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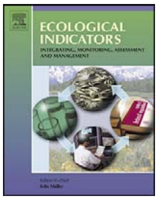

Original article

Assessment of status and trends of olive farming intensity in EU-Mediterranean countries using remote sensing time series and land cover data

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ABSTRACT

For EU-Mediterranean olive groves (Olea europaea), mapped in CORINE, classes of olive farming intensities were derived from the outcome of a multi-temporal remote sensing vegetation dynamics analysis. The management intensity classes were developed in view of a differentiated accounting of olive groves when delineating High Nature Value Farmland areas (HNV) at pan-European level. The remote sensing input data used was the Green Vegetation Fraction (GVF), derived in 10-day intervals from a long-term time series of NOAA AVHRR data. The key physical parameters for the intensity assessment were obtained by parametrization of the observed annual growth cycle. These parameters represent two functional proportions in olive groves, a seasonally changing annual component and a permanent perennial vegetation component, which were interpreted to classify data in three olive farming intensity levels. 27% of the assessed EU-Mediterranean wide olive areas were found to be of very high intensity, 12% were classified as low intensity olive areas and 61% form an intermediate intensity class. Strong intensification was found in Spain, followed by Italy, Greece and Portugal. Most pronounced indications of management changes for the period 1990–2000 were observed for the Spanish provinces Jaèn/Cordoba and the Italian province of Bari.

1. Introduction

The paper demonstrates a methodology to distinguish management intensities of CORINE land cover (CLC) mapped olive groves at European level, based on remote sensing time series derived vegetation dynamics.

1.1. *Thematic background*

This study has been carried out as complementary research element associated to a joint initiative of the European Commission's Joint Research Centre (JRC) and the European Environment Agency (EEA) on a methodology update for the delineation of High Nature Value Farmland (HNV) at pan-European level (Paracchini et al., 2008). The initial HNV mapping methodology to be refined was proposed by Andersen et al. (2003) and used by EEA and the United Nations Environmental Programme (UNEP) to publish a Joint Message (EEA/UNEP, 2004) presenting a preliminary map of HNV farmland. The Joint Message describes HNV farmland as: "Those areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports, or is associated with, either a high species and habitat diversity or the presence of species of European conservation concern, or both."

In order to increase accuracy, the previous HNV map was updated and refined on the basis of new land cover data, regionally differentiated selection criteria and additional biodiversity datasets (Paracchini et al., 2008). However, a major constraint of the present approach, to select a CLC class that is likely to contain primarily HNV land, is that it does not explicitly take into account the intensity of land management. Hence, more precise mapping could be carried out only on the basis of standardised information, e.g. on farming systems and practices, which other than land cover, is hardly available at pan-European level in a standardised format. The presented study aimed to contribute specifically to the methodological refinement of the selection criteria of the CLC class 'Olive grove' for possible further refinements of the European HNV farmland map.

Olives appeared to be a suitable class for a multi-temporal remote sensing analysis in this context, since olive groves are known to differ characteristically in their relative composition of proportional olive tree cover and associated annual herbaceous vegetation (whether arable crop, managed or natural grassland or pasture). This is a function of management intensity ranging from traditional, extensive multifunctional land use (e.g. olive crops and extensive grazing) to highly intense management systems includ-

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ing irrigation and suppression of annual herbaceous vegetation by tilling or herbicide treatment (Allen et al., 2006; Beaufoy, 2001a,b).

1.2. Conceptual framework

The perennial and seasonally changing vegetation components can be captured by satellite observation in the visible, near infra-red and thermal domains, given that continuous satellite observation over a long period can be provided. This allows the computation of time series of vegetation indices (e.g. Normalized Difference Vegetation Index/NDVI) and/or further products derived thereof such as the Green Vegetation Fraction (GVF).

The NOAA AVHRR Earth observation system offers medium to coarse spatial resolution (approximately 1 km pixel size) and provides archived records of up to 20 years of daily data. Though this system provides only coarse spatial resolutions it has the advantage that it covers the entire Earth surface with highly frequent observations thus providing the continuous observation rates required for this type of approach. Moreover, it enables application at continental scale, i.e. pan-European mapping and assessment capacity. While a plant specific detection of important phenological events is limited for this sensor type, for example due to the effects of other vegetation and soil background, broad scale dynamics and changes can be measured and are descriptive of ecosystem conditions (Reed et al., 1994).

With this type of satellite observation system it is expected that the vegetation index response signal for evergreen olive trees would be relatively constant throughout the annual growth cycle (depending on the density of tree canopy). By contrast the annual herbaceous vegetation component would have a pronounced periodical vegetation response over the time period, as a function of vegetation type and density. By separation and proportional quantification of these two different vegetation components it should be possible, within the CLC geographical extension, to characterize different subtypes of olive groves. These can then being associated with different management intensities, based on existing knowledge about their bio-physical characteristics.

