Use of Very High Resolution Airborne and Spaceborne Imagery: a Key Role in the Management of Olive, Nuts and Vineyard Schemes in the Frame of the Common Agricultural Policy of the European Union

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Abstract

In the frame of the Common Agricultural Policy the European Commission is strongly involved in the development of methods for the automatic identification and counting of fruit trees and the measurement of orchard's area, based on Geographic Information System and remote sensing. This paper gives an overview of the research and development activities of the JRC (Joint Research Centre) to support the management of the area-based subsidies of permanent crops (olive, nuts trees and vineyard). It presents results of tests of fruit tree identification using Very High Resolution Images.

INTRODUCTION

Since 1992 the role of remote sensing and geomatics in the management and control of the Common Agricultural Policy (CAP) became more and more important. These techniques are used operationally for major projects, especially the implementation of Land Parcel Identification System (LPIS) for the identification of all parcels for which area-based subsidies are claimed and the annual Control with Remote Sensing activities (CwRS). They cover not only arable lands and forage, but also permanent crops. Three types of permanent crops get subsidies schemes which are partly or completely based on area: olive, vineyards and more recently nuts. The citrus subsidies are based on production but the identification of land parcels is also required. In this context there is a strong interest of the European Commission (EC) to use Remote Sensing with Very High Resolution (VHR) images (satellite and airborne) to identify orchards and individually position fruit trees.

REVIEW OF EUROPEAN PROJECTS USING REMOTE SENSING AND GIS TECHNOLOGY FOR THE MANAGEMENT OF PERMANENT CROPS IN THE CAP

The Joint Research Centre (JRC) provides the DG AGRI (Direction General of Agriculture of EC) and the Member States (MS) with technical assistance for policy making and implementation. The JRC was involved in statistical surveys and in the implementation of registers of permanent crops which are the basis for the management and control of these subsidies schemes (the vineyard registers, the olive registers replaced now by the Olive GIS and the recent introduction of a nuts GIS).

Use of Remote Sensing and GIS for the management of the olive sector

The European Union is the main olive producer in the world, with 75% of the 2 M tons annual world production. The major part is located in Spain (40% of the EU olive trees), Italy (30%) and Greece (21%), whereas Portugal and France are smaller olive growers. The oils and fats Common Market Organisation (CMO) was set up by Council Regulation 136/66/EEC of 22/09/66. In 1996/97 there was a 'crisis' with a record production of 1.86 M tons (due to exceptional yields in Spain and in Italy). In February 1997 the EC stated that a reform of the olive oil scheme was necessary (either based on olive trees or on olive area). However, the EC, acknowledging the current lack of reliable information proposed first to gather reliable and objective information on the number of olive trees and the olive growing areas. These aspects were supported by the JRC under the OLISTAT and OLIAREA projects in the period 1997-1999. OLISTAT stands for the estimate of the number of olive trees in the EU, OLIAREA stands for the estimate of the olive area and the number of maintained trees in the EU. It was also decided to reinforce the system of control and management of subsidies scheme: this was the scope of Reg. (CE) 2366/98, with the implementation of the Olive GIS using orthorectified photography (or 'orthophotos') by all Member States.

The methodology for the OLISTAT project was based on aerial photography acquisition, computer aided photo-interpretation of the number of olive trees within a selected systematic sample, field visits and extrapolation to national levels using statistical estimators. For these projects, the JRC designed an automatic counting tool called OLICOUNT, for counting olive trees on the basis of 1m aerial orthophotos (Peedel *et al.,* 2000) and a tool called OLIAREA to derive the olive area from the position of olive trees. OLISTAT and OLIAREA projects estimate about 5.44 M ha and 757 M olive trees in the UE. The JRC was also involved in the implementation of the Olive GIS which aims to identify and locate every olive parcels and every olive trees of the producers who claim for subsidies. The Olive GIS is operational since November 2003 and covers 2.8 M olive producers ,10 Million olive parcels and the individual graphic location of 600 Million olive trees (Masson, 2002) over the 5 olive-growing countries of the EU (Spain, Italy, Greece, Portugal and France). It will also be implemented in the new olive-growing Member States (Cyprus, Slovenia, Malta).The Olive GIS implementation was 100% funded by the EC budget for a total amount of about 100 M euros.

