**Ministry of Agriculture, Natural Resources and Environment
of the Republic of Cyprus**

Water Development Department

Food and Agriculture Organisation of the United Nations

Land and Water Development Division

TCP/CYP/8921

REASSESSMENT OF THE ISLAND'S WATER RESOURCES AND DEMAND

Objective 1 - Output 1.5.2

PILOT SURVEY PROJECT

Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

National Consultants & Division of Hydrology WDD

Loucas Savvides
Irrigation Expert

Gerald Dörflinger
Watershed Management Engineer

Iacovos Iacovides
Project Coordinator WDD

Panayiotis Skordis
Deputy Project Coordinator WDD

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Abbreviations

WDD	Water Development Department
RSA	Remote Sensing Analysis
DLS	Department of Lands and Surveys
ARS	Agrio Remote Sensing LTD
ROI	Region of Interest
GIS	Geographic Information System

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1 INTRODUCTION

The TCP/CYP/8921 FAO Project, within its objectives for estimating the Water Demand all over Cyprus, has included a pilot survey project. Its aim is to examine the possibility of applying remote sensing techniques for estimating the land and water use, on an annual basis. Such data are important parameters in:

- Planning the agricultural development
- Monitoring the various crop categories
- Estimating the annual water use and demand
- Assessing the water resources situation in a river basin.

Land and water use data were recorded by the WDD on limited areas since long time ago. During the Cyprus Water Planning Project (1970), estimates for land and water use, was done for all Cyprus with the traditional survey method i.e by visiting the fields and recording the type of crops in each farm parcel. Currently the WDD keeps records of the irrigated crops within the Major Government Irrigation Schemes as part of the water management policy.

In 1994 the Water Use Section of the Department of Agriculture, has initiated the survey of the Crops/Growers data bank, updated annually. At present time these data bank are valuable information covering all Cyprus, within and outside the Major Government Irrigation Schemes and together with the WDD records are the source of comparison with the results obtained with the remote sensing technique.

Originally, the Kouris upper watershed was selected as pilot area in investigating the possibility of estimating the water use upstream of a main dam by remote sensing techniques. However, due to various reasons (there were no archive IKONOS images available for the Kouris watershed; acquisition of new satellite images takes about 3 months time, which was not acceptable within the project's timeframe and the minimum area for a new acquisition is 100km^2 instead of 25km^2 for archive images, which forced the project team to acquire archive images due to the available budget), it was replaced with the Chrysochou valley with an area of 25km^2. Such change was justified, as more crop categories existed for better assessment of the applicability of the remote sensing method in land use classification.

The need for collecting and updating land use information has been realized, mainly during the last few years along with the efforts exerted for joining Cyprus with the European Community. The present Pilot Survey Project, gives an opportunity for introducing the new technology of remote sensing in combination with GIS and setting up the correct methodology for succeeding in the objectives.

It must be stressed that, for the first time such technology is applied. Although the results obtained may not be very encouraging, the Study Team feels that the methodology has great potential and should be further improved. Drawbacks have been identified and the steps and procedures necessary to obtain reasonable results are stressed for future consideration.

2 SUMMARY OF RESULTS

The remote sensing technique applied as a pilot project for land use identification and processing **has given at present, limited results**. The Study Team feels that **the methodology has great potentials for applying the technique through the GIS**, however further work is needed for improvement. Many member states of the European Union are successfully applying remote sensing techniques and as Cyprus will soon become a member of the EU, it is an obligation to apply the same techniques.

Due to time and budget limitations it was impossible at this stage to check alternative routes for improving the method and increase the accuracy of the results.

Results on land use interpretation indicate high accuracy for sea and dam water, built up areas and forest, however very low accuracy on crop classification. Only citrus and olive plantations were identified at significant levels. However, as can be seen from the following table, even for these crops only a low percentage of the actual crop areas were identified:

Table 1: Percentage of crop area identified by RSA with respect to the actual cropped area

Crop	Percentage of crop area identified by RSA (IKONOS 4m images) with respect to the actual crop area
Citrus	46% - 57%
Olive	32% - 40%
Deciduous	0%
Vines	0%
Vegetables	0%

IKONOS satellite images with 4 m resolution provide the ideal dataset to be used for remote sensing land use classification. The limitation of IKONOS data is the fact that it is only available in 4 bands that reduce the ability of the user to perform analysis based on bands.

