – 0.6** **0.2 – 0.4**

Figure 29: Classification result: probability of the riparian zone classification. For each pixel the probability of belonging to the finally assigned favourable or unfavourable categories is shown.

Figures 27-29 demonstrate the maps of riparian status classified into probability ranks of the favourable and unfavourable categories (0.0-0.2, 0.2-0.4, 0.4-0.6, 0.0-0.8 and 0.8-1.0). The frequency distribution of the ranks is strongly skewed towards the left indicating that most of the pixels were classified into the respecting category with a very high probability. Ninety six percent of the pixels classified into the favourable category reached a probability of correct assignment between 0.8-1.0. Around 2 percent of the pixels had a probability within the interval of 0.6-0.8 and another two percent is distributed in lower probability classes. Ninety five percent of the pixels classified into unfavourable riparian status reached a very high probability belonging to the interval of 0.8-1.0 while almost five percent of the pixels had a probability in the interval of 0.6-0.8. The low probability of the classification of both the favourable and unfavourable riparian status occurred mostly in two areas: (1) Los Alcornocales south of Andalusia close to Gibraltar and (2) the Sierras de Castril y La Sagra, east Andalusia close to Murcia. The former area is mostly covered by evergreen oak, chestnut and other deciduous species while the latter with coniferous tree species.

Field observations were acquired from the year 2003, therefore another classification was run using phenological indices from the observation's year. Additionally the years 2002 and 2004 were included in the classificator in order to increase the feature space and to account for inter annual variability of the phenology. Using the total permanent fraction the overall accuracy of the classification amounted to 85%, 4 percent less then using the phenology from the whole time series (Figure 30). Producer's accuracy for the favourable class was the same then before but for the unfavourable class it dropped from 90 to 81%. The user's accuracy dropped to 86 and 84% for the favourable and unfavourable classes, respectively. The kappa coefficient indicates that the accuracy of the classification is 70 percent better then a random agreement, 7 % less then in the classification before.

This classification was repeated with the 2003-2004 seasonal permanent fraction images building the feature space (Figure 31). Overall accuracy has increased to 87%, better then the classification with the total permanent fraction. Producer's accuracy of the favourable riparian status class was comparable with results before but that of the unfavourable class increased to 87% compared to the 81% based on the total permanent fraction. User's accuracy amounted to 90% and 84% for the favourable and unfavourable riparian state classes, respectively. The 0.73 Kappa coefficient suggests that the accuracy is 73% better then a random agreement would result. For reasons of simplicity, the favourable and unfavourable categories of the first classification were used in the follow up analysis. Nevertheless, the above mentioned results indicate that both the seasonal and the total permanent fraction deliver comparable results.

User \ Referenc...	natural	bad	Sum
Confusion Matrix			
natural	797	129	926
bad	103	553	656
unclassified	1	0	1
Sum	901	682	
Accuracy			
Producer	0.8846	0.8109	
User	0.8607	0.8430	
Hellden	0.8725	0.8266	
Short	0.7738	0.7045	
KIA Per Class	0.7219	0.6770	
Totals			
Overall Accuracy	**0.8528**		
KIA	**0.6987**		

Figure 30: Error matrix and accuracy assessment of the classification of the favourable and unfavourable riparian status based on the total permanent fractions from the years 2002, 2003 and 2004.

User \ Referenc...	natural	bad	Sum
Confusion Matrix			
natural	784	90	874
bad	116	592	708
unclassified	1	0	1
Sum	901	682	
Accuracy			
Producer	0.8701	0.868	
User	0.897	0.8362	
Hellden	0.8834	0.8518	
Short	0.7911	0.7419	
KIA Per Class	0.71	0.7613	
Totals			
Overall Accuracy	**0.8692**		
KIA	**0.7348**		

Figure 31: Error matrix and accuracy assessment of the classification of the natural and bad riparian status based on the seasonal permanent fractions from the years 2002, 2003 and 2004.

4.2 Analysis of the distribution of the CORINE Land Cover Classes within the favourable and unfavourable riparian-use zone

Figure 32 displays the distribution of CORINE land cover classes within the favourable and unfavourable riparian status classification. In the favourable riparian zone the scrub and herbaceous vegetation associations are represented with the largest area (29%) while in the unfavourable riparian status the arable land category covers the largest area (39%). The latter land cover class only amounts to 11 percent in the favourable riparian status. Permanent crops and heterogeneous agricultural areas cover more or less the same area in both riparian zone categories. Forested areas on the other hand amount to 19% of the favourable riparian zone while only to four percent in the unfavourable riparian status. Wetland, water bodies and artificial surfaces are ignorable in both areas.

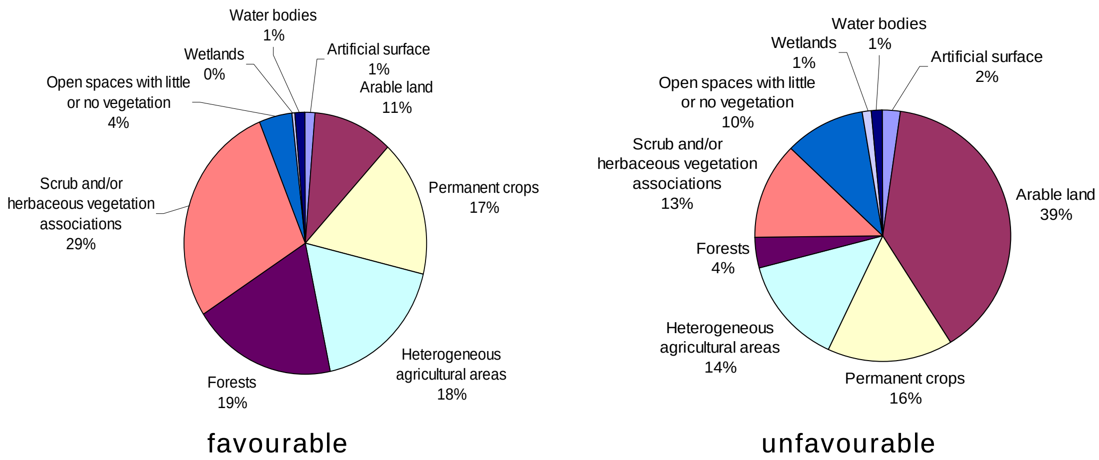


Figure 32: distribution of the CORINE land cover classes within the favourable and unfavourable riparian zone classifications.

Figure 33 displays the area distribution of CORINE land cover classes within the five fuzzy probabilities of the favourable and unfavourable riparian status classifications, respectively. For this analysis the final classification result was used, i.e. the highest probability that each pixel could only belong either to the favourable or to the unfavourable riparian status class. In the favourable riparian zone the scrub and/or herbaceous vegetation associations were classified with the highest probability and are represented by the largest area with 524 thousand hectares. This class is followed by the heterogeneous agricultural areas, permanent corps and forest land covers with ca, 300 thousand hectares. In the highest probability class of the unfavourable riparian zone the arable land class is represented by far the largest area amounting to 541 thousand hectares. Permanent crops and heterogeneous agricultural areas cover around 200 thousand hectares in the unfavourable riparian zone. More interesting is however that all landcover classes were classified with very high probability in the unfavourable riparian zone. Some areas in the favourable zone on the other hand reached only a probability of 0.2 that they belong to the forests or to the scrub and herbaceous vegetation associations.

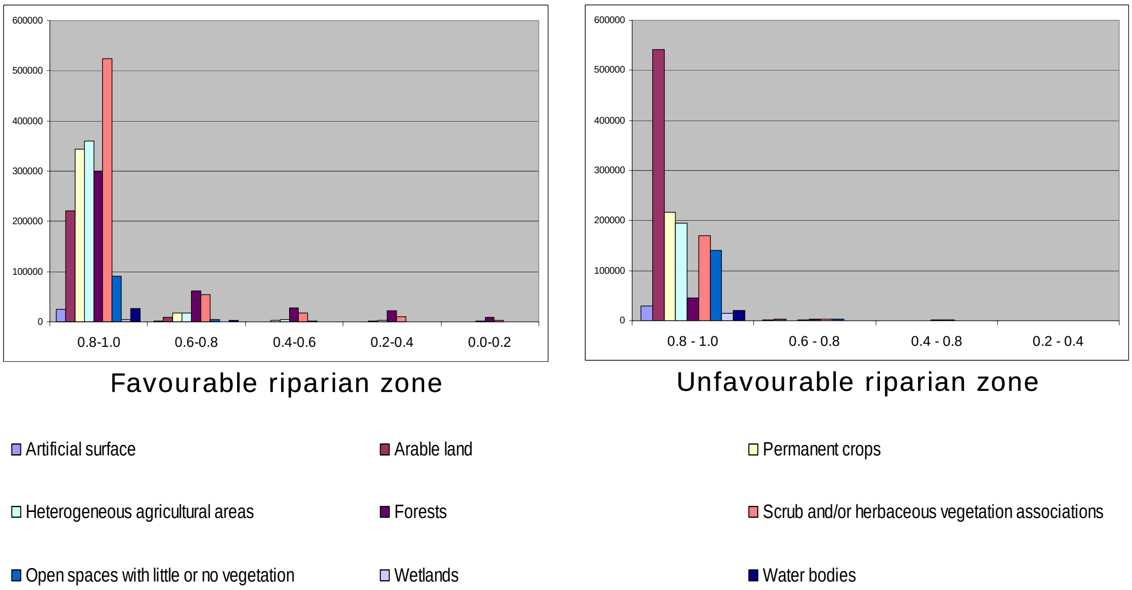


Figure 33: Distribution of the CORINE land cover classes within the probability classes of the favourable and unfavourable riparian zone classification (in hectares).

These areas, with a very low probability of the classification, were further investigated. Figure 34 shows the area distribution of the forest and scrub / herbaceous vegetation Corine land cover sub-classes in the lower probability classes (0.8 and less) of the favourable riparian zone. Many pixels belonging to the forest category also exhibit lower probabilities to these classes. As Figure 24 shows, in the probability classes 0.6-0.8 these concern mostly coniferous forest and transitional woodland land cover classes. In the lower probability classes mostly broadleaved forests exhibit high amount of pixels with dubious classification success.

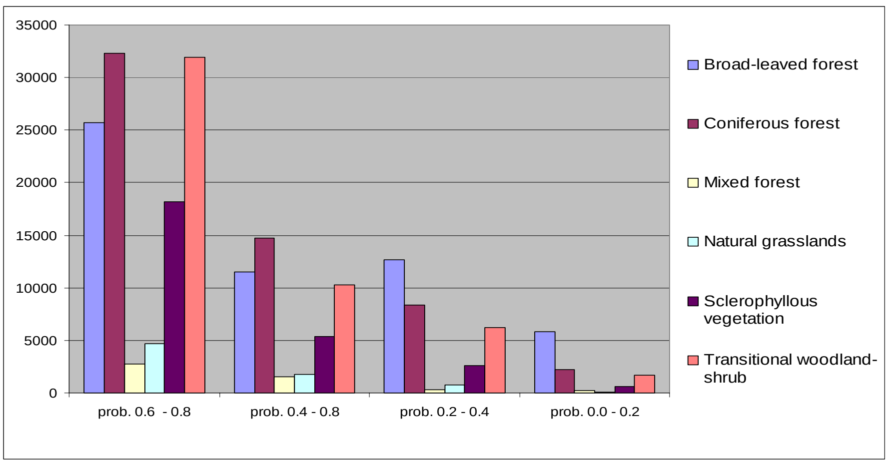


Figure 34: Distribution of the forest and scrub and/or herbaceous vegetation associations classes within the probability classes 0.8 – 0.0 of the favourable riparian zone classification.

4.3 Analysis of the distribution of the CORINE land cover classes in the favourable and unfavourable riparian zones with and without AEMs

In the favourable riparian-use zone under agri-environmental schemes scrub and herbaceous vegetation associations are represented with the largest area, amounting to ca. 50 thousand hectares or 26% of the total area (Figure 35). Permanent crops and heterogeneous agricultural areas amount to 44 and 40 thousand hectares, or 25 and 23 percent of the area, respectively. Finally, forest land cover is represented to a higher degree amounting to 34 thousand hectares or 19 % of the riparian-use area under agri-environmental schemes. While arable land is ignorable in the favourable riparian-use zone it covers the largest area in the unfavourable zone amounting to 31 percent or 20 thousand hectares. As in the favourable zone, permanent crops and heterogeneous agricultural areas also cover larger areas under the unfavourable riparian status. Scrub and herbaceous vegetation associations and forest land cover on the other hand cover only 13 and 6 percent of the unfavourable riparian-use zone.