For all of these projects, the identification of olive trees (either by automatic counting or by photo-interpretation) was based on their individual positioning on 8-bit, 1m pixel panchromatic (Panchro) orthophotos derived from 1:40,000 scale flights, and completed by field survey. The choice of this type of images was driven by cost-effectiveness and data volumes consideration. However using this type of imagery, the identification of trees performs well on large homogeneous groves, but poorly in case of small, irregular or young groves. The new Very High Resolution images (VHR) which are available at a resolution better than 1m should improve the identification of trees.

Use of Remote Sensing and GIS for the management of the vineyard registers

The vineyard register has a longer history (reg. (EC) 2392/86 and 646/87). Originally the use of GIS was not compulsory for the implementation of the vineyard register, but a more recent regulation encouraged the use of GIS (reg. 1549/95). Nowadays, with the obligation of compatibility between the vineyard register and the LPIS, a majority of Member States have already set up a vineyard GIS, sometimes using VHR data (0.5m and even 0.1m pixel resolution for some small vineyards).

Use of Remote Sensing and GIS for the management of the Nuts scheme and other fruit trees

A new area-based Nuts scheme was recently introduced (Reg. 1782/2003, Title IV and Reg. (EC) 2237/2003), covering about 800,000 ha of nuts orchards throughout EU. The scheme covers 5 species: almonds, walnuts, hazelnuts, pistachios, locust beans (caroubs). Chestnuts are excluded. This new regulation is quite complex because there are specific eligibility conditions:

- Only homogeneous and geographically continuous groves are eligible
- Isolated trees and single rows of trees are not eligible
- Mixed orchards (> 10% other trees than nuts) are not eligible
- The minimum plot size should be ≤ 0.1 ha
- The minimum density of nuts trees per hectare is [50] for almonds, walnuts, pistachios, locust beans and [125] for hazelnuts

It is compulsory for the member states to set up (by 2006) a nuts GIS with the number of trees per parcel, their type, their positioning, the calculation of orchard's surface' in the LPIS for managing this new scheme (Reg. (EC) 796/2004). At the end of 2004, the JRC launched a feasibility study for the Nuts GIS in order to define how to implement the Nuts GIS and how to control this scheme, using Remote Sensing and GIS techniques.

For the citrus which are subsidized on production for the moment, the requirement is to declare the area and trees at parcel level.

METHODOLOGY ISSUES

Requirements

In the context of the CAP, Remote Sensing and GIS techniques can be useful for:

- measuring the parcel area (i.e. the orchard or vineyard area) based on (satellite or aerial) orthoimages;
- counting the trees (i.e. getting a global tree count at parcel level), preferably using automatic methods (due to the large volume of data to be handled);
- individually positioning the trees (with an accuracy of around 2m);
- separating the tree species (especially in case of nuts orchards where mixed orchards are not eligible for subsidies);

- identifying 'young olive trees' (or better separate trees planted before 1998 which are eligible and trees planted after 1998, which are not eligible);
- detecting changes in olive parcels (in the regulation on olive direct payment scheme, there is a requirement that the number of trees should not vary of more than ±10% compared to 2005);
- checking the category of parcel (for the 'coupled' part of olive scheme, the amount of subsidies should be based on environmental criteria such as: parcels in terraces, slopes > given % etc.).

Methods of automatic counting of trees

The position of trees should be recorded in the Olive GIS and the Nuts GIS. In order to reduce the workload the automatic identification and counting of trees were investigated. The automatic identification of individual trees using Remote Sensing was originally developed for forestry applications (Pollock 1994; Gougeon 1995; Brandtberg and Walter, 1998). However these approaches are not necessary well adapted to fruit trees, which are usually less dense than forestry and which are characterized by the fact that the fruit tree crown (plus shadow) is locally darker than its surrounding background. That is why the JRC decided to develop the OLICOUNT software which was originally dedicated to olive trees.