On the other hand Landsat TM data offer more bands that can be used and can help to distinguish different crop classes easily, however the 30 m resolution of Landsat TM data did not help in this case due to the small size of the cultivated farm parcels with crops. In most cases the farm parcels were not larger than 1 – 2 pixels.

Among the **problems observed** that have influenced considerably the land use classification through satellite images were:

- **Date of acquisition of the satellite image**. The acquisition date of the satellite images used at present, were on the wrong date (middle of March). During this month the winter weeds, the low vegetation of deciduous, vines and summer vegetables, were obstacle in proper interpretation. The best month would have been towards the end of April
- Only a single satellite image existed in Space Imaging Europe archive (acquired 14th March 2000) and was preferred instead of a new acquisition due to the time and budget limitations of the project. A new IKONOS acquisition could take about 3 months to be delivered from the date of the order and would cost more due to the minimum order area requirements which is 100 km2 rather than 25 km2 for archive data.

- **Some crop categories should have been subdivided for more accurate results**. The crop reflectance depends on the status of the plants and any other intercropping within the same field.
- **Ground truth survey and field checking were inadequate during the present study**.
- **The date of ground truth survey should coincide with the acquisition date**. Accurate interpretation through the computer programme depends mostly on the accuracy of the ground truth surveys. During the present study the ground truth survey was done one and a half year after the acquisition date.

The Study Team recommends that the project should continue for another area considering the abovementioned obstacles and the suggestions for improvement. A Phase II should be set up as a priority project. Remote sensing techniques is a new field for Cyprus and the specialized companies are still limited.

3 PROJECT OBJECTIVES

The objectives of the pilot survey project are as follows:

- Assess the possibility of applying remote sensing techniques for land use identification and processing.
- Assess the agricultural water use on a yearly basis within and outside the Major Government Irrigation Schemes.
- Find out, evaluate and compare the best method to be applied for updating the land use changes on an annual basis.
- Apply the GIS and examine the possibilities of expanding the methodology all over Cyprus, considering time and cost elements involved.

4 AREA SELECTED

The selected area is the Chrysochou valley, covering a 25 km^2. The covered area is under the Chrysochou irrigation project. The reasons for selecting this area are the following:

- It is a compact area, covered by a major Government irrigation scheme.
- The size of the selected area is within the budget capabilities of the project.
- There were satellite images available. Such factor saved time and money and made possible the implementation of the project.
- It is an area with good field survey data, from both the WDD and the Crops – Growers databank of the Agriculture Department.
- Within the selected project area, there are most of the agricultural crops found in all other Major Government Irrigation Schemes. Among the main crop categories are:
    - Citrus
    - Deciduous
    - Vines
    - Olives
    - Fodders
    - Greenhouse
    - Vegetables (including potatoes and tobacco)
- There is a variability of plot size from small, medium to large, thus making possible the evaluation of the applied methodology in all types of farm fragmentation.

