A SOFTWARE FOR MANAGING REMOTELY SENSED IMAGERY OF ORCHARDS PLANTATIONS FOR PRECISION AGRICULTURE

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ABSTRACT

Agronomic and environmental characteristics of fruit orchards/ forests can be automatically assessed from remote-sensing images by a computer programme named Clustering Assessment (CLUAS®). The aim of this paper is to describe the operational procedure of CLUAS and illustrate examples of the information provided for citrus orchards and Mediterranean forest. CLUAS® works as an additional menu ("add-on") of ENVI®, a world-wide known image-processing programme, and operates by integrating the digital values (DV) of the neighboring pixels within a defined range of DV (RDV) and cluster spatial dimensions (CSD). The definition of RDV and CSD is flexible and selected by the operator according to the image specificity and to the study objectives. Remote images with spatial resolution from 0.25 m to 1.5 m have been suitable for tree characterization. For each orchard plot, CLUAS® automatically provides indicators, such as the geographic coordinates, surface and potential yield of each tree; and key parameters of groves, such as the total area and the number, area and potential productivity of trees; and, similarly, for other land uses such as vegetation cover and bare soil. So, CLUAS can contribute to the site-specific/ precision management of fruit orchards, providing quantitative information on each tree, small area/ "micro-plot" of an orchard, or whole orchards.

Keywords: precision/ site-specific agriculture, remote sensing, vegetation indices, classification methods, agricultural indicators, citrus orchards, Mediterranean forest, ENVI® & IDL®.

INTRODUCTION

Site-specific/ precision agriculture takes into account the spatial variability of biotic and/or non-biotic factors, and uses diverse technologies to apply, at variable rates, fertilizers, pesticides or other inputs, fitting the needs of each small area/ "micro-plot" defined. Through systematic sampling and geo-statistic techniques, several authors have shown the spatial variability of diverse soil parameters and of leaf nutrient contents in olive orchards (López-Granados et al., 2002 & 2005) and other perennial crops such as vineyards (Arnó et al. 2006, Taylor et al. 2005). Other authors have analyzed the relation between yields in several zones of an orchard and the information contained in aerial images taken at advanced vegetative states (Bramley et al. 2005). However, neither for fruit tree plantations nor forests has a feasible and economic technology been developed for determining agronomic indicators for each tree and for small areas of orchards from aerial images.

Remote-sensing is becoming an important technology for decision-making in agricultural operations such as fertilization (Blondot et al. 2005), irrigation (Martín et al., 2003) and weed control (López-Granados et al. 2006). The uses of remote sensing in agriculture have been reviewed by several authors such as Felton et al. (2002) and Thorp and Tian (2004).

One method of land use classification in remote images consists of the association of areas that show the same range of reflectance in certain wavebands or vegetation indices (South et al., 2004). The resulting image is a thematic map, in which each class is characterized by a range of spectral/ digital values. Supervised classification methods are based on the knowledge of the geographic area by the operator, who previously defines small areas of each specific land use as being ground-true and, once the classification has been achieved, estimates its correct assessment by means of the confusion matrix/ overall accuracy (OA) coefficient.

ENVI®[1] (*The Environment for Visualizing Images*) is a powerful, world-wide-known computer programme for visualizing and processing images, which has been developed by *Research Systems Incorporated* (RSI). ENVI is written in IDL® (*Interactive Data Language*), a capable and systematized computer language which permits integrated image processes.

Up to date, the agronomic and environmental characterization of fruit orchards has been obtained mainly through ground visits, which do not facilitate the assessment of quantitative information on each tree and on the whole plantation in a feasible, economic way. This paper aims to describe the operational procedure of CLUAS; and to illustrate examples of the automatic quantitative assessment of indicators achieved by CLUAS from fruit orchard and Mediterranean forest imagery.

MATERIAL AND METHODS

CLUAS description and operational process

CLUAS® is written in IDL, works as an "add-on" of ENVI, and has been developed by the Precision Agriculture Group of the Institute for Sustainable

Agriculture (Garcia-Torres et al., 2006 & 2007). CLUAS has been designed to manage the information contained in remote-sensing images for several precision agriculture strategies, i.e. to characterize site-specific tree plantation parameters. CLUAS operates by integrating the digital values (DV) of neighbouring pixels within a defined range of DV and clustering dimension, which is given by a maximum number of columns and rows.

It requires the following steps: first, to select the waveband or vegetation index of the image to be processed; second, to define/ classify the range of DV corresponding to the selected land use, i.e. trees, vegetation cover or bare soil; and, third, to define the maximum size of the clustering, which is defined by a number of columns and rows. In the case of fruit orchards, each DV range defined coincides with that of one of the main soil uses, as follows: trees, other vegetation cover and bare soil; and their determination required their prior supervised classification.

