# THE USE OF REMOTE SENSING AND GIS TECHNIQUES IN AGRICULTURAL APPLICATIONS

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**ABSTRACT**

The following paper details important aspects and summarises the methodology applied and the results derived during the Remote Sensing control of surface subsidised arable land and forage areas which were carried out in Greece in 1995 by GEOMET Ltd, Athens, Greece under contract of Greek Ministry of Agriculture (MoA), under supervision of the European Agricultural Guidance and Guarantee Fund (EAGGF) in Brussels and Joint Research Center (JRC) in Ispra, Italy.

The reform of the "Common Agricultural Policy" of the EC that became active in 1992, has introduced some changes in order to control the production, the marketing and the prices of the agricultural products. Part of this policy is the granting of subsidies to the farmers (of specific cultivation's) and cattle-breeders. These subsidies are ruled by some regulations and are offered to the producers that are interested to submit a declaration for their products, declaring the subsidised type of crop which they are willing to cultivate, as well as the location and the area of the relevant plots.

In 1995, a sample of 2895 declarations for subsidy in two control zones have been controlled by Remote Sensing from GEOMET Ltd in Greece. The MoA was responsible for the preparation, collection, checking of the conformity and fullness of the declarations which were delivered to the contractor. The contractor then checked, for each declared field, the correctness of its declared area and the kind of cultivation against reality, by the use of multitemporal satellite data. The declarations were then classified to " accepted ", "doubtful" and "rejected" . The Ministry finally carried out a ground truth survey, for all the rejected declarations as well as for the 20% of the doubtful ones, in order to verify the credibility of the Remote Sensing methodology and take the final decisions for subsidies.

## 1. CONTROL ZONES - SAMPLE OF THE DECLARATIONS

The two control zones **AITO** and **PYRG** were located in the west of central Greece and north-west of Peloponissos respectively.
The control zone of Nomos Aitoloakarnania (**AITO**) covers a circle with a radius of 25 km with centre co-ordinates : $\varphi = 38^{\circ}\ 21'$ and $\lambda = 21^{\circ}\ 21'$
The most of the zone is lowlands and drained by two rivers, the Aheloos and the Evinos. The main crops are maize, cotton, clover (as fodder crop) and the second ones are cereals, rice, tobacco and watermelons.
The control zone of Nomos Ilia (**PYRG**) covers a circle with a radius of 25 km with centre co-ordinates :
$\varphi = 37^{\circ}\ 49'$ and $\lambda = 21^{\circ}\ 17'$
The most of the zone is lowlands and drained by the Pinios river. The main crops are maize (corn), vegetables, potatoes, watermelons and the second ones are cereals and fodder crops.
In control zone **AITO** a sample of 1444 declarations spread within 9 communities was selected where as, in control zone **PYRG** 1451 declarations spread within 17 communities. The total amount of declared plots was 10232 from which 7547 were subsidised, corresponding in an area of 13,477 Ha and 10,366 Ha respectively.

## 2. MATERIAL SELECTION

### 2.1 Maps - Orthophotomaps

For the control zone AITO the cartographic reference of the declared plots, consolidation and distribution maps of MoA in scales 1: 2,000 and 1: 5,000 were used. On the other hand, for the control zone PYRG the major cartographic material was orthophotomaps in scale 1: 5,000 but also consolidation and distribution maps of MoA were used for the areas that are not covered by orthophotomaps.
Additionally, General Use maps in scale 1: 200,000 issued by the National Statistical Service of Greece (NSSG) for every Nomos and Topographic Maps in scale of 1:50,000 issued by the Hellenic Military Geographic Service (HMGS) were used.

### 2.2 Satellite Images

Two main factors have been taken into account for the

selection of the most suitable satellite data:

- the crop calendar for the areas of interest
- the availability and quality of satellite data.

Additionally, in the control zone AITO, three LANDSAT TM images were used for the control of 300 declarations of the sample, that the declared plots were arable land during the period 1990 -1991.

In Table 1 the technical characteristics of the used images are given.

### 2.3 Ground Samples

The ground samples were selected along road transacts. For the control zone AITO 26 transacts were defined, whereas for the control zone PYRG, 32 transacts. The length of the transacts was between 500 m and 2500 m.

The main factor that were taken into account for the selection of the transacts was to include a large number of different crops, covering each one a big amount of area in order to eliminate the effects of "mixed-pixels" along their boundaries. The exact location of the transacts were defined by photo-interpretation of the images on the screen.

The Ground Survey was executed within a time period suitable for the identification of all the crops of interest.