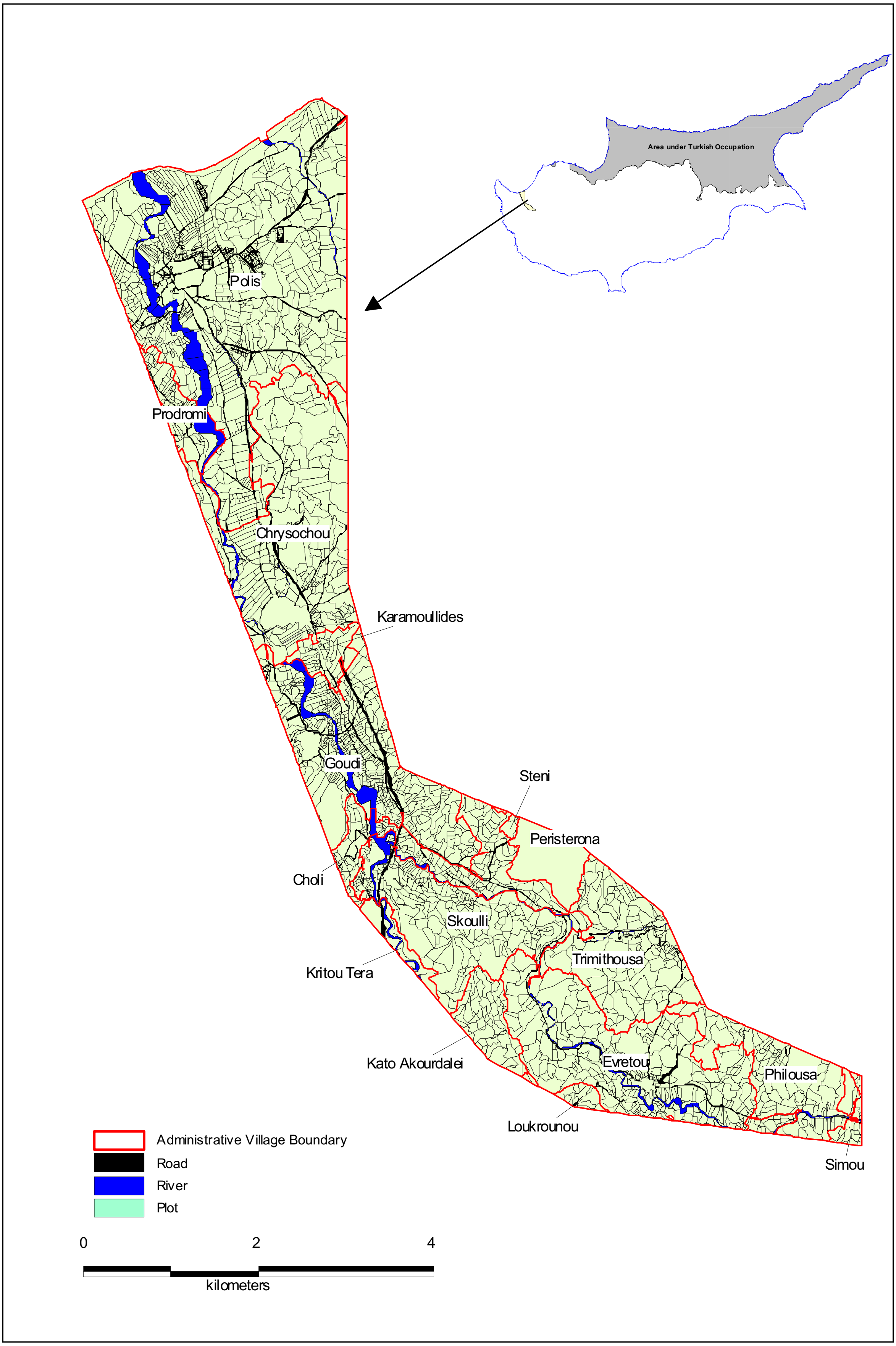

Figure 1: Location Map of the Pilot Survey Project Area

5 METHODOLOGY APPLIED

The steps followed for land use identification and processing were :

- Acquisition of satellite images
- Land use classification through the satellite images
- Scanning the cadastral maps
- Vectorize the farm plots
- Integration of the land use classification results with the vectorized plots
- Import of the IKONOS satellite images on the vectorized cadastral maps
- Check and correct various discrepancies in the results
- Comparison of the obtained land use categories with the field survey data
- Evaluation of the results
- Identifying drawbacks and formulating suggestions for improving the methodology

Acquisition of satellite images

Two sets of satellite images were used:

- **The IKONOS 4m resolution taken on 14th March 2000**
- **The LANDSAT TM 30m resolution, taken on 11th May 2000**

The IKONOS images were available in the archives and ready to be used for the pilot survey project area. Although there were thoughts for acquiring new updated images, however due to delays for having such images and the additional cost involved, it was decided to use the above for carrying out the work.

The LANDSAT TM 30m images were to be used for areas outside the pilot survey project area. However finally, it was decided to use them for the same area, in order to compare the results more effectively.

