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in

Deshayes M. (ed.).
La télédétection en agriculture

Montpellier : CIHEAM

Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 4

1991

pages 71-77

Article available on line / Article disponible en ligne à l'adresse :

<http://om.ciheam.org/article.php?IDPDF=CI911182>

To cite this article / Pour citer cet article

Romeu J., Pala V., Vinas O., Arbiol R. **Use of SPOT orthoimages for agriculture in Catalonia.** In : Deshayes M. (ed.). *La télédétection en agriculture*. Montpellier : CIHEAM, 1991. p. 71-77 (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 4)



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Use of SPOT orthoimages for agriculture in Catalonia

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Abstract: Improved management of agricultural and forest resources requires accurate and updated land use maps. In Spain such maps are produced by the Ministry of Agriculture. The maps, called *Mapa de cultivos y aprovechamientos* (MCA), are produced at a scale of 1:50 000 by photo interpretation of aerial photographs and intensive field work. Updating the maps with the same methods would require the same long and laborious effort.

Production of SPOT orthoimages by the cartography institute, *Institut Cartogràfic de Catalunya* is a convenient method for obtaining georeferenced documents that serve as a basis for photo interpretation.

The method used in this research consists in overlaying the transparency of the map to be updated on the SPOT orthoimage and drawing visible changes of forms and contents on a new transparent film. The resulting document is then completed in the field.

The new method has a definite advantage compared with the traditional system even if the MCA classes cannot be directly interpreted on the orthoimage. With the new method the new polygons can be identified and processed directly at the scale of the published map; the number of documents to be processed is reduced and only a single document is required for field work.

Résumé

Utilisation d'orthoimages couleur SPOT pour l'agriculture en Catalogne

Une cartographie de l'occupation du sol précise et à jour est absolument nécessaire pour une meilleure gestion des ressources agricoles et forestières. En Espagne, ces cartes appelées «Mapa de Cultivos et Aprovechamientos» (MCA) sont produites par le Ministère de l'Agriculture en utilisant une méthode de photointerprétation de photos aériennes et de travail intensif sur le terrain. L'échelle finale d'édition est le 1/50 000^e. La mise à jour de ces cartes avec la même méthodologie signifierait de nouveau le même long et fastidieux travail.

La production d'orthoimages SPOT par l'Institut Cartographique de Catalogne rend possible la production rapide de documents de base géoréférencés pour cette mise à jour.

La nouvelle méthode utilisée dans cette recherche consiste à superposer un calque de la carte à mettre à jour sur une orthoimage SPOT et à dessiner sur un nouveau film transparent le changement de formes et de contenu, si possible, de façon à produire un document qui sera complété sur le terrain.

Bien que la complexité de la légende des MCA (plus de 80 classes) rende impossible l'interprétation directe sur l'orthoimage, la méthode confirme en pratique les avantages théoriques sur les systèmes traditionnels de mise à jour cartographique, c'est-à-dire les nouveaux polygones sont directement saisis à l'échelle de publication, le nombre de documents à traiter est réduit et un seul document est utilisé sur le terrain.

I. – Introduction

The Catalanian cartography institute, *Institut Cartogràfic de Catalunya* (ICC) is an autonomous organization attached to the Territorial Policy and Public Works Council. It has the responsibility to produce topographic maps and to undertake any cartographic work. Two main working areas are being developed at present: generation of 1:5 000 and 1:25 000 scale orthophotomaps and of false color maps at 1:100 000 and 1:250 000 scales from Landsat 5 satellite imagery.

This paper deals with the false color 1:50 000 series which links the two working areas. SPOT imagery and a digital terrain model (DTM) are processed by software developed at ICC.

The second part of the paper deals with the applications of orthophotomaps to agriculture. It describes the methods used by ICC for extracting information required by the Department of Agriculture of the *Generalitat de Catalunya* (autonomous government of Catalonia) on the status and distribution of crops. This part focuses on updating of inventories, monitoring of newly irrigated land, stratification for agricultural statistics, and the use of orthophotomaps as a support in agricultural thematic cartography.