OLICOUNT is based on a combination of image threshold (i.e. using the spectral characteristics of trees), region growing, tests based on tree morphological parameters (i.e. using the morphology of individual trees). More details on the method can be found in (Peedel *et al*., 2000). It operates with four parameters:

- Grey value threshold (minimum, maximum)
- Tree diameter (maximum, minimum)
- Crown shape (maximum, minimum) calculated with the ratio between minor and major axes
- Crown compactness (range) calculated with the ratio blob surface to envelope surface.

OLICOUNT is a semi-automatic approach; an operator is required for tuning the parameters per parcel during the training step and for manually checking the results (trees can be manually added or deleted). The problem is that these manual tasks are time-consuming. The OLICOUNT software has also some limitations, as it was originally designed for olive trees and it was not tested for other fruit trees or with image resolutions of less than 1m. OLICOUNT was adapted to support VHR images and the JRC carried out some tests with other fruit trees species (nuts and citrus). For the moment OLICOUNT works only with one band 8 bit pixels (multi-bands images and pixel depth greater than 8 bits are not supported). The multi-spectral images would require another approach.

Other investigations were also carried out by the JRC with the intent of reducing the manual work required by OLICOUNT (suppression of the training stage and the manual adaptation of parameters). Mathematical morphology was tested, using the method of regional minima. It is based on the principle that since crowns are dark objects, they usually contain a regional minimum. A regional minimum is defined as a connected component of pixels whose neighbors have all a strictly higher intensity value [Soille, 2003]. Unlike OLICOUNT the whole image is processed. Then a mask with the regional minima is built and then it is clipped based on the parcel boundaries layer in order to keep only the minima within the test parcels.

Method to measure the orchard's area

The olive and nuts orchards are identified on the basis either of the national reference system for the identification of land parcels (based either on cadastral parcels, physical blocks or 'ilots' for France). However the reference parcels do not always match the boundaries of the orchards. Prior to any area measurement, the first task is to position the orchard's boundaries. In case of irregular or scattered groves, manual delineation might cause inconsistencies. That is why the JRC developed an original approach based on GIS, which derives the olive area from the position of trees. This method was used for the project called OLIAREA and it was proposed by the Commission as a common methodology to calculate the olive area for the new olive subsidies scheme under Reg. (EC) 1782/2003. The regulation states that the area under olive trees is the area of the olive parcel or for scattered trees, an area of 100m2.

The OLIAREA algorithm is implemented in a GIS platform (Arcview 3.1, © ESRI) and it works completely automatically, in 5 steps: OLIAREA uses 4 parameters: P1 neighborhood analysis parameter, P2 scattered trees area, P3 internal buffer and P4 external buffer. It works completely automatically, in 5 steps:

- Step 1: neighborhood analysis using the P1 parameter (20 m by default) to determine the proximity of trees.
- Step 2: attribution of a standard area (P2 = 100 m2) to the scattered trees.
- Step 3: application of a first 'internal' buffer (P3 = 10m by default).
- Step 4: application of a second 'external' buffer calculated as P4 = 1/3 of the mean planting distance of the parcel δ, with $\delta = \sqrt{\frac{A}{N}}$ (where A = parcel area and N = number of trees).
- Step 5: both buffers are combined, and in option the result can be converted to Voronoi polygons which attribute an area to each tree.

RESULTS AND DISCUSSIONS

A series of tests was carried out on several test sites using various types of images at different pixel resolution. Here we present the results on 2 test sites (Creta in Greece and Maussane in the South-East of France) with a predominance of olive trees (for more details, cf. Masson *et al*., 2004). The purpose was to compare the traditional 1m Black and White orthophotos (used so far for the European projects) to VHR images: Quickbird images (0.6m pixel resolution in Panchro and Pansharp[1] modes) and Ikonos (1m resolution in Panchro and Pansharp modes). Several identification methods were also compared: Computer Assisted Photo-Interpretation (CAPI), OLICOUNT and the regional minima method.