Land use classification through the satellite images

Agrio Remote Sensing Ltd. has undertaken the task for interpreting and classifying the various land use categories of the satellite images. The various classes to be separated were given by the Division of Hydrology of the WDD. The land use categories needed to identify were:

- Citrus
- Deciduous
- Bananas
- Olives
- Vines
- Greenhouses
- Fodders
- Potatoes
- Vegetables
- Tobacco
- Forest

- Cereals
- Uncultivated land
- Built up area
- Sea water and dams

The Company has carried out classification with two different satellite images:

- Classification using the IKONOS 4m resolution
- Classification using the LANDSAT 30m resolution

The categorization was based on the spectral reflectance and emittance of the various land use categories. Ground truth, and field checks were carried out to verify the various land use categories and use them as training sites for the applied programme and increase the accuracy of the results.

Some effort was exerted for manipulating the applied technique, particularly on the multi-spectral bands, pixels, colour shades and threshold used for non-homogeneous land use categories appearing on the satellite images. In addition probability and statistical analysis was used by the Company to enhance the accuracy and evaluate the obtained results.

Scanning the cadastral maps

The Land and Survey Department has provided the cadastral maps of the project area as hardcopies on scale 1:5000. The cadastral maps show all the farm plots and other features (rivers, roads, etc), established in 1924 however updating of the plots has been done since then on an annual basis.

The **IntelliGraph Consultants** have carried out the scanning, using large format scanner with the ability of scanning in 300 dpi resolution black and white and software (MicroStation J and MicroStation V8 for data capturing and MicroStation Descartes for registration and manipulation of the scanned maps).

Vectorize the farm plots

The IntelliGraph Consultants carried out the vectorization process also. This process involved the farm plots, roads, rivers etc and creating closed shapes in order to be ready for the GIS processing. Text was attached to the plots indicating the sheet, plan and plot number. All these information were on separate layers for facilitating the insert of additional information through the GIS system.

Integration of the land use classification results with the vectorized plots

The classification results were vectorized using the ENVI programme. Finally the classified categories were polygon vector layers (one layer for each category) in DXF files. On the created maps were added the grid lines. The IKONOS images had grids based on geographic coordinates (latitude/longitude).

Import of the IKONOS satellite images on the vectorized cadastral maps

An import of the IKONOS 4m resolution images was done by the IntelliGraph Consultants. The overlay of the images was carried out on GeoTIFF format, with quite good accuracy of matching with the warped maps of the Land and Survey Department. After the scanned LRO maps were warped in the coordinate system provided (WGS84/UTM) a mosaic of the ROI was created. The next step was to warp the IKONOS image on the ROI created with the LRO maps. However, after discussions with ARS, the IntelliGraph Consultants could not have any distortion of the pixels, as this would jeopardize the quality of the Remote Sensing Analysis and therefore the IKONOS ROI could not be warped.

The IKONOS image was a GEO product with horizontal accuracies of ± 50 meters and the overlay of the two ROI did not show a good fit as expected. Therefore the LRO maps had to warp to the IKONOS image. This was necessary in order to have the classification shapes as received from ARS falling in the same area as created by the vectorization procedure. The method used (to identify/locate 22 points uniformly distributed on both maps and image) resulted in a good fit and could overly the results of the Remote Sensing Analysis.

An ortho-rectified image from IKONOS - **CARTERRA™ Precision** (of ± 4m horizontal accuracy) or **CARTERRA™ Precision Plus** (of ± 2m horizontal accuracy) - would have a much better fit with the maps. The cost of these images is much higher and the time needed to purchase is around 3 months. Some other issues like the minimum area of purchase and the provision of GCPs (Ground control points) should be examined for these options``.

The **IntelliGraph Consultants** had also tried the IKONOS 1m resolution with much less deviations.

Check and correct various discrepancies in integrating the results

Some discrepancies observed on plots and other features of the layers, were identified, checked and corrected by the Study Team.

Comparison of the obtained land use categories with the field survey data

The results of the various land use categories obtained by Agrio Remote Sensing Ltd. Company were compared with existing field survey data. There were two sources of field survey, the WDD and the Department of Agriculture. The comparison of the results was carried out by the Study Team (Appendices 5-1, 5-2 and 5-3).

Evaluation of the results

An evaluation of the applied methodology and the obtained results was carried out. The purpose of the evaluation was to assess the possibility of applying remote sensing technique and GIS in land use identification and processing with an ultimate target in estimating the water use on a yearly basis (see Chapter 9).