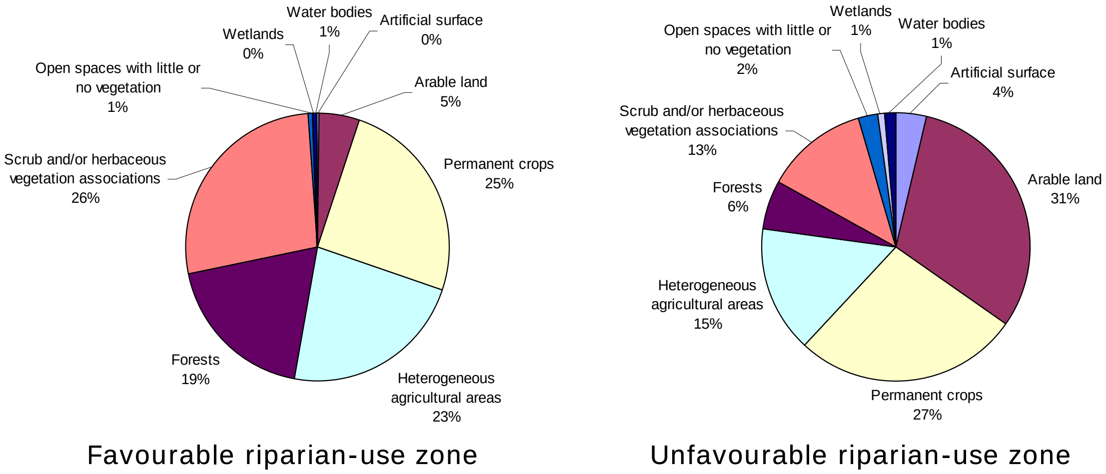


Figure 35: Distribution of CORINE land cover classes (area) within the favourable and unfavourable riparian-use status under agri-environmental schemes.

Figure 36 displays the distribution of the CORINE land cover categories within the probability classes of the favourable and unfavourable riparian-use zone classification over areas under agri-environmental measures. In the favourable zone most pixels belong to the probability class of 8.0-1.0 thus the classification proved to be trustable here. Very few pixels belong to the lower categories with a classification probability of 0.8 or less. In the unfavourable riparian-use zone almost all the pixels belong to the high classification probability of 0.8-1.0 while the probability class under 0.6 is ignorable.

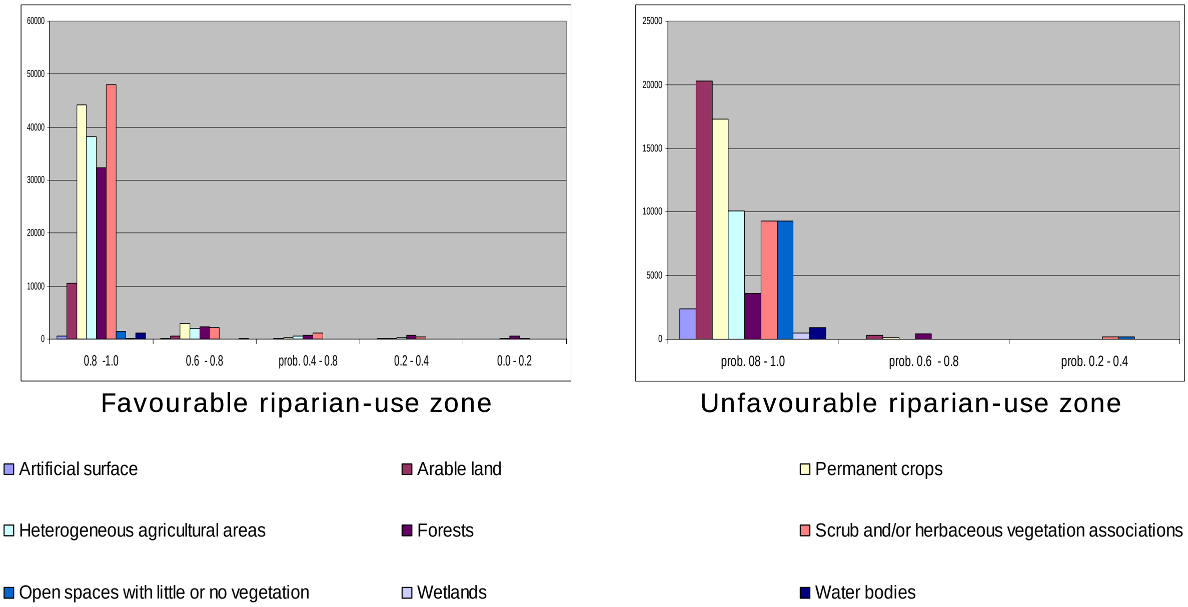


Figure 36: Distribution of the CORINE land cover classes within the probability classes of the favourable and unfavourable riparian-use zone classifications over areas under agri-environmental schemes (in hectares).

In the favourable riparian-use zone where no AEMs were introduced scrub and heterogeneous vegetation associations and forests cover similar areas then in areas with measures (29 and 20 percent, respectively; Figure 37). Permanent crops cover 9 percent less area then in the favourable zone under measures while heterogeneous agricultural areas cover 6 percent less areas. On the other hand, in the favourable riparian-use zone where no agri-environmental measures were introduced arable land covers six percent larger areas then in the riparian-use zone with measures. Arable land in the unfavourable riparian-use zone without agri-environmental schemes also covers larger area (9 percent larger) then in the unfavourable riparian zone where measures were implemented. Permanent crops cover smaller areas in the unfavourable riparian status without agri-environmental measures then under areas with measures (9 percent less). Heterogeneous agriculture, forest and scrub and herbaceous vegetation associations cover more or less the same areas in the unfavourable riparian-use vegetation zone with and without measures implemented. Open spaces with little or no vegetation cover larger areas in both the favourable and the unfavourable riparian zone where measures are not implemented, although in the unfavourable riparian zone this landcover class amounts to larger areas.

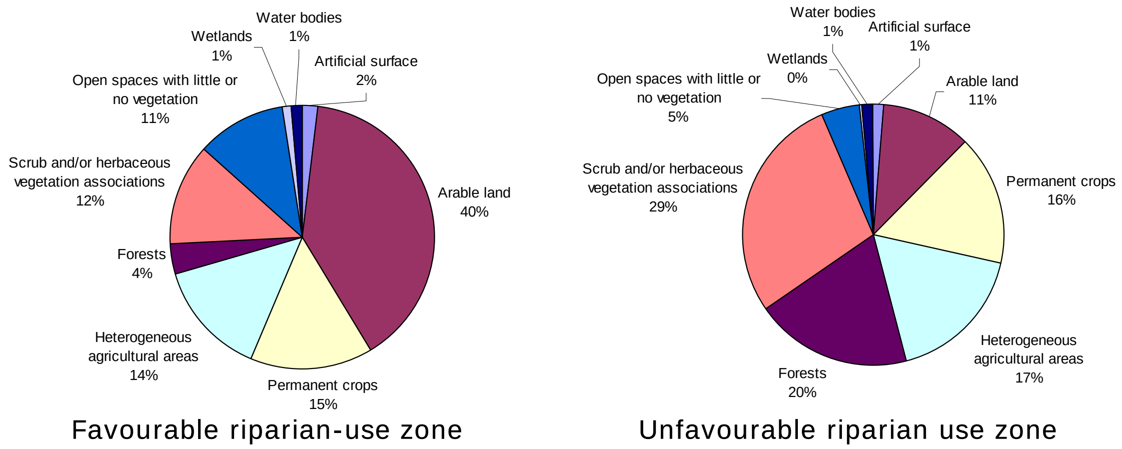


Figure 37: Distribution of CORINE land cover classes (area) within the favourable and unfavourable riparian status **NOT** under agri-environmental schemes.

Figure 38 below displays the distribution of the CORINE land cover categories within the probability classes of the favourable and unfavourable riparian zone classification over areas not under agri-environmental measures. Although most pixels belong to the very high probability class of 0.8-0.1 in the favourable riparian-use zone some pixels were classified with a lower probability mostly belonging to forest and scrub / herbaceous vegetation associations. Some pixels of the former class only reached a classification probability of 0.2. The unfavourable riparian-use zone expressed a very good classification probability with only ignorable amount of pixels belonging to a probability class of 0.8 or less.

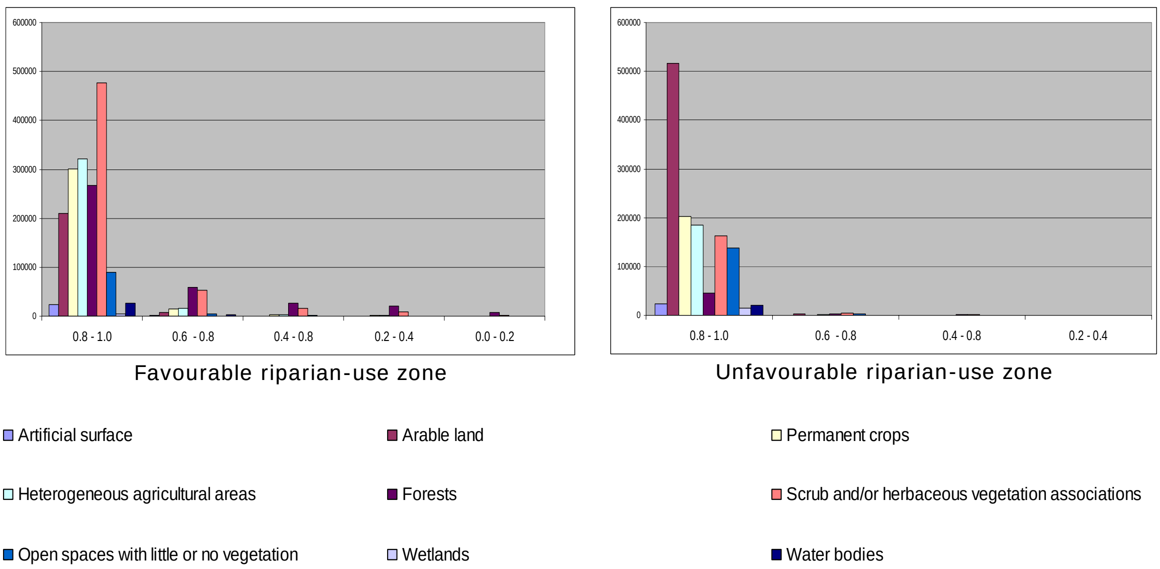
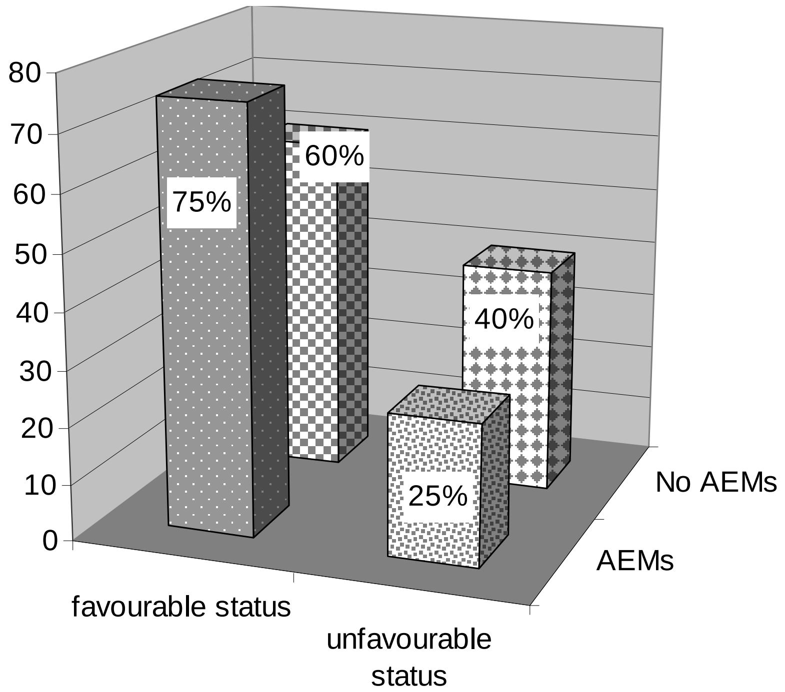


Figure 38: Distribution of the CORINE land cover classes within the probability classes of the favourable and unfavourable riparian-use zone classification over areas not under Agri-Environmental schemes (in hectares).

Figure 39 summarises the area distribution (in percent of the total area) of the favourable and unfavourable riparian status in the Guadalquivir river basin with and without Agri-Environmental Measures implemented. AEMs were implemented over 243 thousands hectares (respecting the 1km buffer on the left and right side of the river) while around 3 million hectares remained without measures. Larger area can be found under favourable then under unfavourable status regardless of whether Agri-Environmental Measures were applied or not. However, in areas where measures were implemented 75% of the riparian-use area falls within the favourable class while only 25% of the area falls within the unfavourable one. Expressed in terms of area, the ratio of favourable over unfavourable is 3 for areas where measure are implemented, whereas in areas without AEMs this ratio only accounts to 1.5. Indeed, only 60% of the area is classified as favourable riparian status while as much as 40% is classified as unfavourable. These results indicate that where measures are implemented (from 1998 onwards) most of the riparian-use zone presents a favourable status and that a proportionally larger area is in favourable status under AEMs then when not under without AEMs. However, these findings do not yet indicate a cause-effect link between the application of AEMs and their possible positive impact on the riparian status.



