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Land use classification from multitemporal Landsat imagery using the Yearly Land Cover Dynamics (YLCD) method

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ABSTRACT

Several previous studies have shown that the inclusion of the LST (Land Surface Temperature) parameter to a NDVI (Normalized Difference Vegetation Index) based classification procedure is beneficial to classification accuracy. In this work, the Yearly Land Cover Dynamics (YLCD) approach, which is based on annual behavior of LST and NDVI, has been used to classify an agricultural area into crop types. To this end, a time series of Landsat-5 images for year 2009 of the Barrax (Spain) area has been processed: georeferenciation, destriping and atmospheric correction have been carried out to estimate NDVI and LST time series for year 2009, from which YLCD parameters were estimated. Then, a maximum likelihood classification was carried out on these parameters based on a training dataset obtained from a crop census. This classification has an accuracy of 87% (kappa = 0.85) when crops are subdivided in irrigated and non-irrigated fields, and when cereal crops are aggregated in a single crop, and performs better than a similar classification from Landsat bands only. These results show that a good crop differentiation can be obtained although detailed crop separation may be difficult between similar crops (barley, wheat and oat) due to similar annual NDVI and LST behavior. Therefore, the YLCD approach is suited for vegetation classification at local scale. As regards the assessment of the YLCD approach for classification at regional and global scale, it will be carried out in a further study.

1. Introduction

The vegetation of our planet is changing (IPCC, 2007), due to both direct human action (land use change) and indirect human pressure (greenhouse gases induced global warming). This change is affecting directly food production, with severe consequences for mankind. Therefore, local to global agencies need an adequate monitoring of production, in order to anticipate food shortages, due to droughts for example. To this end, agricultural areas must be classified into different crops, enabling the estimation of areas under a given production. Additionally, monitoring water stress may be needed, to assess the health condition of these crops.

Traditionally, vegetation census has been carried out from vegetation indices, through single date or multitemporal classification (Tucker et al., 1985; Loveland et al., 2000; Morales et al., 2004; Wang and Tenhunen, 2004; Evans and Geerken, 2006; Sobrino et al., 2006). The most widely used vegetation index for this task is the Normalized Difference Vegetation Index (NDVI – Tucker, 1979), which is based on the absorption difference of photosynthetically active tissues in the red and near-infrared wavelengths of the electromagnetical spectrum. Despite its numerous flaws (Holben, 1986), NDVI is the most widely used vegetation index, which is due to its mathematical simplicity, and to the fact that most alternative vegetation indices need additional information which is difficult to obtain at regional and global scale.

As a consequence, several studies have investigated and confirmed the fact that land use assessment and classification as well as vegetation changes could benefit from the addition of the surface temperature to NDVI estimation. For example, Ehrlich and Lambin (1996) used a principal component analysis of BT (Brightness Temperature)/NDVI slopes to build a land cover classification of Africa. Lambin and Ehrlich (1996) reviewed extensively the drivers between NDVI and BT parameters, and described a general spatial pattern of relationships between NDVI and BT, related to land cover. They concluded that BT/NDVI slope could be used to classify land cover and monitor land cover changes over time. Nemani and Running (1997) used BT and NDVI annual variations to build a classification over United States (later extended to the whole globe), and presented an approach to characterize changes in NDVI and BT parameters, which has been used in other studies (Julien et al., 2006). Lambin and Ehrlich (1997) used the results of Lambin and Ehrlich (1996) to build a change index based on NDVI and BT to retrieve change patterns in sub-Saharan Africa. Sobrino and Raissouni (2000) presented two methods for land cover change