Drawbacks and suggestions for improving the methodology

After studying the applied methodology and analyzing the results, weak points and drawbacks were identified and suggestions were made for improvement.

6 PROCEDURE FOLLOWED

6.1 General description

In order to carry out effectively the project objectives within the time and budget limitations, it was decided to share the work into groups of specialized people. A work programme was set up and dates of completion of the targets were fixed.

Since the remote sensing techniques require technical knowledge, high computer skills and equipment, two private companies have been selected to carry out part of the work. The two companies were:

- INTELLIGRAPH Consultants
- AGRIO REMOTE SENSING Ltd

The Division of Hydrology of WDD has co-ordinated, checked and evaluated the work with the assistance of **Mr. Loucas Savvides (National Consultant)** who has been hired for two weeks period.

6.2 Work carried out by the IntelliGraph Consultants

The IntelliGraph Consultants have carried out the following:

- Scanning the cadastral maps of the 25 km2 selected area.
- Orienting the scanned cadastral maps into the projection system using the coordinates provided by the DLS. Checking and matching the fit of each one cadastral map to its neighboring maps.

Overlay and match the IKONOS satellite images with the warped maps (cadastral maps) of the project area. The IKONOS image had a satisfactory overlay with the LRO maps. The shapes received from the AgrioRemote Sensing Ltd – based on the IKONOS image - had a satisfactory overlay as well. The shapes received from ARS had to be corrected as follows:

a. Delete duplicate shapes
b. Delete lines
c. Close polygons

We imported one class at a time so that we avoid mixing of data. Each class was imported into the MicroStation file, duplicate shapes and lines were deleted, and polygons were closed. Each class was placed on a different level (Layer)

- Vectorize all the map features (plots, roads, rivers etc.) and process the information to a GIS compatible system. Sheet, Plan and plot numbers were placed as text within each farm plot. Each feature and information was placed on a different layer, so that the GIS software could be able to isolate any layer and place any other information needed.
- Import and integrate the land use classification data and information prepared by the Agrio Remote Sensing Ltd.

Annex 1 presents the work and report prepared by the IntelliGraph Consultants.

6.3 Work carried out by Agrio Remote Sensing Ltd.

Agrio Remote Sensing Ltd. has carried out the following:

- Land use classification of the project area using the IKONOS 4m resolution satellite images
- Land use classification of the project area using the LANDSAT TM 30m resolution satellite images for comparison purposes.
- Carry out ground truth sample survey for most of the land use categories. All the major agricultural crop categories were spot checked, (except vegetables) for training and recognition purposes of the computer soft ware
- Verify the land use classification categories and analyze the results using ENVI remote sensing software and applying a supervised classification method for both cases (IKONOS 4m resolution and LANDSAT TM 30m resolution)

Annex 2 and Annex 3 present the work and reports of Agrio Remote Sensing Ltd for the IKONOS and LANDSAT images respectively.

6.4 Work carried out by the Division of Hydrology of the WDD

The Hydrology Section of the WDD has coordinated all the activities involving the application of the remote sensing techniques. The Study Team has carried out the following:

- Planning the various activities related to the pilot survey project
- Arrange the execution of the works within the time and budget limitations
- Select private Consultants and specialized Companies for executing part of the work
- Cooperate with INTELLIGRAPH Consultants and Agrio Remote Sensing Ltd. for ensuring that the taken steps and the work carried out is as per the project objectives
- Supervise the work of the two companies, through regular meetings
- Import the results obtained from the two Companies to GIS data
- Check the results obtained by the two Companies
- Correct several of the vectorized farm plots and other features of the maps and layers
- Process the field survey data to be analyzed by GIS. The data from the WDD had to be prepared in a computer format for being able to be compared.
- Compare the results of the land use categories, obtained by Agrio Remote Sensing Ltd, with the field survey data of the WDD and the Agriculture Department. Evaluation of the results and the overall applied methodology
- Identify problems and drawbacks of the methodology. Prepare suggestions and recommendations
- Preparation of the report

7 ANALYSIS OF THE RESULTS

7.1 Procedure

The results obtained from Agrio Remote Sensing Ltd. were compared with the field survey data of the WDD and the Department of Agriculture. Each crop category has been checked and compared in two steps.