Ratio of favourable and unfavourable status under AEMs :

$$\frac{favourable}{unfavourable} = 3$$

Ratio of favourable and unfavourable status not under AEMs :

$$\frac{favourable}{unfavourable} = 1.5$$

Figure 39: Distribution of the favourable and unfavourable riparian status area within areas under and not under agri-environmental schemes.

4.4 Analysis of the area distribution of the AEMs in the favourable and unfavourable riparian zone

Figure 40 displays the area distribution of the Agri-Environmental Measures within the favourable and unfavourable riparian-use zones. In both areas erosion measures in olive cover the largest area (ca 40%). In the favourable riparian-use zone measures in the dehesa systems are the second largest while under the bad riparian status it is the green farming (33 and 23% respectively). The latter only amounts to seven percent in the natural areas. Rice integrated production covers 18% of the unfavourable riparian status while it reaches only 1 percent of the favourable areas.

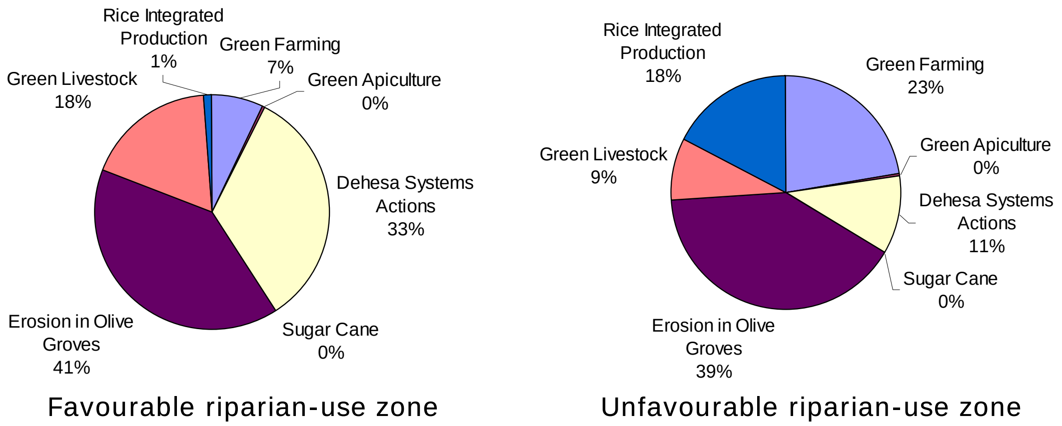


Figure 40: Distribution of the area of agri-environmental measures within the favourable and the unfavourable riparian status classes.

Figure 41 displays the area distribution of the Agri-Environmental Measures within the probability classes of the favourable and unfavourable riparian zone classifications. Areas under measures against erosion in Olive groves, dehesa system actions and green livestock fall within the highest probability class in the favourable riparian status probably due to their dominating area coverage. In the unfavourable riparian status areas under erosion measures in olive groves, green farming and rice integrated production fall within the highest probability class also following the dominating area distribution of these measures within the unfavourable riparian status. Hardly any of the measures fall into the probability class of less then 0.8, which confirms with previous results of good classification probability of the unfavourable riparian-use zone.

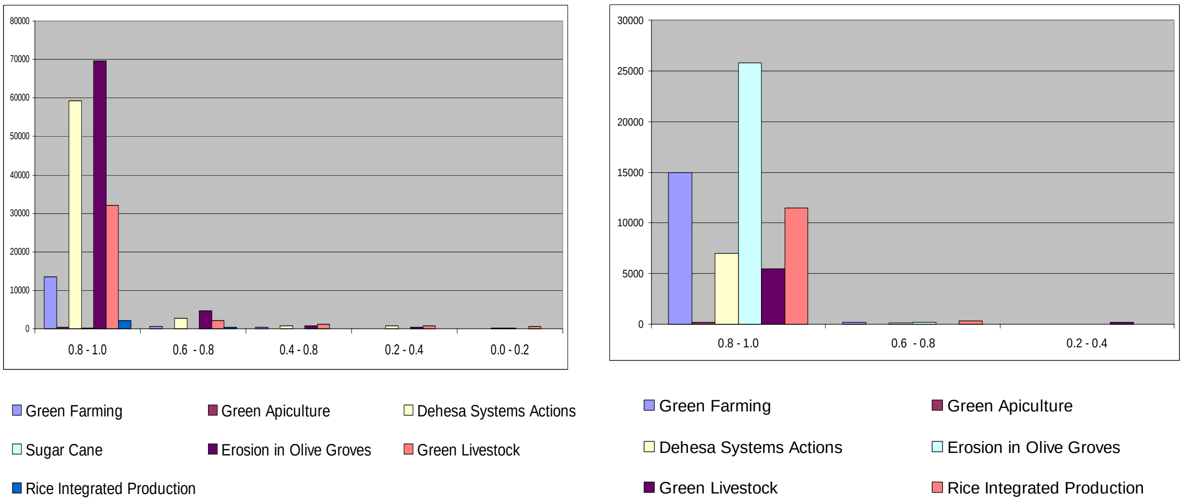


Figure 41: Distribution of the area of agri-environmental measures within the five probability classes of the favourable and unfavourable riparian-use zones.

Figure 42 displays the area distribution of the Agri-Environmental Measures within the favourable riparian-use area. Erosion measures in olive groves dominate over other AEMs and are mostly applied in areas under permanent crops (figure 43). Dehesa systems are mostly applied in heterogeneous agricultural areas, forests and shrub and herbaceous vegetation associations. Green livestock measures are mostly used in heterogeneous agricultural areas, forests and in scrub and herbaceous vegetation associations. Figure 44 displays the area distribution of the Agri-Environmental Measures within the unfavourable riparian-use area. Also here erosion measures in olive groves are the mostly applied measures and as before they dominate in areas with permanent crops (figure 45). Green farming mostly occurs in arable land and heterogeneous agricultural areas but also occurs under artificial surface (farmlands), permanent crops, forests and scrub and herbaceous vegetation associations. Rice integrated production dominates arable land areas while green livestock mostly occurs in heterogeneous agricultural areas and in scrub and herbaceous vegetation associations.

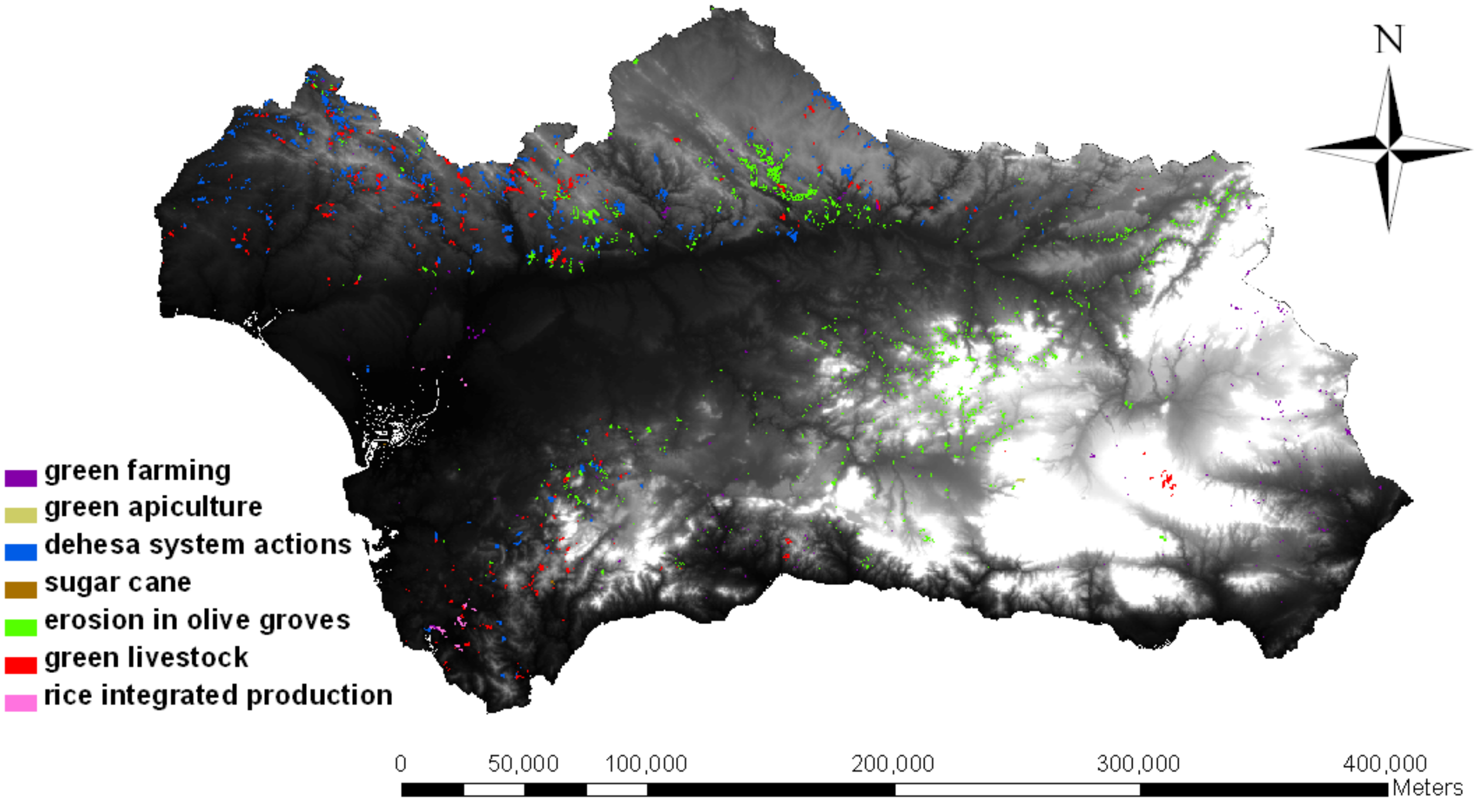
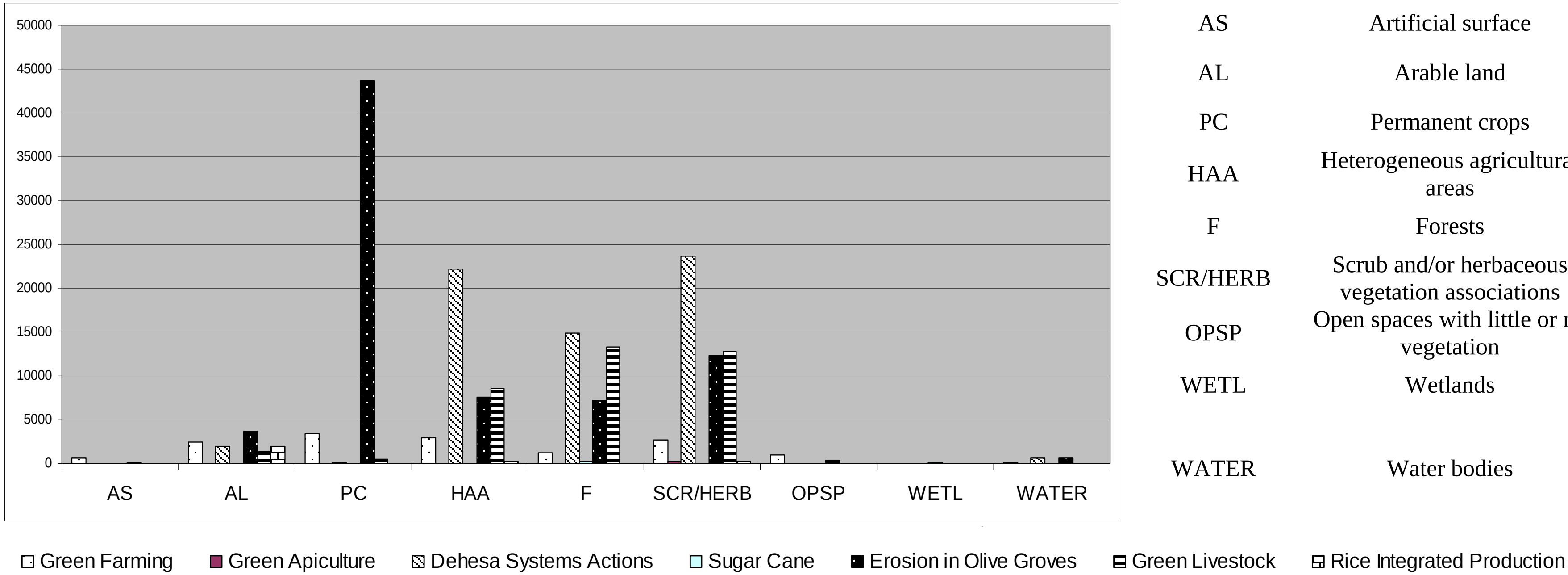


Figure 42: Agri-Environmental Measures within the favourable riparian-use zone.