The numerical process achieved by CLUAS is as follows: 1) The DV of each pixel is converted to 0 if the original DV is out of the range of the DVs selected for the land use in process; 2) The remaining DVs of each pixel (within the range of the DV selected) are integrated by rows, up to find a pixel with DV=0); 3)A similar operation to 2) is then achieved per column, up to finding a pixel with DV=0; and 4) The adjacent integrated row and column DVs are also merged up to a defined number thus called “neighbouring”. Therefore, the output for each cluster/ tree is the number of pixels/ size and the integrated/total DV. CLUAS also provides the geographic coordinates of the geometric centre of the cluster

Assessment of citrus orchard indicators

To illustrate CLUAS capabilities, the remote image of a citrus orchard from a panchromatic Quick Bird satellite scene was processed (Figure 2). CLUAS processing was achieved with a DV range of 368/559 (OA=94%), neighbouring of 8, and maximum clustering of 10 columns and 7 rows.

Assessment of Mediterranean forest indicators

……To demonstrate CLUAS capabilities, a remote image of a citrus orchard from a panchromatic Quick Bird satellite scene was processed (Figure 3). CLUAS processing was achieved with a DV range of 319/515 (OA=95%), neighbouring of 8, and maximum clustering of 14 columns and 14 rows.

RESULTS AND DISCUSSION

Assessment of citrus orchard indicators

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[1] ENVI® 4.2: Research System Inc., 4990 Pearl East Circle, Boulder, CO 80301, USA.

[2] IDL® 6.2: Research System Inc., 4990 Pearl East Circle, Boulder, CO 80301, USA.

[3] IDL.IAS.1®/ CLUAS®: Technology Transfer Office, CSIC, c/ Alfonso XII no.16, 41002-Seville, Spain,

a) b)

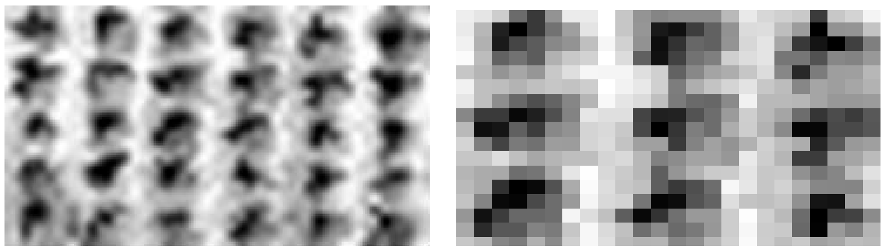

Fig. 2. a) Partial view of a 0.7 ha citrus orchard from a panchromatic Quick Bird satellite scene taken at May 10, 2005, in Posadas (Cordoba, southern Spain); pixel size was 0.7 m; citrus trees are in black, other vegetation cover in grey and bare soil in white; and b) Detail of the zoom view x8.

The ASCII/ Excel format report generated by CLUAS after processing the citrus orchards shown in Figure 1 is indicated in Table 2. Each citrus tree is defined by its geographic coordinates and for several agronomic parameters, such as its surface (number of pixels/ m^2) and potential yield (integrated DV).

For example, the cluster AG4/ 4th citrus tree had the largest size, with 56 pixels, and a potential yield of 28144, and the cluster AG6/ 6th citrus tree exhibits a size of 7 pixels and a potential yield of 3675, and this difference can be observed visually in Figure 1. In addition, the CLUAS report provides indicators for the whole citrus trees in the image, i.e. the total number of cluster/ citrus trees, a total surface of trees (866 pixels), the percentage of citrus tree surface over the total plot surface (NTAG/ NTP, 0.59), and the potential overall productivity (IVDA, 427784), among others.

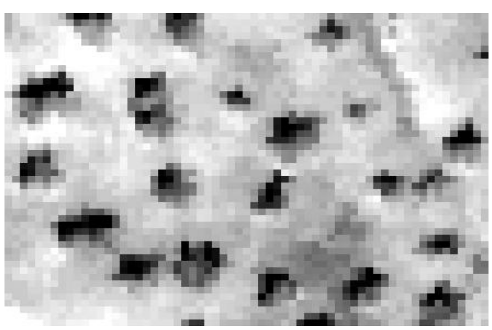

Figure 3. a) Partial view of a 0.15 ha citrus orchard from a panchromatic Quick Bird satellite scene taken at May 10, 2005, in Posadas (Cordoba, southern Spain); pixel size was 0.7 m; *Quercus* spp. trees are in black, other semi-desiccated vegetation cover in grey and bare soil in white (Detail of the zoom view x7).

…..Similarly, the report generated by CLUAS after processing the Mediterranean forest shown in Figure 2 is indicated in Table 3. Each Quercus tree is defined by its geographic coordinates and for several agronomic parameters, such as its surface (number of pixels/ m^2) and potential yield (integrated DV). For example, the cluster AG4/ 4th citrus tree, exhibits a size of 10 pixels and a potential yield of 5305. In addition, the CLUAS report provides indicators for the whole area of the image, i.e. the total number of clusters/ Quercus trees, total surface of trees (903 pixels), the percentage of tree surface over the total plot surface (NTAG/ NTP, 0.59), and the potential overall productivity (IVDA, 427784), among others.