II. – Orthophotomap generation

1. Data

Several studies have demonstrated the suitability of SPOT panchromatic images registered by high-resolution visible (HRV) sensor for 1:50 000 orthophotomap generation (Baudoin, 1986). Moreover, the availability of both P and XS images (**Table 1**) from a single satellite source facilitates merging of information previously contained in separate images.

Table 1. Characteristics of SPOT HRV bands.

Bands	Wavelength	Pixel size (m)
XS1	0.50 - 0.59 green	20
XS2	0.61 - 0.68 red	20
XS3	0.79 - 0.89 near-infrared	20
P	0.50 - 0.75 panchromatic	10

The dates for satellite programming were fixed between June and September as images can be obtained without cloud cover and snow in summer; they also have the best radiometry.

A DTM with a high precision level is required for geometric correction. Initially, the DTM generated by the defense mapping agency was used. It consisted of a grid of elevations at 3-second intervals. Maps to locate ground control points included 1:5 000 scale orthophotomaps and 1:25 000 scale topographic maps.

2. Geometric correction

The most common geometric distortions in satellite images are caused by earth rotation, perspective, spacecraft velocity, attitude, altitude, and desired projection (e.g. UTM).

Additionally, in the case of SPOT, distortions due to relief are more accentuated in lateral views (**Table 2**).

The traditional method for geometric correction is based on the adjustment of a polynomial function that correlates digital image coordinates (line, column) and the geographic position of ground control points. This method was adopted for producing 1:100 000 scale maps from Landsat TM images (Arbiol, 1986).

For SPOT imagery, the **polynomial model** is not suitable for rough terrains. An alternative and more sophisticated method that uses terrain information supplied by DTM was adopted.

Several authors (Salamonowicz, 1986; Gudan, 1987) have developed models that establish the satellite orbit and sensor attitude variations for each image line from a few ground control points. ICC tested two other models that are based on the collinearity equations. Both rely on image position parameters, and

Table 2. Displacement (in meters) according to lateral view angle and terrain height.

Height (m)	Lateral view angle		
	0 degree	5 degrees	10 degrees
2000	72	247	424
1000	36	123	212
500	18	61	106
100	3	12	21

geographic coordinates and height of ground control points. A least squares adjustment technique (Mikhail, 1976) is used. The parameters are used for geometric correction of the image.

A simplified model simplifies the problem; it considers relief features with reference to a flat base (and not spherical), the satellite orbit as rectilinear, and the sensor attitude as constant. The Earth rotation effect is stimulated by correcting orbit inclination and sensor attitude. The model takes into account the panoramic effect because it uses an array of sensors. The flat-surface approximation of the geoid and variations in sensor attitude remain as residual errors.

In the **more realistic** model the satellite position is qualified in terms of orbital parameters (inclination; longitude of descending node, orbit radius, and geocentric latitude) and its linear attitude is described by six more parameters. The Earth's shape is described by an ellipsoid. The geometric correction of the image needs a time-consuming loop compared with the first model which only requires systematic computation (no loop) of a simple expression.

3. Metric accuracy

Two different tests were made to control the accuracy calculated from the three different models (Table 3).

Table 3. Characteristics and results of the test for comparing three geometric correction models.

Spectral band	PAN	PAN
Date	22 March 1986	22 March 1986
Incidence angle	R20.4	R7.3
Area	Marseille	Barcelona
Test points	40	32
RMSE	X / Y	X / Y
Polynom degree 2	66.7/ 8.9	11.5/8.2
Simplified model	12.2/ 10.2	9.4/8.8
Realistic model	10.5/ 6.3	8.7/8.8

4. Image registration

After correction of both images (XS, P), an image-to-image registration was required as geometric correction only guarantees a mean error of ± 1 pixel and image overlaying is very sensitive to small position differences.