AS	Artificial surface
AL	Arable land
PC	Permanent crops
HAA	Heterogeneous agricultural areas
F	Forests
SCR/HERB	Scrub and/or herbaceous vegetation associations
OPSP	Open spaces with little or no vegetation
WETL	Wetlands
WATER	Water bodies

Figure 43: Distribution of the area of AEMs within the CORINE land cover classes in the favourable riparian area.

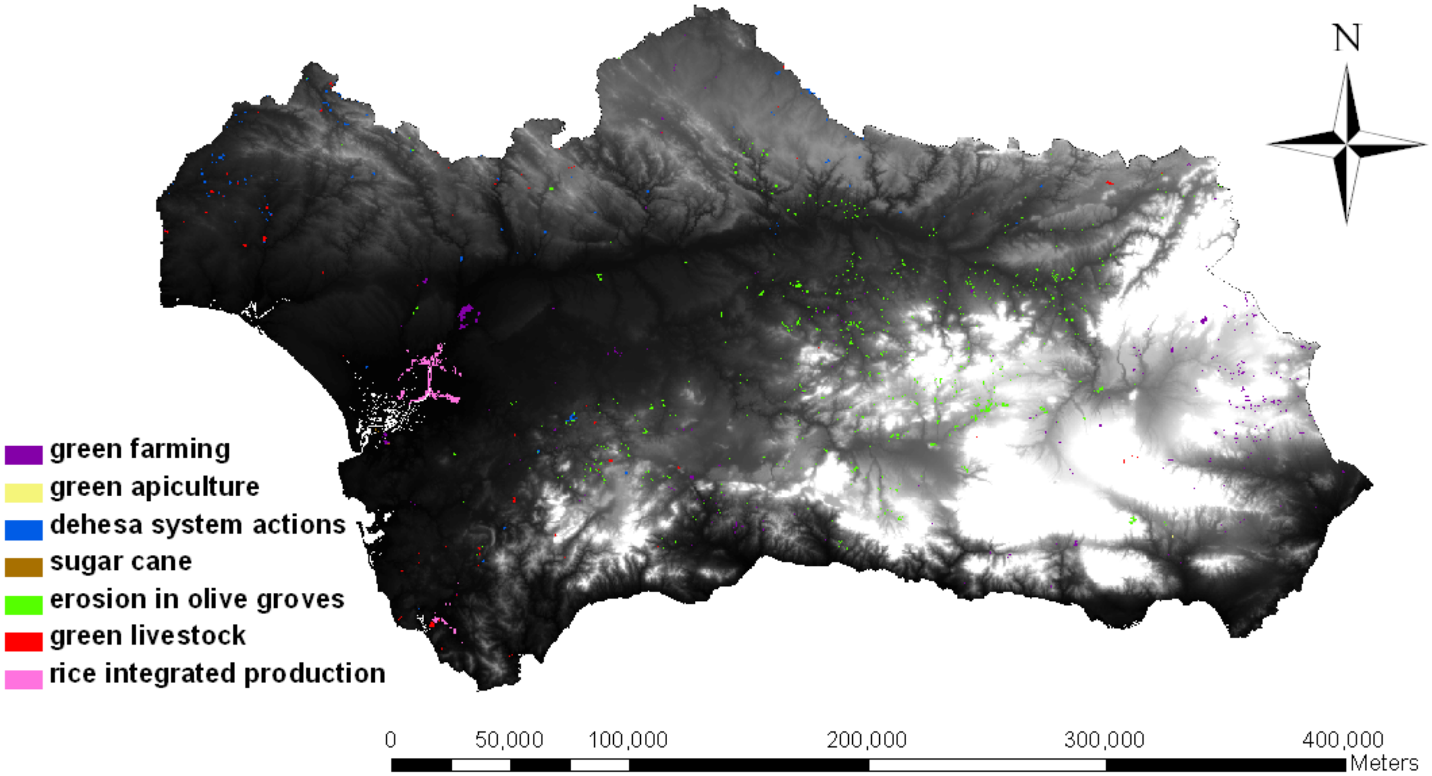
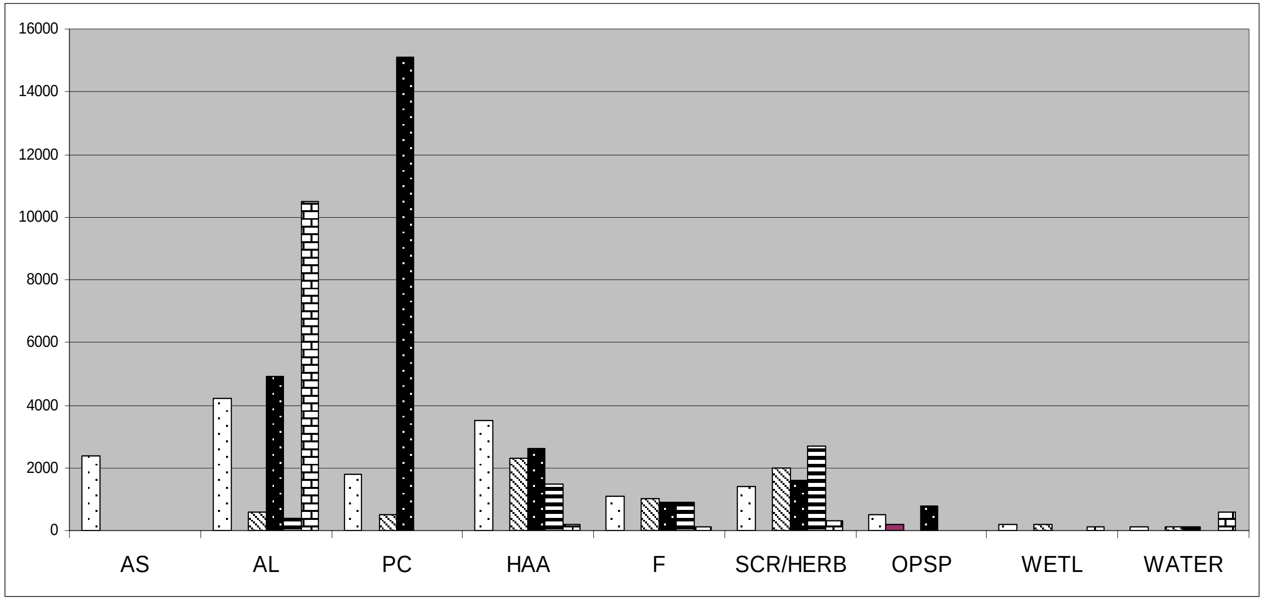


Figure 44: Agri-Environmental Measures within the unfavourable riparian-use zone.



AS	Artificial surface
AL	Arable land
PC	Permanent crops
HAA	Heterogeneous agricultural areas
F	Forests
SCR/HERB	Scrub and/or herbaceous vegetation associations
OPSP	Open spaces with little or no vegetation
WETL	Wetlands
WATER	Water bodies

Figure 45: Distribution of the area of AEMs within the CORINE land cover classes in the unfavourable riparian area.

4.5 Temporal evolution (1989-2004) of the total permanent fraction in the favourable and unfavourable riparian-use zone with and without AEMs

Figure 46 displays the area distribution of the favourable riparian-use zone with AEMs implemented (light green), the favourable riparian-use zone without measures implemented (dark green), the unfavourable riparian-use zone with measures implemented (yellow) and the unfavourable riparian-use zone without measures (red). The temporal evolution of the total permanent vegetation fraction from 1989 till 2005 in these areas is shown in Figure 47. Favourable riparian status express higher amount of permanent fraction throughout the years then the unfavourable status both in areas where measures were implemented and in areas without the measures. Furthermore, favourable riparian areas where measures were implemented can be further distinguished from natural areas without measures based on the higher amount of permanent vegetation fraction. Similar is the situation in areas under unfavourable riparian status where the implementation of agri-environmental measures results in higher amount of permanent vegetation fraction throughout the years.

These results show that we can monitor and distinguish areas with and without Agri-Environmental Measures based on the amount of permanent vegetation fraction derived from remote sensing time series images. However, the temporal evolution of the permanent vegetation fraction shows similar development (i.e. the shape of the time series curve) independently whether measures were implemented or not. This means that at the start of the time series in 1989 the difference between the permanent fraction of areas with and without measures is comparable to that in 2004 both under the favourable and the unfavourable riparian status. Therefore at this point we cannot state if these areas differ in their permanent vegetation fraction because of implementation of agri environmental measures or if these measures were generally implemented in areas where vegetation were already in a healthier stage.

For example it is highly probable that farmers signing to agri-environmental schemes selected those areas to implement these where historically the agricultural practices were already more extensive, hence where farm income tended to be lower. On the other hand a slight positive trend can be observed from 1999 onwards in the evolution of the permanent fraction. Generally agri-environmental measures were introduced in 1998 in the Quadalquivir river basin thus implementation of the measures could potentially contribute to explaining this evolution.

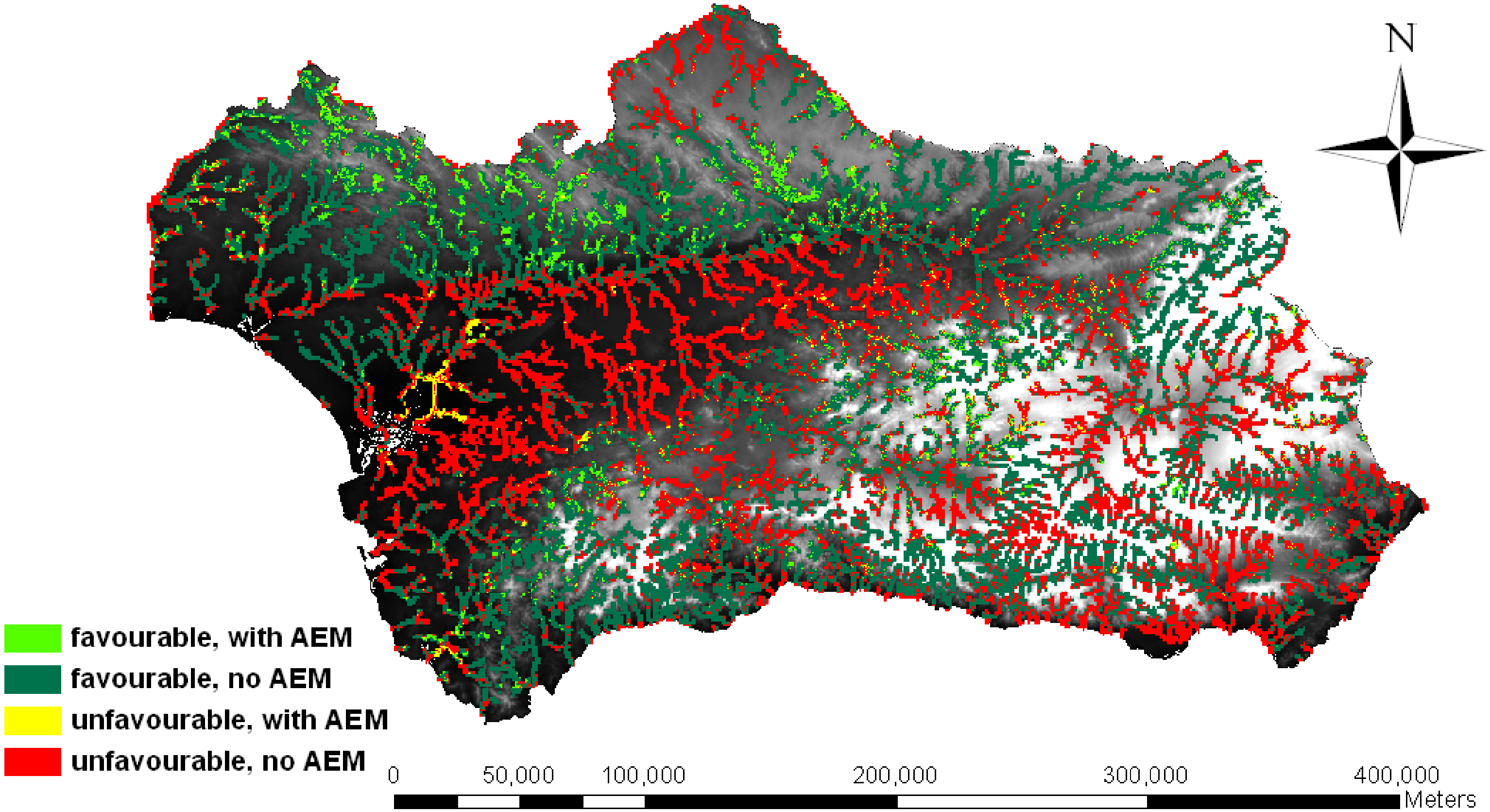
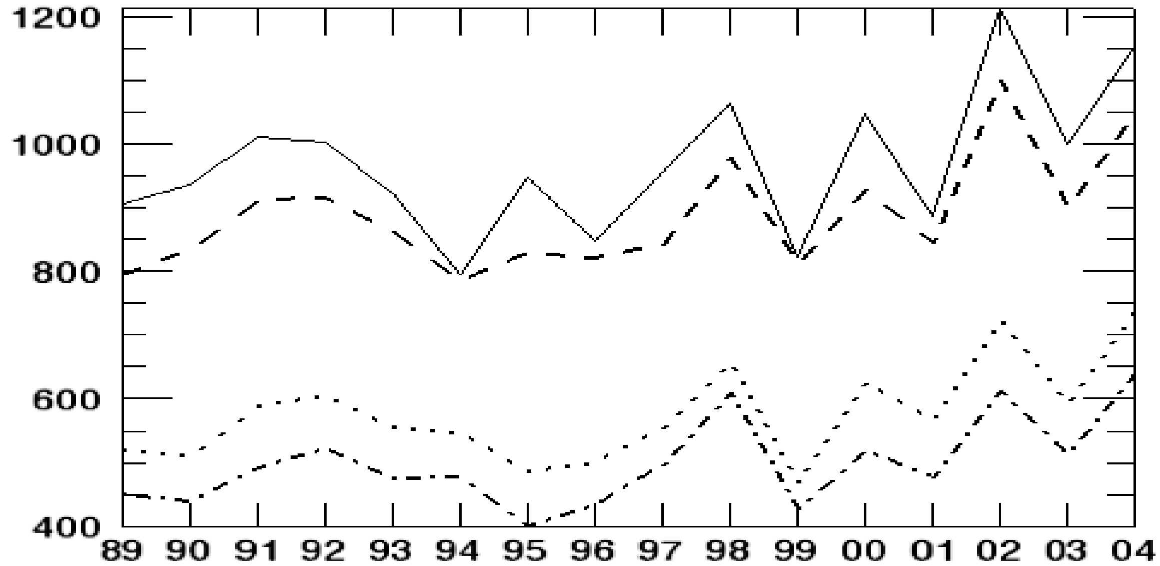