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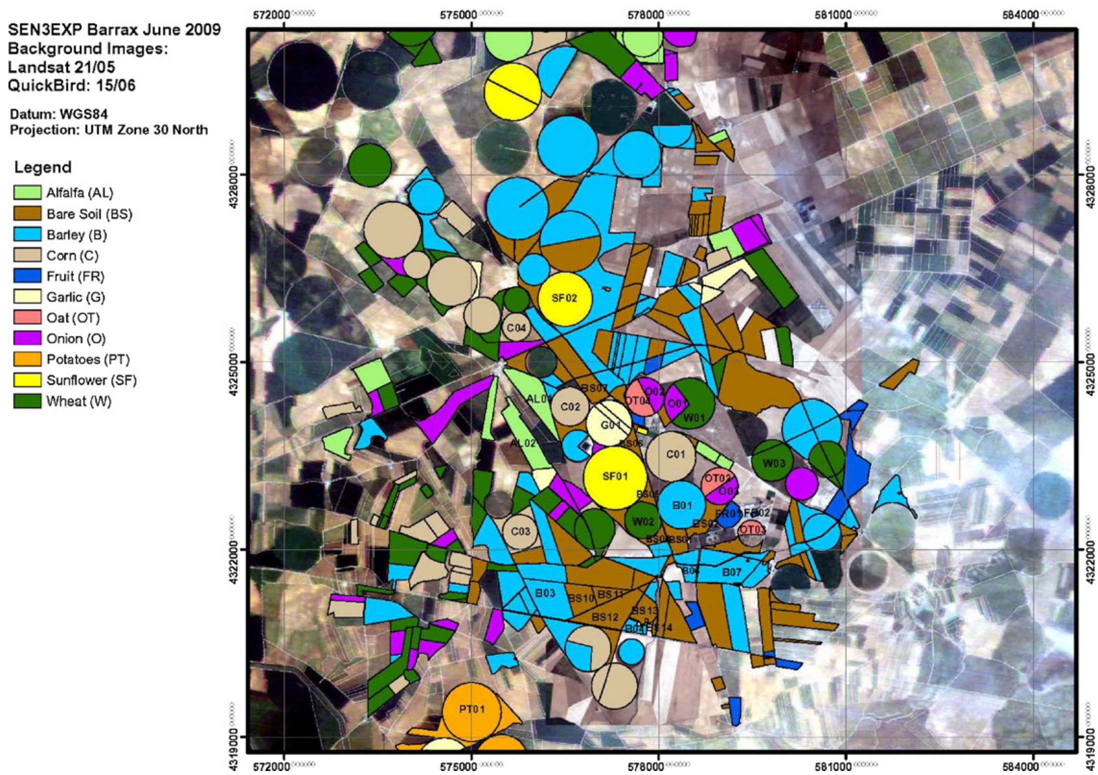

Fig. 1. Description of the study area: Barrax, Albacete, Spain.

detection in Morocco based on NDVI and Land Surface Temperature (LST) temporal variations. Borak et al. (2000) confirmed that coarse resolution estimates of change were best related to fine resolution estimates when BT and NDVI evolutions were considered.

Based on these results, Julien and Sobrino (2009) designed the Yearly Land Cover Dynamics (YLCD) method, which consists in the regression of LST yearly time series against NDVI time series to retrieve three parameters associated with the annual vegetation cycle. These parameters allow distinguishing between broad vegetation categories (Julien and Sobrino, 2009). However, since vegetation species react differently to similar meteorological conditions, mainly through stomata dilatation which in turn depends on leaf characteristics and surface, this method should be able to distinguish between plant species. This is the hypothesis tested in this study, through the use of multitemporal data acquired over an agricultural area in Spain.

2. Study area and data

2.1. Study area

The agricultural area of Barrax (39°3′N, 2°6′W, 700 m) is located in Albacete (Spain). The area has been selected in many other experiments due to its flat terrain, minimizing the complications introduced by variable lighting geometry, and the presence of large, uniform land-use units. Barrax has a Mediterranean type climate, with heavy rainfall in spring and autumn and lower in summer; it presents a high level of continentality, with sudden changes from cold months to warm months and high thermal oscillations in all seasons between the maximum and the minimum daily temperatures (Moreno et al., 2001). The soils of the area are Inceptisols in terms of soil taxonomy, belonging subgroup to Petrocalcic Calcixerepts subgroup (Soil Survey and Staff, 1999). About 65% of cultivated lands at Barrax are dry land (67% winter cereals; 33% fallow) and 35% irrigated land (75% corn; 15% barley/sunflower; 5% alfalfa; 5% onions and vegetables). More details about the test site are presented in Moreno et al. (2001). Fig. 1 presents the study area and the crops used in this study.

2.2. Data

For this study, Landsat images have been provided by the National Geographic Institute of Spain (Instituto Geográfico Nacional – IGN), which has launched the National Plan on Remote Sensing (Plan Nacional de Teledetección – PNT) initiative with the aim of supporting the use of remote sensing in Spain. In the framework of the PNT, Landsat imagery from 2008 to present has been acquired over Spain by the IGN and provided for free to interested users. The IGN also intends to acquire the complete Landsat historical database over the Spanish territory (only some historical Landsat images are currently available). A complete description of the processing of these Landsat images by PNT (geometric, radiometric, atmospheric and topographic corrections) can be found in Peces et al. (2010).

Data from Thematic Mapper (TM) sensor on board Landsat-5 platform have been used in this study. This sensor is widely known by the scientific community, so a detailed description is not provided in this paper. Just as a reminder, TM sensor has four spectral bands in the Visible and Near-InfraRed (VNIR) range (blue, green, red and NIR, corresponding, respectively, to bands 1, 2, 3 and 4), two bands in the Short-Wave InfraRed (SWIR) range (bands 5 and 7) and one band in the Thermal-InfraRed (TIR) range (band 6). Spatial resolution is 30 m for VNIR and SWIR bands and 120 m for TIR band. Bandwidths are around 0.1 μm for VNIR bands, 0.25 μm for SWIR bands and 2 μm for the TIR band.

Since the Barrax site appears in 2 Landsat scenes (corresponding to paths 199 and 200, row 33), a total of 31 images were available from January to December 2009, although only 16 images could be used for this study due to cloud contamination (see Table 1). Data were labeled as cloud contaminated when at least one cloud could