Step 1. **Compare the plots of each crop category from the three sources**.

In order to carry out the comparison, the field survey data was put into digital format and visualized on the vectorized plots of the cadastral maps as prepared by IntelliGraph Consultants. Then the maps of various crop categories from the three sources were compared to see the differences and evaluated.

- The plots of the field survey having only part planted could not show the exact portion under the crop. Instead the whole plot was shown as planted. It may be said that this is a disadvantage of the method for checking.
- Compare the two sources of field survey (WDD and Department of Agriculture) with the interpretation results of Agrio Remote Sensing Ltd.
- Identify the differences and pinpoint omissions, additions, misinterpretations and related problems.
- Present the results graphically (maps showing the differences)

Annex 4 and Annex 6 present the maps created for the purpose of the analysis above.

Step 2. **Compare the total area of each crop category**.

- Comparison of the WDD field survey areas and the areas obtained from Agrio Remote Sensing Ltd.
- Comparison of the areas obtained from the Department of Agriculture (Crops-Growers databank) and the areas obtained from Agrio Remote Sensing Ltd.

These analyses were performed both on the total areas for the whole Pilot Project area and on a village boundary basis.

Annex 5 presents the tables created for the purpose of this analysis.

7.2 Interpretation results of satellite images, IKONOS 4m resolution

The final results obtained by the analysis performed by Agrio Remote Sensing Ltd. using IKONOS 4m resolution data were not as anticipated, based on the survey data that the WDD has available for the same classes. However, there are serious factors that that should be considered and are indicated in the 'Conclusions and Recommendations' section of the ARS report. These factors were critical for the success of such study, however due to time, and budget limits that the WDD had, it was no possible to avoid them.

Table 2: Percentage of crop area identified by RSA of the IKONOS 4m resolution image with respect to the actual crop area (from field survey data of the WDD and the Department of Agriculture)

Classification Category	Estimated percentage of crop area identified by RSA on IKONOS 4m image with actual crop area	Comments
Sea Water	100	-
Dam Water	100	-
Forest	100	-
Build up areas	97	-
Citrus	46-57	Main problem for citrus was the natural growing grass that had identical spectral response as citrus
Olives	32-40	Main problem for olives was the scatter pattern of olive trees that was mixed with natural growing grass and other vegetation
Deciduous	0	no deciduous trees had leaves at the time of image acquisition
Vines	0	no vines at the time of image acquisition
Fodders	0	
Vegetables	0	no vegetables at the time of image acquisition
Greenhouses	Identification seems good (however there are no available plots from field survey for comparison)	
Tobacco	0	no Tobacco at the time of image acquisition
Potatoes	0	no Potatoes at the time of image acquisition
Uncultivated land	0	**Uncultivated land was not indicated by the WDD to ARS for classification** **Refer to Unclassified class**
Cereals	0	**Cereals were not indicated by the WDD to ARS for classification for classification**

Note: Most of the above crop categories with 0% recognition were placed in the unclassified category.

7.3 Interpretation results of satellite images, LANDSAT TM 30m resolution

Although the LANDSAT TM 30m resolution was supposed to be used for the areas outside the irrigation projects, it was decided to use the same project area for comparison purposes.

The results obtained from Agrio Remote Sensing Ltd using the LANDSAT TM 30m resolution, are also poor. Although there were good interpretation results for built up areas, sea and dam water, the identification of the various crop categories were below level of acceptance.

Interpretation and classification was done for the following:

Table 3: Estimated percentage of crop area identified by RSA of the LANDSAT TM 30m resolution image with respect to the actual crop area (from field survey data of the WDD and the Department of Agriculture)