Figure 46: Favourable and unfavourable riparian-use zone with and without AEMs implemented



Solid line: areas with AEMs classified as favourable riparian status
Dashed line: areas without AEMs classified as favourable riparian status
Dotted line: areas with AEMs classified as unfavourable riparian status
Dashed/dotted line: areas without AEMs classified as unfavourable riparian status

Figure 47: Evolution of the total permanent fraction in favourable and unfavourable riparian-use zones with and without AEMs.

4.6 Temporal evolution of the total permanent fraction in the favourable and unfavourable riparian status under olives cultivation with and without AEMs

The previous analysis concerned the whole riparian area independently of its land cover where forested areas and arable land or permanent crops were analysed together. To further explore the potential cause-effect relations between the implementation of AEMs and the favourable / unfavourable status of the riparian-use zones the evolution of the permanent vegetation fraction was further analysed in areas with olive cultivation only (Figure 48 – Figures 49-50 show high resolution based examples *(from Google Earth.com)*). As presented before, in both the natural and bad riparian status erosion measures in olives represented the larger area. Combined with the fact that the agricultural management actions imposed by the measure itself can be related to expected effects that are observable by remote sensing, further detailed analysis was performed only for those areas. Figure 51 presents the temporal evolution of the total permanent vegetation fraction with and without erosion control measures in the favourable riparian-use zones. The favourable riparian status where agri-environmental measures were implemented shows the highest amount of permanent vegetation fraction, and also the curve expresses a positive trend towards 2004. This is especially obvious after 1999 where the effects of the implementation could be expected. Without the implementation of agri-environmental measures the development of the permanent vegetation fraction is “flatter” without any clear trend in the data. Also, when comparing these two areas in 1989 and in 2004 clear differences can be observed in the amount of the permanent vegetation fraction.

Differences can also be seen in areas with and without agri-environmental measures under olives land cover in the unfavourable riparian-use zone (Figure 52). The permanent vegetation fraction is at a similar low value in both areas in 1989, unlike under the natural riparian status where already at the beginning of the time series substantially different values were observed in areas with and without measures. Although both areas reach higher permanent vegetation fraction in 2004, areas where the measures were implemented (full line) show a clearer positive trend, reach much higher values and display greater differences when compared to areas without the measures.

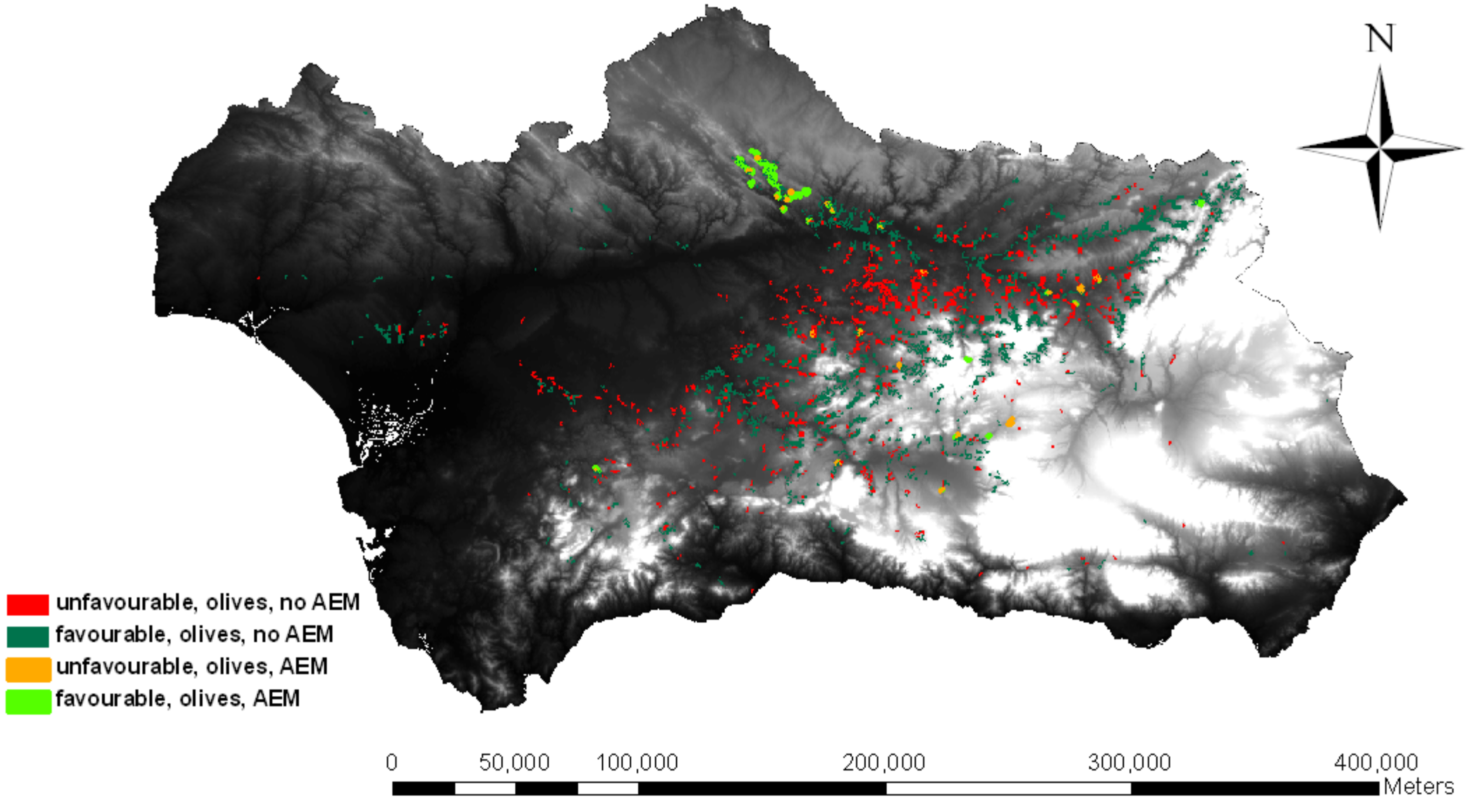
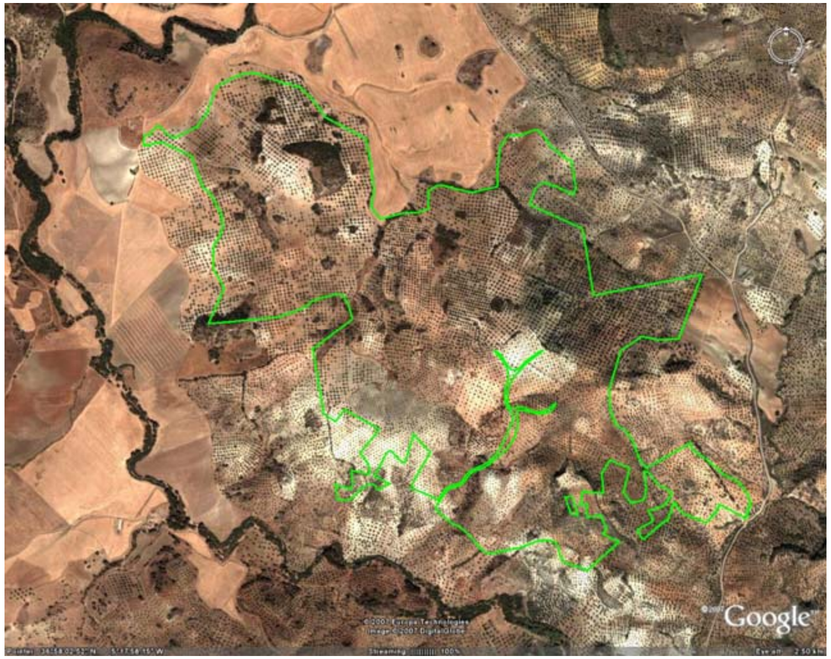


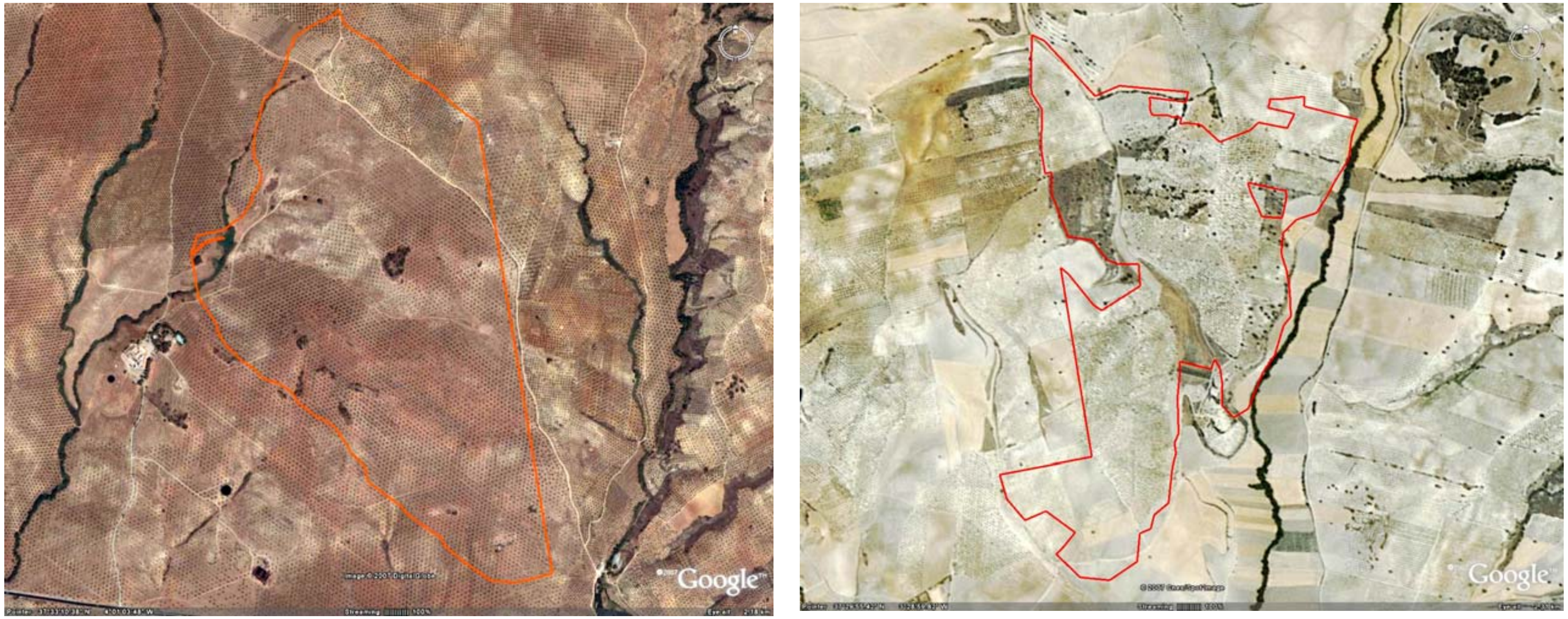
Figure 48: Distribution of erosion control measures in olives in the favourable and unfavourable riparian-use zone.