For the image registration, homogeneous control points (image-to-image) were found on both images to build a second-order polynomial function that converts the geometry of the XS image into the geometry of the P band. The points on the image were not selected manually to avoid introducing a position error; instead, digital correlation techniques were used to overcome the problem.

Once a set of systematically defined points were computed, those giving large errors were deleted. Some reasons of poor correlation are:

- radiometric artifacts in the image
- points over the sea
- radiometric differences between both sensors

These points were detected using the "Danish method" to attribute weights to control points. Once the polynomial function was defined, the geometry of the XS image was adjusted to the geometry of the P image to enable proper registration of the four SPOT bands.

5. XS and P combination

Some authors (Chavez, 1986; Cliche, 1985) discuss the problem of combining information from different sensors with different spatial and spectral resolution: for instance, merging multispectral information (TM, MSS, HRV-MSS) with panchromatic high-resolution images (HRV-P, NHAP). In this case the resulting information combines the advantages of color from the XS image and of better resolution from the P image.

The technique that gives the best results is based on HSL (hue, saturation, lightness) transformation for more intuitive color management (Foley, 1982). The HSL transformation is applied to multispectral bands. The P image is then substituted to the lightness image and the inverse transformation is then applied. The best resolution of the panchromatic image is thus achieved for all resulting bands.

HSL transformation usually allows more controlled color management and improves the quality of the final product. For instance, more saturated colors are obtained by modifying the values in the S component.

6. Final processing

Before generating the final image, a set of procedures are applied to enhance local radiometry. The first process is a Laplacian filter that displays high frequencies on the image. Linear structures are made more visible despite an increase in noise.

This is followed by contrast enhancement using the local histograms computed inside each square of a regular grid. A normalizing operation is computed for each window (square). A contrast function resulting from a combination of the normalizing functions related to the four windows closest to the pixel is applied to each pixel. The functions are weighted according to the distance between the pixel and windows.

Since pixel size at 1:50 000 scale is 0.2 mm and the human eye is very sensitive to blocks with these dimensions (Wiesel, 1985), it is necessary to compute a new image with a pixel size that hides this effect on printed maps. A 1.4 reduction factor is applied, which is enough to get the desired effect. The 16 neighboring pixels are taken into account in a discrete $\sin(x)/x$ interpolation function of new pixels. This function smooths the noise increased by the Laplacian filter.

Finally radiometric retouching of each band avoids some basic color predominance and excessive dark or light shades.

7. Printing

The processed digital images need to be converted into analogical images. A writer laser system is used to produce three screened films (cyan, magenta, and yellow colors) at the desired scale.

The final map, like the 1:100 000 scale map series of Catalonia (Arbiol, 1986), includes marginal information to facilitate map reading by users who are not familiar with this kind of images. The main land covers in each map are shown using small examples taken from the image. Magnetic declination date, image time and date, and a brief process description are also included. A guide map of the area with toponyms, the hydrographic network, and roads is also provided. Another map helps to locate each sheet in the series. The image is fitted in a geographic overlay with the administrative boundaries and main place-names in the image.

8. Production of a series

ICC plans to generate an orthophotomap of the entire Catalanian territory. However, the production of a series involves additional difficulties due to mosaicking, cloud detection and elimination, and radiometric variations.

The 86-sheet series will maintain a certain uniformity but each sheet will be processed separately to increase its visual interpretation possibilities. Production of the series will take at least 1 year with the existing resources.

III. – Examples of use of SPOT orthophotomaps in agriculture

One of the main constraints to regular use of satellite images by land development planners is the cost of the images and the computing time. Microcomputers are used for processing satellite imagery and microcomputers and the use of conventional photo interpretation techniques for printed photographs.