Colour hardcopies in A4 format of the first geocoded SPOT-XS image of each zone, in scale 1: 10,000 were used for the registration of the crops' boundaries by the investigators. Additionally, were used B/W hardcopies in A4 format of the geocoded SPOT-P image in scale1: 25,000 and maps in 1: 50,000 scale have been used for the orientation of the investigators and easy approach of the transacts.

The samples of the Ground Survey were used not only for the definition of the crops' appearance during the photo-interpretation procedure but also for the classification of the images.

## 3. DATA PROSSECING

### 3.1 Data Input - Digitisation and Localisation of the Plots

The declarations were delivered in analogue form (lists) and the data of all declarations had been entered into the alphanumeric Data Base by the contractor.
The main problems during data input, had to do with the deficiency of the cartographic reference, the declared area and the kind of crop. During the input of the data the errors and the deficiencies had been registered into lists. In agreement with MoA the half-finished declarations and the error lists were send back for their completion.

For the digitisation of the plots the PC Arc/Info and the Autocad 13 were used. All the available consolidation maps of MoA were digitised in advance. Finally, the alphanumeric and the geometrical data base using the vector module of the ERDAS Imagine 8.2 system on SPARC stations, were integrated in a flexible GIS.

The localisation of the plots on the digitised maps or orthophotomaps has been executed with a unique code for every plot and with the name of the map and the community, that the plot belongs.

### 3.2 Pre-processing of Satellite Images

The pre-processing of the satellite data includes two types of corrections, the radiometric and the geometric.

The method of the histogram shifting was applied for the radiometric corrections. It is based on the fact that the effects of the atmospheric scattering can be somewhat minimised by shifting the histogram "to the left" (JENSEN J., 1986).

Using the Topographic Maps of MoA in scale 1: 5,000 and 1: 2,000 as reference, the SPOT-P images were rectified. The rest of the satellite data (LANDSAT-TM, SPOT-XS) was rectified by applying "image to image" registration. Thirty seven (37) to fifty six (56) Ground Control Points (GCPs) were used for every image. For the geometrical correction it was decided to apply a second order polynomial transformation. For the control of the geometrical correction accuracy, 14-18 Control Points were used (Control Points were different from the GCPs). The RMS errors of the rectification and the control accuracy for the satellite images are given in Tables 2 and 3.

All SPOT images were resampled to 10x10 $m^2$ pixel size using the Restoration module of ERDAS Imagine. The LANDSAT images were resampled to 10x10 $m^2$ pixel size by using the cubic convolution method. The Restoration algorithm take into account the height and the azimuth of the sun, the individual characteristics of the sensor and produces sharper, crisper rectified images by preserving and enhancing the high spatial frequency component of the image during the resampling process and improves the classification accuracy and the radiometric quality of the images (CHIESAC., TYLER W.,1994).

For the optimum visual interpretation a contrast enhancement was applied with the method of linear stretching.

## 4. CONTROL OF THE DECLARATIONS

In order the declarations to be classified into "accepted", "rejected" and "doubtful" where checked into three stages (EAGGF,1995) :

- Parcel Level
  At this stage each plot is checked for its area and land use, against the satellite image displayed on the computer screen and a "control code" is given to each field depending on the conformity with the photo-interpretation. Table 4 indicates the various codes and the proposed guidelines.

- Group Level
  At this stage the total declared area (Dg) within a group of similar type of crops, is checked against the one which derives from the interpretation (measured, Mg) of the satellite image by summing the area of the individual plots coded in the previous stage. Table 5 indicates the rules for classified the crop groups.

- Dossier Level
  At this stage the final classification of the whole declaration (dossier) is being made to "accepted", "rejected" and "doubtful". Table 6 indicates the rules for classified the dossier.

The identification of the land use in a first stage for each plot was made carrying out supervised classification on multitemporal images set. The results of the classification were checked against ground samples different than the ones used in the classification algorithm. The obtained accuracy of the classification was better than 85% for any classified land use, which were cereals, cotton, corn, clover and vegetables.

For the identification of a specific use in a plot, the accuracy of the classification for the specific use must be greater than 75%, it must appear in an area bigger than 70% of the plot's total area and the second found land-use must be less than 20% of the plot's total area. This was done by computing summary tables, resulted from the overlay of the vectors on the results of the classification.

Those plots that can not be controlled by the supervised classification or have been declared for set-aside, should be controlled by visual interpretation of the satellite images on the computer screen on plot level. However, all the plots were finally photo-interpreted to check for the adjustment of their boundaries and their area, and the automatic classification was finally used only to check land use.