Classification Category	Estimated percentage of crop area identified by RSA on LANDSAT30 M image with actual crop area	Comments
Sea Water	Different figure from the IKONOS (smaller figure)	-
Dam Water	>> (smaller)	-
Forest	>> (much less area)	-
Build up areas	>> (much higher figure)	-
Citrus	57-70	
Olives	0	Scattered olives could not be detected in the image – thus it was impossible to get any sample
Deciduous	0	no deciduous tress had leaves at the time of image acquisition
Vines	3	
Fodders	0	A very small and uncertain parcel with fodder was indicated and was not
Vegetables	0	no vegetables at the time of image acquisition
Greenhouses	Identification seems good (however there are no available plots from field survey for comparison)	
Tobacco	0	no Tobacco at the time of image acquisition
Potatoes	0	no Potatoes at the time of image acquisition
Uncultivated land	0	**Uncultivated land was not indicated by the WDD to ARS for classification** **Refer to Unclassified class**
Cereals	0	**Cereals were not indicated by the WDD to ARS for classification for classification**

Note: Most of the above crop categories with 0% recognition were placed in the unclassified category.

8 PROBLEMS ENCOUNTERED

The problems encountered in the applied methodology are grouped in two categories:

- Problems related to the digitization and vectorization of the cadastral maps (base maps).
- Problems related to the land use classification from the satellite images.

8.1 Problems related to the vectorization of the cadastral maps

The most important problems observed on the digitization of the cadastral maps were as follows:

1. The scanned and vectorized farm plot boundaries of the cadastral maps were not very exact. There were gaps, self-intersections and other lines in between. The IntelliGraph Consultants would have corrected these shortcomings however due to time being short it was decided that the study team would carry out the corrections.
2. Text strings placed into the plot shapes that attach the sheet/plan information and the plot number to each plot were not always placed correctly within the plot or the text string was not containing the correct plot number. A lot of time was spent to correct these errors.

8.2 Problems related to the land use classification from the satellite images.

Among the problems observed in achieving accurate land use classification are the following:

1. Date of acquisition of the satellite images. Satellite images aquired during March had difficulties in classifying and indentifying the vegetables, deciduous, vines and intercropped trees, young trees full of weeds, fallow fields and cereals.
2. The IKONOS 4m resolution is NOT extremely high. One has to take into consideration the size of cultivated parcels that exist in the study area. In this case the cultivated parcels were small. In many cases crops that were requested for classification could only be found in a scatter pattern at the boundaries of two other crop classes. This was the main reason that the Landsat TM data resulted into less accurate results due to the resolution in relation again with the size of cultivated parcels in the specific study area.
3. The ground truth survey was not done properly and extensively enough.
4. The date of ground truth and field surveys should have been coincident with the date of satellite image (acquisition date).
5. Some crop categories should have been sub-divided for taking different reflectance of pixels for better identification through the computer programme.
6. After interpretation of the various land use categories, more field checks would have been needed for improving the results and the areas of each polygon.

9 EVALUATION OF THE METHODOLOGY

9.1 General evaluation

The results so far obtained, after applying the remote sensing technique are below level of acceptance. However the outcome could be further improved, if the appropriate steps and procedure is applied and more work is carried out.

The Study Team believes that a lot of the encountered problems can be overcome in the future and the accuracy of the results will be considerably raised. The limited budget allowance for the pilot project study and the short time involved, did not allow in changing the procedure and follow more accurate routes.

The problems related with vectorization of the plots and having a final clean digital base map of the plots, can easily be overcome. The interpretation of the satellite image in to the various crop categories will also be improved, provided that the acquisition date is properly selected and more ground truth checks and field surveys are carried out. The technique of land use classification will also give better results, if sub-categories are made and the pixels are properly selected through ground truth evaluation.

Due to budget and time limitations, it was impossible to introduce at this stage, some of the suggested improvements and hence the obtained results cannot be considered as the final product.

9.2 Cost evaluation

The cost involved at this stage for the 25km^2 pilot survey area is estimated to be as follows:

Table 4: Project Cost

	Total Cost (US $)	**Cost/km^2** (US $)
• IntelliGraph Consultants	3978	159/km^2
• Agrio Remote Sensing Ltd. IKONOS 4 M	6625	265/km^2
• Agrio Remote Sensing Ltd. LANDSAT 30 M	2917	117/km^2
• National Consultant (two weeks)	1500	60/km^2
• Assistant to Project Coordinator (two weeks)	750	30/km^2
TOTAL	**15770**	**631/km^2**

(Exchange rate 1.56 $ / Cyprus pound)

A request was made to the IntelliGraph Consultants and Agrio Remote Sensing Ltd. to provide the Study Team with details of the above cost on staff (professional, technical, skilled or unskilled etc.), equipment and other (cost of satellite images and field surveys).