AEMs applied

AEMs not applied

Figure 49: Example of olive plantations in the favourable riparian-use zone with and without AEMs.



AEMs applied AEMs not applied

Figure 50: Example of olive plantations in the unfavourable riparian-use zone with and without AEMs.

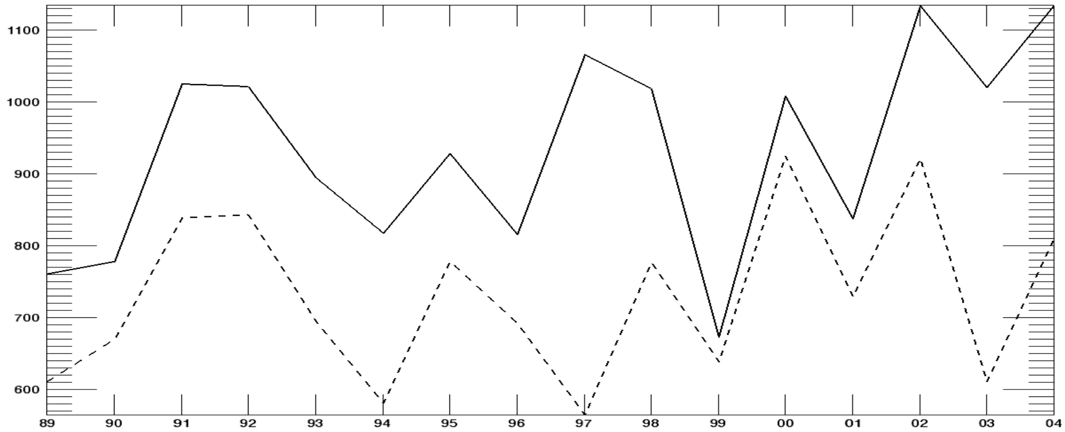


Figure 51: Temporal evolution of the total permanent vegetation fraction with (solid line) and without (dashed line) erosion control measures in the favourable riparian-use zone.

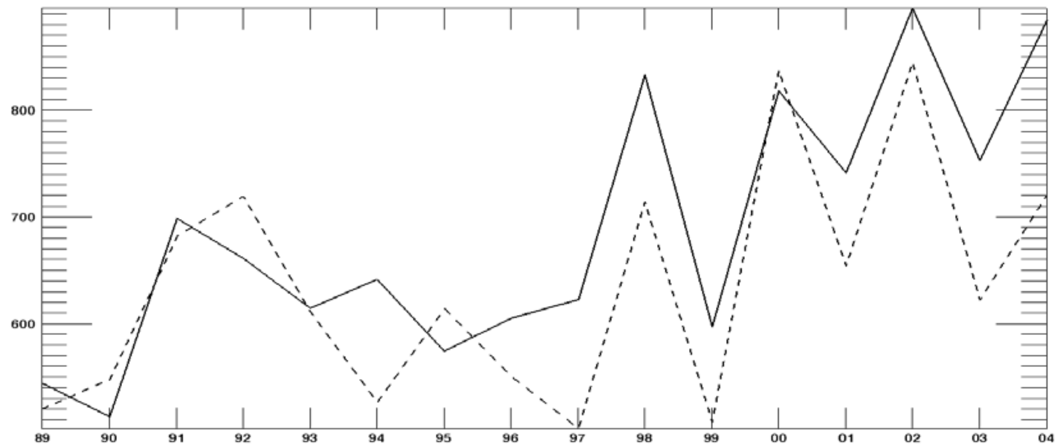


Figure 52: Temporal evolution of the permanent vegetation fraction under olives Corine Land Cover classes with AEMs (solid line) and without AEMs (dashed line) classified as bad riparian status.

Figure 53 combines the above results. The Figure plots the temporal evolution of the seasonal permanent vegetation fraction under olives in the favourable riparian-use zones with measures (full line), in the favourable zone without measures (dashed line), in the unfavourable zone with (dotted line) and in the unfavourable zone and without agri-environmental implemented (dash – dot). In 1989, before the measures were implemented, the olive plantations in the favourable and unfavourable riparian zones are well distinguishable based on their permanent vegetation fraction. The favourable areas, where later the measures were implemented already manifest higher values in 1989 probably due to the fact that farmers signed up those areas for measures where agricultural practices traditionally were extensive. Interesting is however the temporal evolution of the permanent vegetation fraction in the unfavourable riparian-use zone where AEMs were introduced. These areas start up with very low permanent vegetation values in 1989 but in 2004 reach higher values then olive plantations in the favourable zone without agri-environmental measures. This indicates that the natural riparian status alone does not explain healthier vegetation status (indicated by the higher amount of permanent vegetation on the area). The implementation of agri-environmental measures, introducing more sustainable farming practices, can be expected to contribute positively to more permanent biomass that can be indicative for vegetation recovery and /or health status.

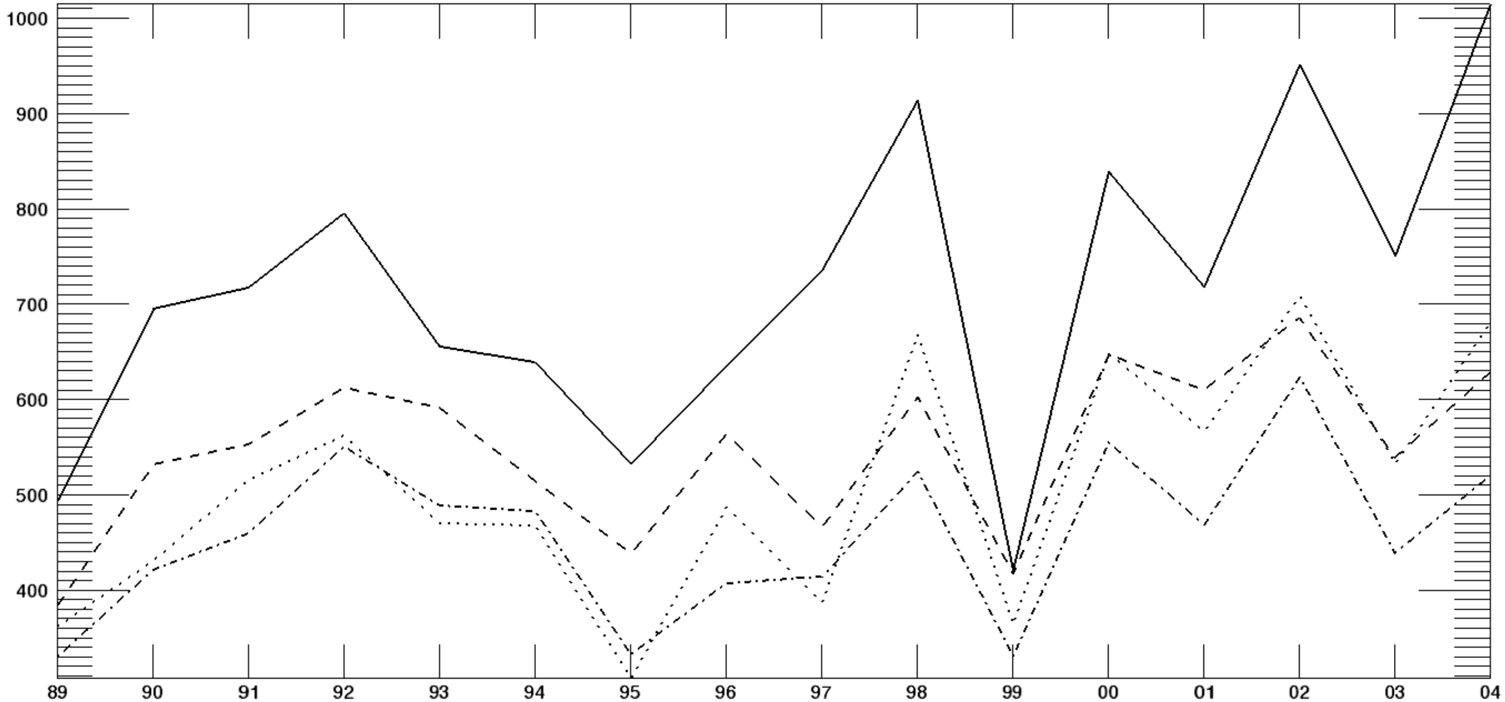


Figure 53: Evolution of the seasonal permanent vegetation fraction in the olives Corinne Land Cover classes with and without agri-environmental measures in the favourable and unfavourable riparian status.

full line: favourable riparian-use zones with AEMs
dashed line: favourable riparian-use zones zone without AEMs
dotted line: unfavourable riparian-use zones zone with AEMs
dash – dot: unfavourable riparian-use zones without AEMs

The fact that the favourable areas, which from 1998 were under AEMs, have already constant higher indicator values in 1989 probably points out that those areas were either (a) more natural areas with a relative extensive landuse, and related lower income, and/or (b) that farmers signed up more to AEMs in those areas because of higher erosion vulnerability. The cross-tabulation of slope classes with the favourable and unfavourable riparian-use zones with and without AEMs supports the latter assumption. In Figure 54 the percentage of area of slopes under 10 and above 10 degrees are shown in the favourable and unfavourable riparian-use zones with and without AEMs. In the favourable riparian-use zones where AEMs were applied 60 percent of the area is on slopes above 10 degree while in other riparian-use zones most of the area is on slopes with less then 10 degree inclination.

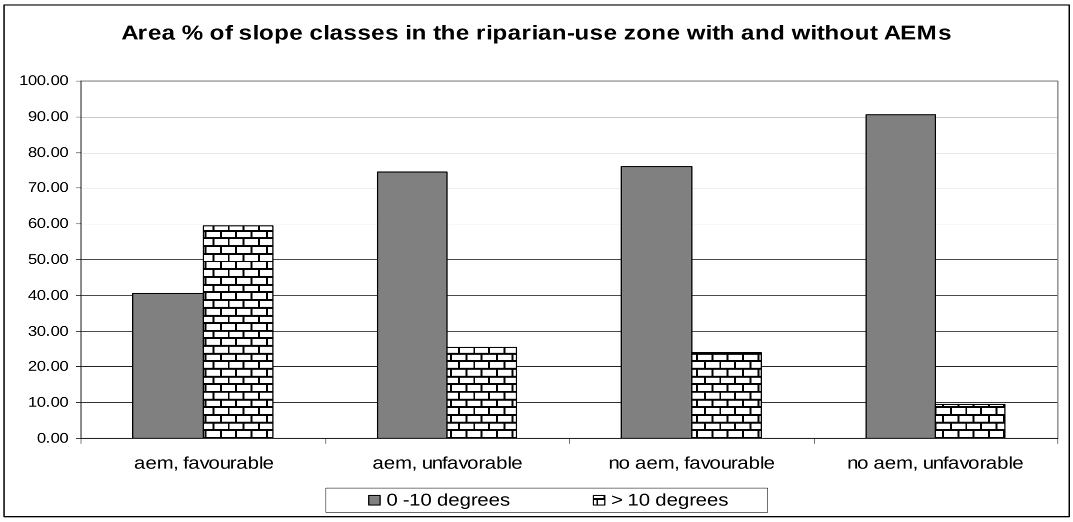


Figure 54: Slope classes expressed in percentage of area in the favourable and unfavourable riparian-use zone with and without AEMs applied.

According to the agri-evironmental policies in Andalusia, erosion measures are to be implemented only on slopes >10degrees. We have to point out here that the calculated area percentages for the various slope classes as shown on figure 54 were derived from a digital terrain model at 1 km pixel detail only and that consequently subpixel or local field variations are not and cannot be accounted for.

4.7 Linear trend analysis of the phenological indices under olives in the favourable and unfavourable riparian-use zones with and without AEMs.