The main conclusion is that VHR images improve significantly the tree recognition, compared to the 1m orthophotos. The omission rate (ie trees present on the field which were not identified by a manual or automatic method) is reduced to a very low level by photo-interpretation of the VHR images (between 3% and 7%). In addition, compared to the 1m Panchro orthophotos used so far: the identification of trees is improved by a factor of 6 with Quickbird or Ikonos images using CAPI. Using OLICOUNT the identification of trees with VHR images is also improved of a factor of 2-2.5, compared to 1m orthophotos.

When comparing various methods of tree identification, it appears that CAPI performs always better than the automatic methods (both OLICOUNT and the regional minima method). When comparing OLICOUNT and regional minima (tested on olive trees with Quickbird image) the omission rate is similar but the commission rate (ie. trees which were identified by the automatic method but which are not present on the field) is higher for regional minima (22%) than for OLICOUNT (8%). This is due to the fact that regional minima detects also objects which are 'non trees' (e.g. bushes, mixed crops, terraces etc.). It should be improved by using a mask of 'non trees' areas (e.g. by using a threshold on near Infra-Red and visible bands).

However the advantage of the regional minima method is that it is more stable whereas the OLICOUNT performance is very sensitive to the adjustment of parameters, especially the commission rate: using OLICOUNT with adjusted parameters the commission rate is 13% instead of 35% when the parameters are not adjusted.

Both Ikonos and Quickbird images in Panchro mode are suitable for the tree recognition and in spite of the better resolution of Quickbird compared to Ikonos, there is not a significant difference between those images for the tree recognition. The Ikonos PanSharp[1] mode (where the multispectral channels at 4m resolution are 'sharpened' with the Panchro mode at 1m resolution) does not improve the recognition of trees compared to the Panchro mode where the separation between the species is very difficult.

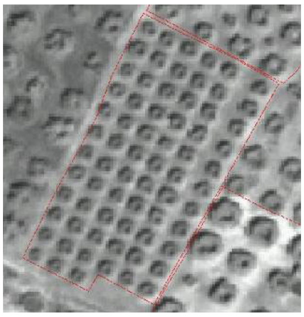
The automatic identification of trees works well on regular and well maintained groves, but it performs badly in the following cases (cf. Figure 1)

- Joint crowns
- Very irregular parcels
- Parcel not well maintained (presence of shrubs, or weeds in the parcel)
- Young trees: trees with a diameter of less than 1.2-1.5 m cannot be identified with VHR images
- Trees in the border of parcels (which are very often associated species)

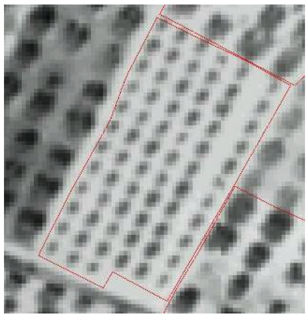
Possible improvements were investigated. A morphological filter called 'ultimate erosion' was tested and improves the separation of joint crowns. Other advanced morphological image analysis could also be investigated.

[1] Pansharp stands for pansharpened mode which is generated by a fusion between multispectral bands with the geometric information contained in the Panchro band

Regular and well maintained grove, Maussane (FR)

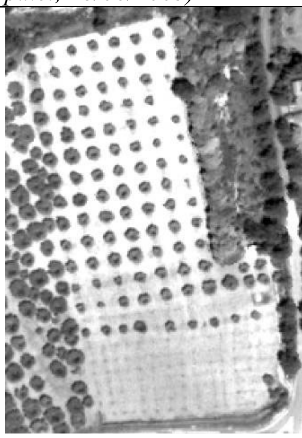


The olive trees are very well identified with a characteristic ring shape, due to pruning practices (Quickbird image, 0.6m pixel, 18/06/2003)

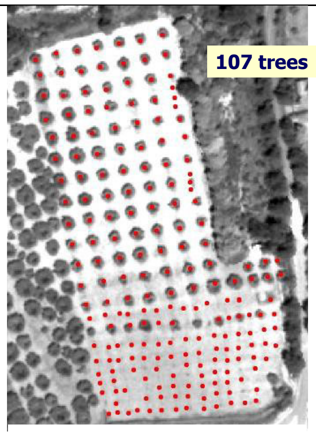


In comparison: the same parcel (left) on the 1m orthophoto (1997)