As ICC's main thrust is the production of orthophotomaps, efforts are directed towards the development of methods for facilitating interpretation of this type of photographs. The Department of Agriculture is very interested in upgrading its information systems by adopting modern cartographic techniques that use the orthophotomaps created from SPOT imagery.

1. Inventory updates

The first task in photo interpretation is updating the crops and production map, *Mapa de Cultivos y Aprovechamientos* (MCA), which was made by the Ministry of Agriculture and covers the entire Spanish territory. Some features of this map are:

- 1 200 sheets at 1:50 000 scale
- focus on natural vegetation and permanent crops
- annual herbaceous crops are differentiated in irrigated and nonirrigated areas
- a very detailed legend with differentiation up to species level
- more than 90 different codes
- based on photographs and intensive field work

This inventory needs to be updated because it took around 10 years to complete the work and the criteria used by photo interpreters were not the same throughout the project.

The following method was used for updating (MOREIRA, 1987; CORINE, 1988). It involves:

- Digitalization of the MCA polygons on a transparent film at the scale of 1:50 000 and overlaying on the SPOT false color orthoimage.

- Interpretation of overlaid document. Vegetation evolution can be assessed more accurately because the image acquisition date is known. Changes in land use can be interpreted by an analyst. At this stage, it is easy to differentiate:

- growth of urban areas
- forest fires
- transformation of woodland into agriculture land
- abandonment of fields
- appearance of new irrigation
- new plantations
- clearcuts

- The MCA legend is more complex than that resulting from orthophotomap interpretation. However, as areas where changes have occurred can be located from the images, field work can be planned more efficiently.

- The new polygons drawn on the orthoimage can be digitized directly and included in the database where the map is stored.

The MCA update tests used sheet 360 (Agramunt sheet in the province of Lleida). Some characteristics of this area are:

- very flat area (200 m–300 m)
- about 60% of agricultural land is irrigated from a network of channels
- main irrigated crops are: maize, wheat, fruit trees
- main nonirrigated crops are: barley, wheat
- some isolated hills covered by natural vegetation
- average plot size is around 1 ha

The image taken in June 1986 was selected because this is the best period to differentiate vegetation. Some results obtained from photo interpretation are:

- Incorrect cartographic positioning of a large number of polygons was observed in MCA. This was easily corrected by using the orthoimage. The final metric precision is conditioned by the error committed during the construction of the orthoimage (10 m RMS error) and that in the digitalization phase.

- Woods and scrub areas tend to diminish as they are cleared to provide new agricultural land.

- Agricultural plots over gypsum with poor productivity were abandoned and have become scrubland.

- Labeling of plots from orthoimage interpretation could be evaluated with 90% accuracy.

This method of updating can significantly reduce costs for both processing and field work. This reduction makes it possible to keep the MCA up-to-date.

2. Other applications

Another type of application of the SPOT orthophotomaps is related to its accuracy in representing a varied geographical reality. This characteristic makes them very suitable for use as a base for various types of information. The obvious examples of this type of use are soil mapping, potential vegetation maps, fire risk

maps (access, water points), or any other mapping application that requires a precise geographical reference.

One of the concrete applications of the SPOT orthophotomap at ICC is the compilation of crops statistics. In this projet, SPOT images are used in the digital classification form for classification processing and the printed form for the stratification of study areas.

Another suggestion by the Department of Agriculture is the possibility of updating irrigation zones which can be easily interpreted from false color orthophotomaps.

IV. – Conclusion

SPOT imagery has many applications in agriculture. A digital image processing computer is not always required to obtain information from these satellite images. Very important and varied information that is difficult to obtain otherwise can be extracted from published orthophotomaps by specialists in various fields other than agriculture.

Easy handling of the printed images, geometric quality of the interpretations carried out on the orthophotomap and the possibility of regular coverage are a definite advantage for inventory, monitoring management of agricultural resources. Orthophotomaps are also a useful basic tool for producing thematic maps.

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