The evolution of the seasonal vegetation fraction through time was further analysed via a statistical test of whether the observed positive trend in the data was significant or not. Several functions were fitted to the time series curve out of which the linear function seemed to be the most appropriate in all cases. The following four areas and their resulting time series curves were analysed:

- Olives in the favourable riparian-use zone under AEMs
- Olives in the favourable riparian-use zone not under AEMs
- Olives in the unfavourable riparian-use zone under AEMs
- Olives in the unfavourable riparian-use zone not under AEMs

The linear trend analyses with the meteorological variables as predictors are presented in Figure 55. In the favourable riparian-use zone both with and without AEMs only time was a significant predictor, the meteorological variables did not explain the pattern in the permanent fraction data.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-52347.5	4334.422		-2.151	.055
	time	27.547	12.763	.811	2.158	.054
	TREND(mint	-15.607	51.013	-.084	-.306	.765
	TREND(max	-75.083	69.172	-.414	-1.085	.301
	TREND(prec	-.121	.297	-.113	-.409	.690

a. Dependent Variable: spi

Favourable, AEM

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-30051.0	1804.047		-2.546	.027
	time	16.315	6.191	.899	2.635	.023
	TREND(mint)	-35.293	24.745	-.354	-1.426	.182
	TREND(maxt	-68.454	33.554	-.707	-2.040	.066
	TREND(prec)	-.067	.144	-.118	-.469	.648

a. Dependent Variable: spi

Favourable, no AEM

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-43902.2	4687.643		-2.989	.010
	time	22.952	7.676	.883	2.990	.010
	TREND(ma	-62.211	40.964	-.448	-1.519	.153

a. Dependent Variable: spi

Unfavourable, AEM

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-24866.3	2403.330		-2.005	.070
	time	13.550	6.505	.754	2.083	.061
	TREND(mint)	-36.401	26.002	-.369	-1.400	.189
	TREND(maxt	-55.511	35.257	-.579	-1.574	.144
	TREND(prec)	-.147	.151	-.261	-.976	.350

a. Dependent Variable: spi

Unfavourable, no AEM

Figure 55: Linear trend analysis of the seasonal permanent fraction with time and meteorological variables as predictors; favourable and unfavourable riparian-use zone over areas with and without AEMs.
Mint = minimum temperature,
Maxt = maximum temperature,
Prec = precipitation

In the unfavourable riparian-use zone under AEMs time (0.005) and maximum temperature (0.045) were significant predictors. These two variables were included in a subsequent analysis as predictors. However, with two predictors only time proved significant on the 0.05 level. In the unfavourable zone not under AEM none of the meteorological variables expressed a significant explanatory value in the temporal development of the permanent fraction and time was only significant on the 0.1 level

Linear trend analysis of the seasonal permanent fraction in olives under AEMs in the favourable riparian-use zone is presented in Figure 56. The adjusted R square measure indicates only a week linear relationship between the permanent fraction and time as a predictor variable although the significance (0.042) of the least square regression indicates linear trend present in the data. The Durbin-Watson statistic is larger then two that indicates negative autocorrelation in the successive error terms in the data. However, the test statistic is higher then the upper limit of the critical vales bound and thus the null hypothesis of no autocorrelation is not rejected. Also the PACF diagram shows no significant autocorrelations at any of the calculated lags.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.513[a]	.263	.210	143.682575	2.468

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
R^2 = 0.455
Durbin-Watson = 1.873

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	103099.9	1	103099.935	4.994	.042[a]
	Residual	289025.6	14	20644.682		
	Total	392125.5	15			

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
Significance: 0.006

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-34047.2	5557.332		-2.188	.046
	time	17.414	7.792	.513	2.235	.042

a. Dependent Variable: spi

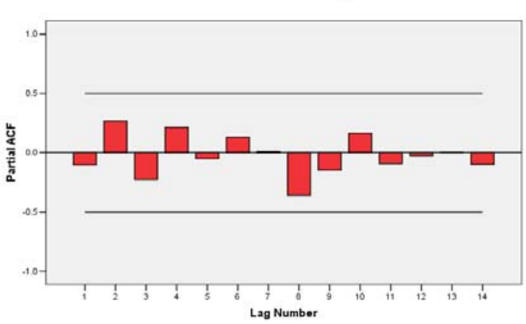


Figure 56: Linear trend analysis of the seasonal permanent fraction in olives under AEMs classified as natural riparian status.

The analysis exhibits no linear trend in the data between the years 1989-2004 over areas without AEMs in the favourable riparian-use zone. The adjusted R square remains very low (Figure 57) and the model is not significant on the 0.05% level. The Durbin-Watson test statistic is somewhat higher then 2, which would indicate autocorrelation in the data. However, the significance table indicates that the test statistic is greater then the upper limit thus the null hypothesis of no autocorrelation does not have to be rejected. The partial autocorrelation function plot proves that the model residuals are not autocorrelated at any of the calculated lags thus the model results and significance can be accepted.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.445[a]	.198	.141	80.1113151	2.254

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
R2 = 0.308
Durbin-Watson = 1.798

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22229.928	1	22229.928	3.464	.084[a]
	Residual	89849.519	14	6417.823		
	Total	112079.4	15			

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
Significance = 0.032

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-15594.6	8674.109		-1.798	.094
	time	8.086	4.345	.445	1.861	.084

a. Dependent Variable: spi

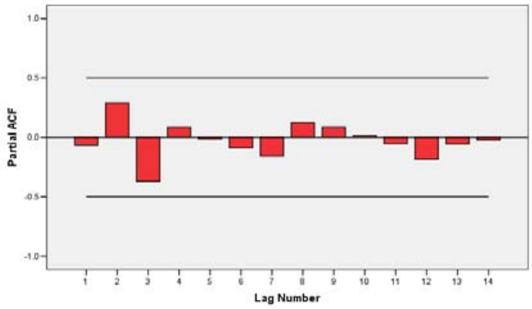


Figure 57: Linear trend analysis of the seasonal permanent fraction in olives not under AEMs classified as natural riparian status.

Over areas with AEMs in the unfavourable riparian-use zone the adjusted R square measure exhibits a moderate linear relationship between the permanent fraction and time (Figure 58). It is somewhat stronger then in case of the favourable riparian areas with AEMs and the significance of the model is also higher. The Durbin-Watson test statistic is somewhat high but the significance table indicates that the null hypothesis of no autocorrelation of the model residuals does not have to be rejected. The PACF plot indicates a dubious value at lag 2 but it is very close to the 0.05% significance level so that autocorrelation can be rejected.

In the unfavourable riparian-use areas without AEMs the R quadrate statistic is very low, in fact is the lowest among all the areas investigated (Figure 59). This shows hardly any relationship between the evolution of the seasonal permanent fraction and the sixteen years period from 1989-2004. Furthermore, the linear model is highly insignificant at the 0.05% level. The Durbin-Watson statistic indicates that no autocorrelation of the residuals can be expected and thus the model results are trustworthy. The partial autocorrelation function plot confirms these conclusions.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.568[a]	.323	.274	105.412522	2.680

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
R2 = 0.424
Durbin-Watson = 2.054

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	74168.399	1	74168.399	6.675	.022[a]
	Residual	155565.2	14	11111.800		
	Total	229733.6	15			

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
Significance = 0.009

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-28977.7	1413.615		-2.539	.024
	time	14.770	5.717	.568	2.584	.022

a. Dependent Variable: spi

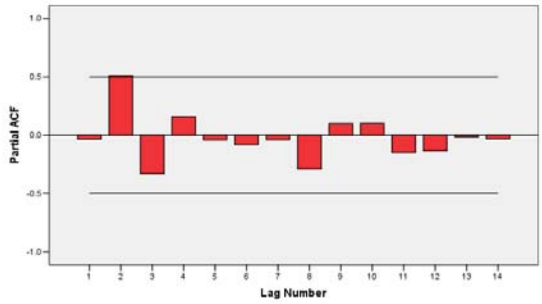


Figure 58: Linear trend analysis of the seasonal permanent fraction in olives under AEMs in the unfavourable riparian-use zone.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.364[a]	.132	.070	82.5172908	2.308

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
R2 = 0.213
Durbin-Watson = 1.833

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4526.439	1	14526.439	2.133	.166[a]
	Residual	5327.446	14	6809.103		
	Total	109853.9	15			

a. Predictors: (Constant), time

b. Dependent Variable: spi

Without the year 1999:
Significance = 0.083

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-12591.1	8934.618		-1.409	.181
	time	6.536	4.475	.364	1.461	.166

a. Dependent Variable: spi

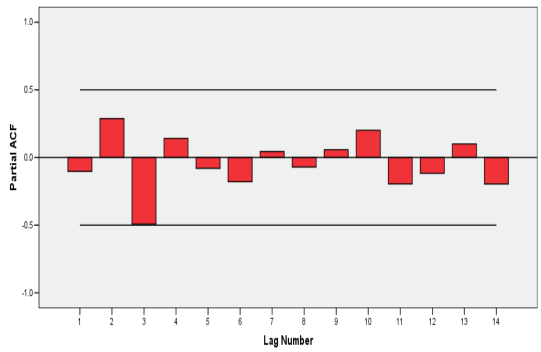


Figure 59: Linear trend analysis of the seasonal permanent fraction in olives not under AEMs classified as bad riparian status.

5 Discussion

5.1 Assessment of the functioning of the riparian-use zone and the effectiveness of AEMs

The classification based on the GVF derived permanent vegetation fraction, used as proxi indicator for a degree of extensiveness of land use, applied in combination with field observations confirmed the relation between the status of the riparian-system and the degree of intensity of adjacent agriculture within the riparian-use zone. The accuracy of the riparian-use zone classification was 89% which is thought satisfactory for categorizing the river network of Andalusia in the favourable and unfavourable classes. The probability of the classification fell into the interval of 0.8-1.0 in as much as 95% of the entire area of the river network. Over densely vegetated evergreen oak and coniferous forest stands the classification was less appropriate to distinguish between the favourable and unfavourable status (probability < 0.8). The reason for this is that the here presented method was calibrated for agricultural areas where a high cyclic vegetation fraction and in comparison a lower permanent vegetation fraction is observed which facilitates the calculation of the start and end point of the growing season.

The Sierras de Castril y La Sagra is covered with coniferous forest stands while in the southern area (Los Alcornocales) Holm Oak (*Quercus ilex*), a semi-deciduous oak species dominates. Over these areas higher permanent vegetation fraction will be observed with a lower cyclic variability. This modest seasonal phenomenon does not allow to properly calculating the start and the end of season using the automated lagged moving average model. These forested areas decrease the overall accuracy of the class assignment to 89 percent while the classification results in the rest of the riparian zone are reliably based on the probability of the class membership. It is expected that these results allow extrapolating the classification method to at least other Mediterranean areas.

In Andalusia the most frequently applied agri-environmetal measure is erosion control in olives. The measure incorporates leaving undergrowth on the area which would result in higher remotely observed permanent vegetation fraction. Riparian-use zones under unfavourable status with AEMs implemented demonstrated a more significant ($p < 0.022$) positive trend and higher permanent vegetation in 2004 then areas without AEMs but under favourable status ($p < 0.042$). These observations suggest a cause effect relationship between the application of AEMs and increasing amount of permanent vegetation cover thus, based on the introduced concept in chapter I.1, improving the status of overall ecological functioning of the riparian-use zone.

Riparian-use zones where the permanent vegetation fraction reached very high value by the end of 2004 but had been designated into the unfavourable status during the field work can be explained as follows. The ground observations are based on the degree of vegetation cover, the structure of the vegetation and the naturalness of the river channel. These phenomena cannot be observed using AVHRR images with a spatial resolution of 1km. These ground observations are detailed point observations of the narrow riparian-system strip while for our study we assumed the wider riparian-use zone as functional unit. Even if the overall riparian-use zone evolutes to a more favourable condition, eventually induced and 'speeded up' by implementation of AEMs, this evolution does not immediately reflect in a drastically increased or improved status of the riparian -system strip which is described mainly by tree cover and structure in the QBR. Although the temporal analysis was done based on the classification designation for the year 2003, it is of course possible that some of these pixels should now be classified as 'favourable' and vice versa. Nevertheless, these findings support that the amount of permanent vegetation present in the riparian zone will not exclusively depend on the designation into the natural class. The implementation of agri-environmental measures in the riparian-use zone is a substantial element in management plans to achieve higher vegetation cover and associated good status of the zone.

While detailed information on farming practices helps to understand the process driving the sustainability of agriculture, the sheer diversity of farming practices and local conditions are difficult to capture at an aggregate level (COM (2000) 20). For this reason it is important to develop indicators that capture the key trends in farming activities as e.g. intensification-extensification, at a range of geographical levels in order to identify both national as well as localised trends. Indicators need to cover a broad spatial scale (from local to global), a spatial continuum rather then point observations and a relatively long time range in order to assess changes of agricultural practices and their effects. Relations between implemented measures, specific farming practices and the state and change of environment is indicative for their impact assessment (Cherlet, 2007). Using field observations combined with time series of remote sensing data opens the possibility to compile a spatial continuous classification of the state of the riparian-use zone.

The here proposed remote sensing approach based on vegetation phenology indicators allows to create a spatially explicit map of the status of the riparian-use zones. Successful use of low resolution data offers the possibility for spatially continuous maps at regional to global scales. The riparian-use zone classification can be a direct input for the River Basin Management Plans as required under the Water Framework Directive (WFD). Confirmation of the association of extensive agricultural land use with better riparian system status as monitored through remote sensing vegetation phenology indicators is a step forward to spatially address riparian-use zone management and targeting of agri-environmental and water protection measures. Furthermore the results indicate the possibility of assessing the effectiveness of agri-environmental measures on erosion control in olive areas in southern Spain. Further work is needed to open more of this potential for systematic assessment of AEM impact on these environmental aspects. Linkages with other datasets, such as riparian or farmland birds or nutrient use and losses, are expected to contribute to the impact assessment of

AEM schemes related to the Community priorities on biodiversity and water quality.