Parcel partly planted with very young trees, Maussane (FR)



Difficult to identify the young trees in the South part of the parcel (Quickbird image, 0.6m pixel, 18/06/2003)

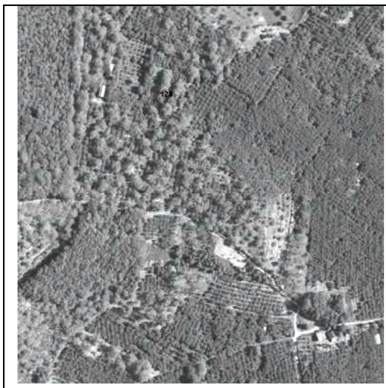


Field survey: very young trees could not be identified by CAPI or by automatic counting

Figure 1: Examples of VHR images on various categories of olive groves

OLICOUNT was also successfully tested on other species than olive trees (nuts, citrus and associated fruit trees). However the separation between fruit species (only possible by CAPI for the moment) was not very successful using summer or spring images, both in Panchro and multispectral modes.

The JRC started a series of tests on nuts trees using VHR images (cf. Figure 2). The main problems found so far are: (i) the separation of hazelnut trees which are grown with a higher density than other nuts trees (300 to 500 trees/ha) and appear like a continuous canopy at maturity, (ii) the separation between nuts species. The most sensitive issue is the separation between olive trees and almond trees which are very often grown together; in such case the almond orchards are considered non eligible for subsidies. Additional tests will be carried out with winter images in Pansharp mode where the separation between olive trees (evergreen) and almond trees (deciduous) should be easier.



Mature hazelnut groves, Viterbo

Hazelnut orchards (sometimes mixed with chestnuts) in the region of the lake of Vico, province of Viterbo, Italy. On this 1m orthophoto it is difficult to separate individual trees Compared to the 1m orthophoto the Quickbird Multispectral pansharpen image(right) is better to separate trees but in some parcels hazelnut trees look like continuous canopy. The multispectral bands may help to identify walnuts trees

Chestnut trees in the middle of a young hazelnut grove, Viterbo

Figure 2: Examples of VHR images on hazelnuts orchards

Area measurements

OLIAREA was successfully used for the statistical estimates of olive area all over the EU. This algorithm has been proposed by the JRC as a common method for the area measurement of olive parcel, which should be applied by all Member States under Reg. (EC) 1782/2003. The standard parameters of OLIAREA could be slightly adapted for the measurement of olive parcel. In addition it was proposed to set up a tolerance on the 'islands' generated by the algorithm (in order to avoid the artifacts of very small islands which are not significant from an agronomic point of view).

As far as the nuts are concerned, there is also a requirement to measure the nuts parcel area. However a simplified approach was proposed by the JRC. Instead of deriving the area from the position of every trees (which is very time consuming and not really relevant for the nuts where the amount of subsidies is only 125 Euros/ha), it is proposed to measure the area from the position of border trees using GIS functionalities. The operator locates either the corner trees (if the parcel is regular) or all border trees (in case of irregular grove). A raw perimeter is generated from the position of those trees. An external buffer of half the mean row spacing is applied to the raw perimeter and the nuts parcel area is calculated from this position. A ceiling to the limits of the reference parcel should also be applied.

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L'imagerie aérienne et satellitaire à très haute résolution : un rôle clé pour la gestion des cultures d'olives, amandes et vignes dans le cadre de la Politique Agricole Commune.

Mots-clés *: Télédétection, traitement d'image, géomatique, SIG, comptage d'arbres, images THR*

Résumé

Dans le cadre de la Politique Agricole Commune, la Commission Européenne est fortement impliquée dans le développement de méthodes pour l'identification et le comptage automatique d'arbres et la mesure des surfaces de vergers, basées sur des Systèmes d'Information Géographique et sur la télédétection. Ce papier donne une vue générale des activités de recherche et développement du JRC (Joint Research Centre) pour assister la gestion des subventions à la surface cultivée des cultures pérennes (olives, amandes et *vignes). Il présente les résultats de tests d'identification des arbres fruitiers à partir d'images à Très Haute Résolution.*