The derivation of vegetation variables is achieved by parametrization of a long-term remote sensing time series of Green Vegetation Fraction applying a model hereafter called SINFIT. The SINFIT model derives parameters for the quantification of the permanent and hence stable vegetation component as well as for the seasonally changing vegetation component. For the land cover class ‘Olive grove’ which has particularities in the botanical and agronomical sense (e.g. evergreen plant), these key measures are representing crucial indicators used to derive the level of management intensities. Beaufoy (2001b) reports about 3 prevalent European olive farming types, describing their bio-physical characteristics and agronomic management techniques:

(1) low-input traditional plantations,
(2) intensified traditional plantations and
(3) intensive modern plantations.

Low-input traditional plantations (1), generally consisting of sparsely planted, old trees, sometimes mixed with other fruit trees, are mostly found in hilly or mountainous regions or in marginal lowland, frequently on terraces. The soil or ground cover management consists of frequent or occasional grazing and/or mowing and/or tillage. Fertilization and pesticide use is almost absent or occurs occasionally. The plantations are generally not irrigated and yields are low (200–1500 kg/ha).

Intensified traditional plantations (2) generally consist of younger plants grown at a higher density that are regularly pruned. They are mainly found on hills and rolling plains, sometimes on terraces. Repeated cultivation and/or use of herbicides is typical for the soil/ground cover management. Fertilizer and pesticide application rates and yields are higher (yields of 1500–4000 kg/ha) compared to the low-input plantations.

The intensive modern plantations (3) with short-stem varieties and high tree densities are mainly found on rolling and flat plains. Herbicide use is common for the removal of the vegetation understory. Chemical fertilizers with high application rates are often applied through the drip irrigation system. Yields range from 4000 to 10,000 kg/ha.

In this study, the remotely sensed observations are focused on annual ground vegetation dynamics and soil coverage of the groves rather than on the state of the individual olive trees. However, the signal delivers important indications about vegetation dynamics and allows the linkage with management practices and/or management intensities.

The last part of this work was dedicated to analysing evidence for changing management intensities derived using this approach, and focusing on the reference years 1990 and 2000.

2. Methods and material studied

2.1. Area description

Satellite data processing was conducted for the entire Mediterranean region (27°N to 46°N and 10°W to 42°W). However, the studies regarding the classification of olive groves are limited to the areas, where this land cover class was captured by CORINE land cover and available for the study years 1990 and/or 2000 (EEA, 2005).

2.2. Remote sensing data

For this study, the MEDOKADS remote sensing data base, maintained within the European Commission’s Research Framework Program 6 and the DeSurvey project (A Surveillance System for Assessing and Monitoring Desertification) was used. MEDOKADS (Mediterranean Extended Daily 1 km AVHRR Data Set) is provided by the Free University of Berlin, Institute for Meteorology (Koslowsky, 2003; Koslowsky et al., 2005). It comprises a fully intercalibrated, radiometrically pre-processed time series of NOAA AVHRR 0.01 degree data from 1989 to 2004, including Normalized Difference Vegetation Index (NDVI) and surface temperature (Ts). 10-day composites of NDVI and Ts were used to compute the Green Vegetation Fraction (GVF) by linear spectral mixture modelling. The linear unmixing decomposes the data into fractions of a vegetated, non-vegetated and a synthetic “cold” endmember, the latter expressing cold or wet pixels, that do not follow the inverse relationship between NDVI and Ts (containing remaining clouds, water, etc.). Endmembers are derived statistically using percentiles and the inverse relationship between NDVI and Ts. The vegetation abundance is re-scaled to GVF, re-distributing the “cold” abundance on vegetation and soil abundance proportionally. Due to corrective effects of the “cold” endmember, unmixing leads to a higher stability of GVF data in comparison to NDVI data with regard to atmospheric effects. Detailed reporting of this procedure has been published previously (Weissteiner et al., 2008a).

Due to the relatively low signal to noise ratio of AVHRR, the dataset exhibits strong oscillations. Hence, after unmixing, to reduce noise, a Savitzky-Golay filter (Chen et al., 2004) was applied. Missing data and outliers outside the 3 sigma criterion were replaced by the seasonal averaged values of the remaining years. NDVI values were normalized to NOAA9 standard, based on correction formulas derived by Trishchenko et al. (2002). Using both NDVI and Ts has been shown to characterize land cover in a more comprehensive and climatically resistant manner than by