5.2 Connection to biodiversity

More and more studies report a direct link between agriculture and the ecological status of riparian habitats. In north-western Mississippi, riparian zones were documented to lack the typical floodplain-stream interaction because of the impacts of farming practices and channelisation (Smiley at al., 2007). Heavy grazing compacts the soil, reduces infiltration while increasing runoff and erosion. These result, among others, in low avian diversity due to the narrow and fragmented riparian vegetation stripes and increased gully erosion. Downstream areas at gravel mining sites in Arkansas were reported to have lower game fish biomass and abundance then the upstream areas due to the altered stream channels (Brown and Lyttle, 1992). Stream width and depth, width-to-depth ratio, and stream order coupled with elevated phosphorus, sediment, and nitrate concentrations appear to have effect on fish community composition, like spawning success and food availability (Petersen et al., 1998).

The riparian zone is a very important landscape element as it builds a transitional zone between the aquatic and the terrestrial ecosystems (Nilsson and Svedmark 2000). Many species nesting along the riparian corridor are strongly associated with the stream and occupy the habitats immediately adjacent to the stream channel. Other species nest in the interior portions of the larger forests and woodland associated with these corridors and will be absent or rare if the forested corridors are too narrow to provide for nesting habitats. Especially in heavily farmed or urbanized areas forested stream corridors will achieve very high importance as habitat for birds, mammals, reptiles, amphibians. The presence or absence of “focal” indicator species is one way to assess the quality of he riparian forests. These species either can be used as indicators of a threatened biological community or are sensitive to e.g. fragmentation and can indicate the status of riparian habitats. The protection of the so called “umbrella species” (especially those with large area requirements) will result in the protection of many other species (Noss, 1990).

Loss of appropriate habitat condition often contributes to the decline or extinction of a population (RHJV, 2004). Many bird species depend upon shrub cover with dense understory cover and early successional habitats for nesting. The development of a dense understory in turn will require natural hydrological processes. The alteration of streams and rivers by humans contributes significantly to riparian habitat loss. Riparian zones are often one of the few habitats remaining for birds within agro-ecosystems (Smiley et. al., 2006) therefore the conservation of riparian zones within intensive agricultural areas is of outmost importance. Land clearing and cultivation of crops cause habitat fragmentation of riparian zones, channelisation alters the naturalness of the habitats and the replacement of woodland with agricultural land result in direct decline of the avian fauna. In general, avian richness and abundance increase with increasing amount of woody vegetation (Fuller et al., 2001) therefore management plans for riparian habitats within agricultural landscapes often involves facilitating the development of woody vegetation and increasing the habitat area of riparian zones.

It is not only the avian community that is affected by human induced alteration of riparian habitats. Trees along streambanks provide shade, erosion protection, and leaf litter that often affect the density and diversity of fish, aquatic insects, and algae. Channel width and channel sinuosity are influenced by land use being greater in agricultural areas. Larger streams have gravel bars extending farther from the edge of water to the streambanks, therefore tend to be more separated from their riparian zones that negatively affects biological communities. Streams in agricultural basins typically have high concentrations of nutrients and less riparian shading thus allowing more sunlight to reach the streambed promoting algal growth. Greater amounts of this food source encourage greater numbers of a fish called the stonerollers. Whether this greater abundance can have detrimental effects on the aquatic community is unknown, although apparently stonerollers selectively graze on different types of algae and affect the density and composition of benthic invertebrates (Gelwick and Matthews, 1992).

Figure 60 and 61 show possible biodiversity hotspots maps over the riparian area of the Andalusia river basin, linked to AEMS and without their effects respectively. The trend analysis of the temporal evolution of the seasonal permanent vegetation fraction is represented where areas with a significant positive trend are displayed. Figure 60 shows the favourable riparian-use areas under erosion control measures in olives (light green) and the favourable riparian-use zones without these measures (dark green) that exhibited a significant positive trend throughout the years 1989-2005. Both because of the favourable status and of the significant positive trend in the permanent vegetation fraction these areas are expected to become or persist as biodiversity hot-spots. The unfavourable riparian-use zone that exhibited a positive trend in the permanent vegetation fraction and was under AEMs is displayed with red. These areas, although classified as unfavourable, have a potential to become biodiversity hot spots because of the positive trend in the permanent vegetation cover and because of the application of AEMs. Figure 61 presents significant positive and negative trends of the permanent vegetation fraction in the favourable and unfavourable riparian zone independently of Agri-Environmental Measures applied. Based on the assumption of better status of the riparian zone in case of positive trend of the permanent vegetation green is assigned to possible biodiversity hotspots (light green, favourable zone) and to riparian areas with the potential to become one (dark green, unfavourable zone). All together with improving condition, these areas provide valuable habitats to flora and fauna species or protect water quality and regulate stream temperature. They may stabilise stream banks and reduce soil erosion and sediment input. Orange and red areas (negative trends in the favourable and unfavourable riparian zones, respectively) represent surfaces in danger of disappearing habitats.

More validation on these aspects is now needed, but the described remote sensing based methodology proved to have the potential for characterising the wider riparian functional unit providing valuable information for related policy support and decision making.

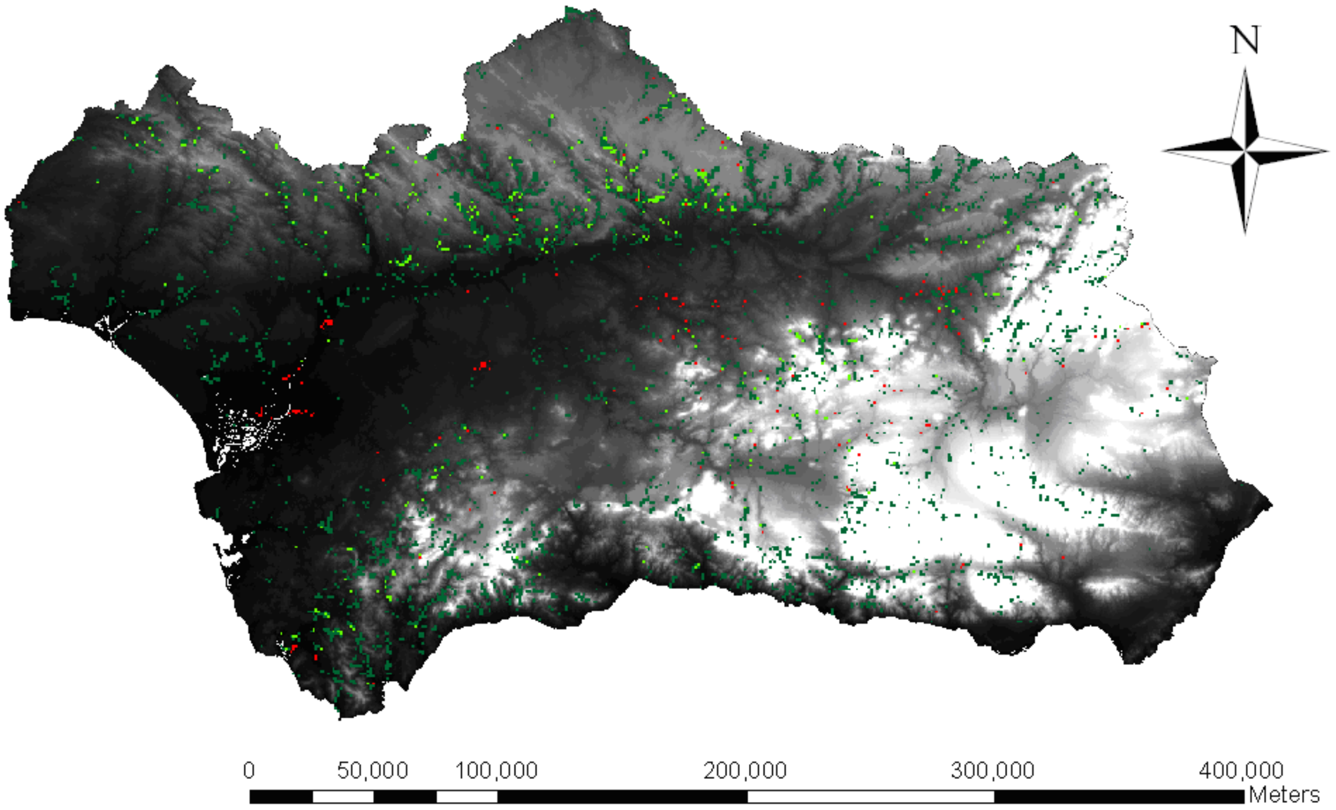


Figure 60: Potential biodiversity hotspots in Andalusia: significant positive trends in the permanent vegetation fraction in the favourable riparian-use zone with AEMs (light green), in the favourable riparian-use zone without AEMs (dark green) and in the unfavourable riparian-use zone with AEMs (red).

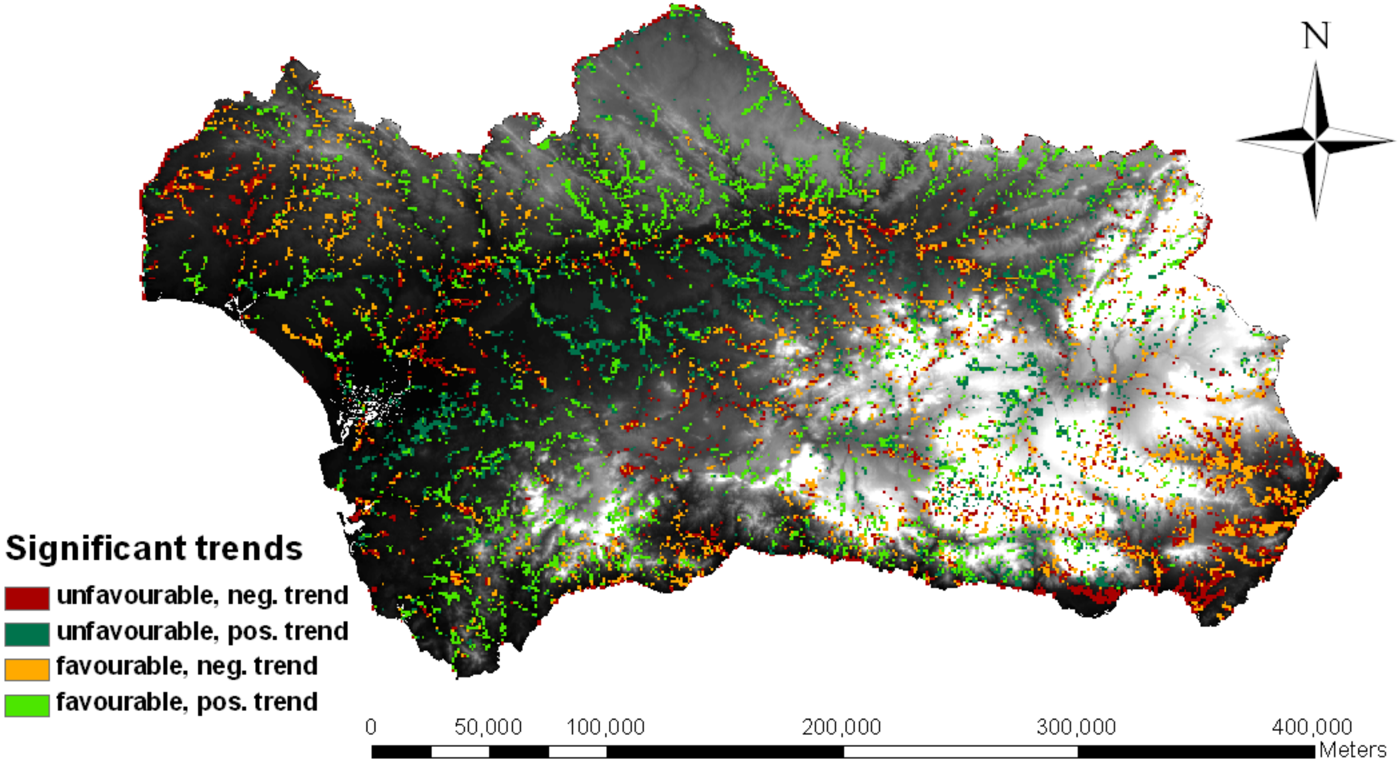


Figure 61: Potential biodiversity hotspots in Andalusia regardless of AEMs: significant positive trends in the permanent vegetation fraction in the favourable riparian-use zone (light green) and in the unfavourable riparian-use zone (dark green). Areas with significant negative trends are in danger (favourable riparian-use zone in orange and unfavourable in red).

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Abstract

The report introduces the concepts and results of a case study on riparian zones in Andalusia, Spain with focus on the assessment of actual environmental impact of Rural Development Agri-Environmental Measures (AEMs) by implementing spatial data and remote sensing based methods. 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 present study suggests widening the concept of riparian zones into a larger riparian area including immediate surrounding land. The riparian zones of the Guadalquivir river network have been mapped and analyzed by using three types of spatial data. Confirmation of the association of extensive agricultural land use with better riparian system status as monitored through remote sensing vegetation phenology indicators is a step forward to spatially address riparian-use zone management and targeting of Agri-Environmental and water protection measures. Furthermore the results indicate the possibility of assessing the effectiveness of AEMs on erosion control in olive areas in southern Spain.

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