In AITO zone, for 300 applications which were randomly selected, control was additionally carried out to check whether the declared for subsidy plots were arable during period of 1990 -1991, using multitemporal LANDSAT TM images of those years.

CAPI (Computer Aided Photo Interpretation) was carried out in a specially designed environment of the ERDAS Imagine 8.2 software. The environment allows for the simultaneous use of several windows, geographically linked among them, to display the multispectral, panchromatic and classified images with the vector database which contains all necessary information and provides entries for the user to add control results such as control code (see Table 4) and measured area.

CAPI results were then processed by our diagnosis software to perform control at group and dossier level. Finally all the "rejected" and 20% of the "doubtful" applications were to be checked by the Ministry of Agriculture by ground truth survey and the results were returned for statistical analysis.

The diagnosis software was also used to print three types of lists, on plot, group and dossier level, that were handled to the administration. These were accompanied by printed maps in A3 size and 1: 10,000 scale, for helping the on-the-spot controls. The maps contained the SPOT-P image, the parcel boundaries (changes in boundaries introduced by CAPI are indicated in a different colour) and cartographic reference codes (parcels to be field inspected are again indicated by code numbers of different colour). All documents and maps were prepared in a community level.

## 5. RESULTS

In dossier level, the results of Remote Sensing were 50% accepted, 35% rejected and 15% doubtful.

By comparing the results of Remote Sensing and those of the on-the-spot checks for 3,400 plots, differences in land-use and area (more than 0.1 Ha) were occurred for less than 5% and 3% respectively. Differences in land-use are mainly caused from the delayed sawing or re-sawing of some plots with maize (corn) cultivation caused by abnormal weather conditions in the control zones, while differences in area were founded in some plots which were cartographicaly referred on ortho-photomaps and the delineation of their boundaries were inaccurate.

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## 7. TABLES

**Table 1. Technical characteristics of images**

| Control Zone | Satellite | Type | Acquisition Date | Path, Row or K,J | Processing level | Incidence angle | Image type | Cloud cover |
|---|---|---|---|---|---|---|---|---|
| AITO | SPOT 2 | PAN | 01-03-95 | 87,272/7 | 1A | R15.5° | SAT | <5% |
| | SPOT2 | XS | 17-05-95 | 86,272/9 | 1A | L15,5° | SAT | good |
| | SPOT3 | XS | 11-06-95 | 86,273 | 1A | R22,0° | SAT | good |
| | SPOT3 | XS | 22-07-95 | 86,273 | 1A | R 3,0° | SAT | <5% |
| | LANDSAT 5 | TM | 15-10-90 | 184,00 | System correct | | MS | 10% |
| | LANDSAT 5 | TM | 12-06-91 | 184,00 | System correct | | MS | 20% |
| | LANDSAT 5 | TM | 19-11-91 | 184,00 | System correct | | MS | 10% |
| PYRG | SPOT 3 | PAN | 04-04-95 | 87,274 | 1A | R 9,3° | FS | <5% |
| | SPOT 3 | XS | 04-04-95 | 87,274 | 1A | R 9,0° | FS | <5% |
| | SPOT 3 | XS | 26-05-95 | 87,274 | 1A | R 9,0° | FS | <5% |
| | SPOT 3 | XS | 21-07-95 | 87,274 | 1A | L27,0° | FS | <5% |

**FS : Full Scene , SAT : Shift Along Track , MS : Mini Scene**

**Table 2. Results of geometric corrections**

| Control Zone | Image | Acquisition date | Number of GCP's | X RMS (pixels) | Y RMS (pixels) | Total RMS (pixels) |
|---|---|---|---|---|---|---|
| AITO | SPOT-P | 01-03-95 | 46 | 0.525 | 0.601 | 0.798 |
| | SPOT-XS | 17-05-95 | 44 | 0.241 | 0.226 | 0.330 |
| | SPOT-XS | 11-06-95 | 52 | 0.201 | 0.211 | 0.292 |
| | SPOT-XS | 22-07-95 | 54 | 0.119 | 0.156 | 0.196 |
| | LANDSAT | 15-10-90 | 37 | 0.233 | 0.226 | 0.325 |
| | LANDSAT | 12-06-91 | 37 | 0.208 | 0.221 | 0.303 |
| | LANDSAT | 19-11-91 | 37 | 0.253 | 0.212 | 0.330 |
| PYRG | SPOT-P | 04-04-95 | 56 | 0.395 | 0.483 | 0.594 |
| | SPOT-XS | 04-04-95 | 41 | 0.203 | 0.219 | 0.298 |
| | SPOT-XS | 26-05-95 | 54 | 0.198 | 0.229 | 0.302 |
| | SPOT-XS | 21-07-95 | 55 | 0.159 | 0.162 | 0.227 |

