ESTIMATING VEGETATION PARAMETERS OF CEREALS USING AN ASTER 1A IMAGE

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ABSTRACT:

The purpose of the present study is the validation of the ASTER images through the indirect estimation of several parameters of dry crops cover. Since 1999 the Department of Geography of the University of Salamanca (Spain) has established a network named REMEDHUS in this area consisting of twenty three stations for the measurement of soil moisture over a large area of 1,300 km^2 characterized by different soil and land use types. The objective of this project is to develop an efficient monitoring system of climatic, edaphologic and biophysical parameters. Moreover, the climatic monitoring is carried out by a meteorological station that provides a daily dataset.

In 2005, this database was completed with a field campaign to estimate biophysical parameters such as plant biomass, water content and height. The direct field measurement was done around the REMEDHUS stations in two campaigns in April 2005, the same date of the acquisition of an ASTER 1A image in the same area. The vegetation cover present in these plots is a dry crops shape (cereals), in the growing stage of its phenologic cycle. The image was orthorectified by a rigorous model. The radiometric treatment consisted of two-level calibrations based on: 1) the ERSDAC (Earth Remote Sensing Data Analysis Center, provider of ASTER) algorithm implemented by a specific application with the coefficients, gain and offset, provided in the image file, and 2) conversion of these at-satellite radiance values in at-surface reflectance by means of a method developed by Pons and Solé-Sugrañés (1994) for VNIR Landsat TM images, here adapted for ASTER. RVI (Ratio Vegetation Index) and NDVI (Normalized Difference Vegetation Index) were tested with the obtained reflectance values. Good correlations were obtained with both indices and the biophysical on-the-ground parameters (aerial biomass, water content and plant heights), in all cases correlation coefficient higher than 0.7. The results show that it is possible to infer a direct relationship between the plant parameters and the indices, taking into consideration two prior constrictions: the radiometric performance of the images into physical values and the use of the vegetation indices at the growing stage of the crops cycle, related to vegetative activity.

1. AREA

The study site is located in the semi-arid sector of the Duero Basin, Spain, (41,1º–41,5º N; 5,1º–5,7° W), covering a plain area of about 1300 km2 (Figure 1). The REMEDHUS network has been operating in this area since June 1999. The total number of stations of soil moisture measurement used in this study is 23 and all are over agricultural fields (Ceballos et al., 2005).

The most frequent land-uses in this area are: rainfed crops (winter cereals and pastures), irrigated crops, vineyards and small forest covers. The vegetation ground measurement coincides with dry lands (stations of soil moisture measurements of REMEDHUS).

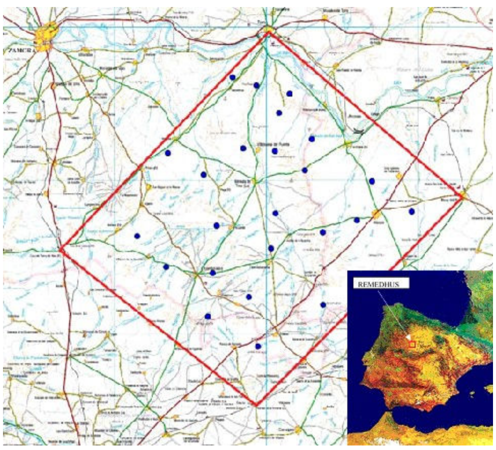

Figure 1. Location map of the study area: Soil Moisture Measuring Station Network (REMEDHUS) in Spain.

2. DATA

2.1 Basics on ASTER imagery

ASTER level 1A products are generated from the raw level 0 instrument data by adding metadata, including the geometric and radiometric correction coefficients, and reformatting into Earth Observing System (EOS) hierarchical data format (HDF) files; the imagery data remain identical (Arai and Tonooka, 2005). The level-1B data is generated by applying these coefficients for radiometric calibration and geometric re-sampling. Using level 1B, it is necessary to convert the digital levels into radiance values applying the unit conversion coefficients for each band. Level 2B are products of physical parameters generated on the basis of user request (Ninomiya et al., 2005): level 2B01 is at-surface radiance and level 2B05 is at-surface reflectance. The necessary atmospheric correction is based upon a look-up table approach using results from a Gauss-Seidel iteration radiative transfer code. The complete algorithm is detailed in the ERSDAC documentation (http://www.science.aster.ersdac.or.jp/en/documnts/pdf/2b0105.pdf).

2.2 Field data

The field measurement consists of direct (destructive) estimation of water content (g), aerial biomass expressed in damp weight (g m^{-2}) and plants height (cm). The agricultural use of the selected plots is rainfed cereals, mainly barley and wheat. The field measurement took place at the same date of the satellite image (April, 28), in the growing season.

3. METHODS

3.1 Geometric correction

Firstly, a process of geometric treatment is needed to correlate the field measurement and the digital operations on the image. Orthorectification by rigorous model (Toutin, 2004) is applied by means a 30 ground control points and a DEM proceeding of the official cartography of the Castilla-León Region government (performed at 15 m pixel size, as ASTER spatial resolution, and 1 m high-resolution). The geo-location resulting from this process has a sub-pixel accuracy. The resample from raw scene to warped scene was made using nearest neighbour method trying not to change the original value of digital levels of every pixel.