Table 2. Outcome of the information provided by CLUAS on a citrus orchard (see Figure 1, only data of the top six trees are shown for abbreviation).

Trees/ AG	X /Y	NPAG	VDAG	VDAG/NPAG	m2
AG1	315688.6/ 4186001.3	29.0	14172.0	488.7	14.2
AG2	315689.0/ 4185996.3	30.0	14673.0	489.1	14.7
AG3	315689.7/ 4185991.0	29.0	14288.0	492.7	14.2
AG4	315690.7/ 4185986.3	56.0	28144.0	502.6	27.4
AG5	315696.1/ 4185986.3	22.0	10952.0	497.8	10.8
AG6	315691.6/ 4185983.8	7.0	3675.0	525.0	3.4
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NTP:	1479	NTAG/NTP:	0.59		
NTAG:	866	IVDA:	427784		
		VDAM:	494		

Abbreviation: NTP, total number of pixels in the image; AG, cluster- citrus tree; X and Y, geographic coordinates; NPAG, number of pixels in each cluster/ citrus tree; VDAG, integrated digital values of each cluster; NTAG, total number of pixels in all clusters/citrus trees; IVDA, integrated digital values of all clusters/ citrus trees; VDAM, average digital values of clusters/ citrus tree. . ------- Data omitted for abbreviation

Assessment of Mediterranean forest indicators

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surface (number of pixels/ m^2) and potential yield (integrated DV). For example, the cluster AG4/ 4th citrus tree, exhibits a size of 10 pixels and a potential yield of 5305. In addition, the CLUAS report provides indicators for the whole area of the image, i.e. the total number of clusters/ Quercus trees, total surface of trees (903 pixels), the percentage of tree surface over the total plot surface (NTAG/ NTP, 0.59), and the potential overall productivity (IVDA, 427784), among others.

Table 2. Outcome of the information provided by CLUAS on the Mediterranean forest shown in figure 2 (only data of seven trees are shown for abbreviation).

AG	X/ Y	NPAG	VDAG	VDAG/ NPAG	m^2
AG1	315827/ 4186954	17	8045	473.2	8.3
AG2	315836/ 4186956	24	11303	471	11.7
AG3	315850/ 4186960	42	21070	501.7	20.5
AG4	315842/ 4186954	10	5305	530.5	4.9
AG5	315826/ 4186945	42	18799	447.6	20.5
AG6	315835/ 4186947	49	22764	464.6	24.0
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AG21	315865/ 4186941	22	10271	466.9	10.7
AG22	315867/ 4186935	51	24125	473	24.9
NTP:	3024	NTAG/NTP:	0.3		
NTAG:	903	IVDA:	428853		
		VDAM:	474.9		

Abbreviation: NTP, total number of pixels in the image; AG, cluster-Quercus tree; X and Y, geographic coordinates; NPAG, number of pixels in each cluster/ Quercus tree; VDAG, integrated digital values of each cluster; NTAG, total number of pixels in all clusters/Quercus trees; IVDA, integrated digital values of all clusters/ Quercus trees; VDAM, average digital values of clusters/ Quercus tree. ------- Data omitted for abbreviation

Our data show that CLUAS, from remote imagery of tree orchards/ forest, provides detailed agronomic information both “tree by tree” and for each small area/ micro-plot of the orchard defined. So CLUAS can contribute to setting up the basis for site specific/ precision management for orchards with a feasible, economic technology for determining agronomic indicators for each tree and for small areas from aerial images of orchards and, therefore, the carrying out of extensive/ uniform treatments over the whole plot could be avoided.

The potential productivity parameter changes with each waveband/ vegetation index used, and, consequently, each of them should be interpreted accordingly. For example, if a vegetation index is used in which the tree is defined by a lower range of DV than that for other land uses (vegetation cover and bare soil), the lower the potential yield values the higher the potential productivity. The application of CLUAS to whole orchard images provides, among other information, the percentage of soil covered by trees, other vegetation covers and/or bare soil, which can contribute to the monitoring and assessment of agri-environmental regulations.

FINAL COMMENTS

The processing of remote imagery of tree groves by CLUAS provides useful agronomic tree to tree information, for small areas/ zones within an orchard, and for whole orchards. This information can be used as a basis for the precision management of fertilizers, pesticides and watering, since there is an obvious relationship between tree size and potential productivity and nutrient requirements, plant protection products such as fungicides, and watering doses. Further details of CLUAS and its evaluation in olive plantations were described by García-Torres et. al. (2008).

ACKNOWLEDGMENT

This research was partially financed by the Spanish Commission of Science and Technology through the projects AGL2004-01034 and AGL2007-60926/AGR.

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