**Table 3. Results of geometric corrections checks**

| Control Zone | Image | Acquisition date | Number of GCPs | X RMS (m) | Y RMS (m) | Total RMS (m) |
|---|---|---|---|---|---|---|
| *AITO* | SPOT-P | 01-03-95 | 16 | 6.13 | 3.75 | 7.19 |
| | SPOT-XS | 17-05-95 | 15 | 5.00 | 4.10 | 6.47 |
| | SPOT-XS | 11-06-95 | 17 | 2.12 | 1.95 | 2.88 |
| | SPOT-XS | 22-07-95 | 17 | 2.76 | 3.81 | 5.38 |
| | LANDSAT | 15-10-90 | 14 | 7.75 | 4.88 | 10.16 |
| | LANDSAT | 12-06-91 | 15 | 7.65 | 6.10 | 10.78 |
| | LANDSAT | 19-11-91 | 14 | 3.89 | 5.92 | 7.08 |
| *PYRG* | SPOT-P | 04-04-95 | 16 | 3.07 | 2.72 | 4.10 |
| | SPOT-XS | 04-04-95 | 16 | 3.19 | 3.20 | 4.52 |
| | SPOT-XS | 26-05-95 | 16 | 3.29 | 4.02 | 5.19 |
| | SPOT-XS | 21-07-95 | 15 | 3.79 | 3.81 | 5.38 |

**Table 4. Parcel level**

| OBSERVATION | CODE | PROPOSED GUIDELINES |
|---|---|---|
| - interpretation of land use impossible | **T1** | Doubtful for technical reasons : take declared area and declared land-use |
| - plot outside image | **T2** | |
| - plot outside control zone | **T3** | |
| - plot covered by clouds | **T4** | |
| - plot without cartographic reference | **T5** | |
| - plot limit problem not solved on the image | **T6** | |
| - declared to be less than 0.3 ha *(Technical limit of remote sensing using satellite images)* | **T7** | |
| - area measured less than 0.3 ha | **A1** | take measured area |
| - plot declared in more than one application *(A2 is only assigned where the total declared area exceeds the total area of the plot)* | **A2** | give zero value to disputed area |
| - declared as rotating set-aside but found to be another land-use | **A3** | |
| - plot found to be ineligible in reference periods | **A4** | |
| - declared as one crop group but found to be another | **C1** | assign the observed land-use, give zero value to disputed area |
| - declared as one crop group but found to be more than one | **C2** | divide plot and apply previous rules to measured area |
| - land-use found as declared | **C3** | take found area and land-use |

**Table 5. Group level**

| DESCRIPTION | PROPOSED GUIDELINES |
|---|---|
| 1a. (Dg-Mg)/Mg < 2%<br>**OR**<br>1.b (Dg-Mg)/Mg < 10% **AND** (Dg-Mg) < 2ha<br>**OR**<br>1c. (Dg-Mg) < 0.5ha<br>**AND**<br>2. Doubtful area < 20% Mg | **ACCEPTED** |
| 3a. (Dg-Mg)/Mg ≥ 10% **AND** (Dg-Mg) ≥ 0.5ha<br>**OR**<br>3b. (Dg-Mg)/Mg ≥ 2% **AND** (Dg-Mg) ≥ 2ha | **REJECTED** |
| 4. Doubtful area > 20% Mg<br>**AND**<br>5. No cause for rejection (3a , 3b) | **DOUBTFUL** |

Dg = Declared group area
Mg = Total of all plot areas within the group measured as defined in Table 4

**Table 6. Dossier level**

| DESCRIPTION | PROPOSED GUIDELINES |
|---|---|
| 1. All the groups are accepted<br>**AND**<br>2a. $\Sigma$(Dg - min(Dg, Mg)) < 5ha<br>**OR**<br>2b. $\Sigma$(Dg - min(Dg, Mg)/Mg) < 2% | **ACCEPTED** |
| 3a. One group or more is rejected<br>**OR**<br>4a. $\Sigma$(Dg - min(Dg, Mg)) ≥ 5ha<br>**AND**<br>4b. $\Sigma$(Dg - min(Dg, Mg)/Mg) ≥ 2% | **REJECTED** |
| 5. One group or more is doubtful | **DOUBTFUL** |