3.2 Radiometric correction

3.2.1 Digital levels from 1A to at-satellite radiances

At-satellite radiance can be obtained from level 1A applying the coefficients gain and offset for every pixel:

$$L = \frac{[A]DN}{[G]} + [D] \qquad (1)$$

Where:
L: radiance, $W/m^2/sr/\mu m$
A: linear coefficient
G: gain (constant values in each band)
D: offset
DN: digital levels of band n

The application of this formula has two approaches: using mean values of A and D in [1] or using array values of A and D in [1] for each pixel, included in the image header file. Here the radiance has been calculated with the complete array

3.2.2 At-satellite radiance to at-surface reflectance

The method proposed is based on a simplified model for radiometric corrections proposed by Pons and Solé-Sugrañés (1994) and refined in Salvador et al. (1996) for Landsat TM. Since we use only the red and infrared bands of ASTER, coinciding closely with those of Landsat, the model can be adapted. This radiometric correction includes atmospheric and illumination corrections. The inputs required are: DEM, standard astronomic parameters such as exoatmospheric solar irradiance and atmospheric optical depth, date and time of the satellite pass and sensor viewing angle. The model assumes that all surface are Lambertian reflectors, which is reasonable for the green cereals cover at this phenologic state (midgrowth) and can not be used over self-shadowed pixels.

The adapted equation for the present work is:

$$R = \frac{\pi L d^2}{\left(\mu_s S_0 e^{(-\tau_0/\mu_0)} e^{(-\tau_0/\mu_v)}\right)} \qquad (2)$$

Where:
R is at-surface reflectance.
L is at-satellite radiance (obtained in the previous step).
d is the Sun-Earth distance at the acquisition date. d can be calculated (Yang and Vidal, 1991) as

$$d = 1/\ \{[1+e\cos(\{D-4\}2\pi/365.25)]\ /\ (1-e^2)\} \qquad (3)$$

D is the day number of the year and e the orbit eccentricity.
μ_s is the cosine of the angle between incident beam and the normal at the surface, depending of the DEM (slope and aspect for each pixel of DEM).
S_0 is the exoatmospheric solar irradiance for the two bands; the reference values (Dozier, 1989) are: 1557 $Wm^{-2}\mu m^{-1}$ for the red band and 1047 $Wm^{-2}\mu m^{-1}$ in the infrared.
τ_0 is the optical depth of the atmosphere for the two bands, extracted of the U.S. standard values or by means of an empiric estimation with the radiation value (provided by the climatologic station in the area). Standard values were chosen (τ_0 red=0.25; τ_0 NIR=0.20).
μ_0 is the cosine of the angle between the solar vector and the normal to a horizontal surface. This angle is provided as metadata in the header file.
μ_v is the cosine of the zenithal viewing angle (cosine of the off-nadir angle, supplied in the header file).

3.3 Vegetation indices

Vegetation indices typically correlate well with the plant biomass and the leaf area index on agricultural covers, since they often reflect the vigour and health of the plants (Pinter Jr. et al., 2003) and offer a good basis for calculating plant biophysical parameters. The NDVI is the most commonly used index for extracting the biophysical properties of the vegetation. There is the problem of NDVI saturation at high LAI values (Smith et al., 2005) which can mean that the NDVI is not appropriate in the discrimination of high-density covers (Srinivas et al., 2004). In particular, the NDVI can only be related directly to the biomass in the plant growth stage, when photosynthetic activity is very high and the NDVI expresses the plant mass potential, which is the case of the present work.

The reflectance values derived from the radiometric correction were used to calculate the vegetation indices: RVI (Pearson and Miller,1972) and NDVI (Rouse et al., 1974). Finally, the results were overlaid with the measured stations and correlated with the parameters of the vegetation.

4. RESULTS AND DISCUSSION

The Table 1 shows the correlation between biophysical parameters and the two indices resulting from the reflectance levels:

Coefficient of Correlation, *r*		
	RVI	NDVI
Water content(g)	0,7757	0,7605
Biomass (g/m2)	0,7976	0,7734
Height (cm)	0,8196	0,8015

Table 1. Correlation between biophysical parameters and the RVI and the NDVI indices.

Observing the correlations obtained, it can be suggested that:

- Values of correlation greater than 0.7 should explain the dependency between the dependent and the independent variables, or, in other words, it is possible to predict the ground values from vegetation indices values extracted from the image.
- The variables best correlated are RVI and height. Biomass is also well correlated.

Taking advantage of the ASTER Research of Opportunity, this paper presents the results of comparing some vegetation parameters with the ASTER images provided by ERSDAC. The methodology used is based on Vegetation Indices that are correlated with the direct ground measurements. On the other hand, the use of recent remote sensing imagery presents the difficulty of obtaining physical values prior to digital treatment. For a common user, this step might not be not very familiar, especially when working with recent sensors. Thus, this work presents a simple method to perform easily the radiometric correction of digital values and the possibility to compare results with ground measurements.

A likely correlation has been found between the ground parameters (biomass, height, water content) measured in the cereals cover in this area and digital measurements made by ASTER images. Biomass and height are in particular directly proportional to the values of vegetation indices.

The best correlation was obtained with RVI and NDVI related with biomass and plant height, coinciding with a maximum of photosynthetic activity in the month of study (April). Nevertheless, the vegetation indices illustrate growing activity rather than plant biomass. If the biomass is well correlated with the vegetation indices, it might be because in April biomass is strictly related to the vegetation activity for rainfed crops.

This correlation might encourage the progress of this study issue, however it is advisable to establish in future experiments new ground vegetation areas and also to improve some aspects of the measurements, i.e. Leaf Area Index, radiometric direct measurements, green cover percentage, etc. Besides, it would be necessary to establish permanent stations and monitor them throughout the whole year with a larger number of images.

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