The field survey cost carried out by the WDD and the Department of Agriculture is not included, since these surveys are done regardless of being used by the pilot study.

The IntelliGraph Consultants have given the following information of the cost for the 25km^2 area in Chrysochou area:

Table 5: Costs of IntelliGraph Consultants

	CYP	US $
Scanning and Digitizing 25km^2 of 1:5000 maps	2000	3120
Registration of raster classified images with digitized vectors	450	702
Production of hard copy maps of POI with classification analysis and digitized vector overlay	100	156
TOTAL	**2550**	**3978**

Table 6: Detail analysis of costs of Intelligraph Consultants

			CYP	US $
a. Scanning				
	Skilled personnel	6 hours@8.00	48	74.9
b. Map registration & Warping, ROI creation and warping				
	Skilled personnel	40 hours@8.00	320	499.2
c. Digitizing 25km2 of 1:5000 maps				
	Skilled personnel	260 hours@8.00	2080	3244.8
d. Production of hard copy maps of POI with classification analysis and digitized vector overlay			100	156.0
TOTAL			**2548**	**3974.9**

(exchange rate 1.56 $ / Cyprus pound)

The above rates were satisfactory for the work as described above. However, an unexpected amount of work was created after the classification vector data were received from the Remote Sensing Analysis. Each class was treaded separately to remove duplicate elements, lines and to make sure that the classes were forming closed polygons. Each class was then imported separately into the master file at a different level (layer) with the plots, roads and rivers. The class shapes were too many and very small in many cases (less than 50m^2). In many cases they were crossing the existing shapes of plots, rivers and roads, thus a very large amount of new shapes were introduced. These had to be numbered with Sheet no, Plot no and classification number, for each class separately and created a lot of additional work. The cost for such work should have been foreseen. An additional amount of CYP750 or 1170$ should have been added for this particular element of work, plus additional cost for quality control and corrections estimated at CYP250.00 or 390$.

With the same methodology/parameters a similar project will be therefore more expensive. The quoted amount by IntelliGraph Consultants work was CYP2450 or 3822$ ie CYP98/km^2 or 153$/km^2 instead of CYP3450 or 5382$ ie CYP138/km^2 or 215.3$/km^2. However, experience gained from this first project is expected to increase the productivity of the team and therefore lower quotations might be considered.

Cost Evaluation for Multi spectral Classification performed with IKONOS 4 meter resolution data submitted by Agrio Remote Sensing Ltd:

Table 7: Project Cost using Archive IKONOS data for 25 sq km

	CYP	US $
• IKONOS Data for 1m + 4m GEO archive SIE data (25 sq km)	997	1555
• 1day - Initial Survey	200**	312
• DATA pre-processing 4m Res. Data (Stretching /Filtering / Mosaicking)	200	312
• DATA pre-processing 1m Res. Data (Stretching /Filtering / Mosaicking)	200	312
• Classification / Post Classification Analysis (90CYP x 25 sq km)	2250	3510
• 2 sets of TRUE COLOR image maps of ROI (4 CYP x 25 sq km x 2 sets)	200	312
• 2 sets of TRUE COLOR image maps with selected classes overlays of classification analusis (4 CYP x 25 sq km x 2 sets)	200	312
TOTAL	**4247**	**6625**

(Exchange rate: 1 CYP = 1.56 US $)

Approximate working days required fro the completion of such work for 25 sq km for the classes requested

	Working DAYS
Assuming one day for initial filed survey **	1
Data Preprocessing	2
Classification/Post Classification performed	20
Report writing and preparation of results	10

TOTAL	**33 days**

NOTES:

** The Initial field survey should be extended. More time is necessary to identify correct samples for the classes to be classified. (a total of 2-3 days is recommended for an area of 25 sq km)

Initial filed survey can be performed by 1 skilled personnel on remote sensing and one unskilled personnel.

Classification/Post Classification Analysis and report writing was performed by 2 skilled personnel on remote sensing.

Table 8: Total project cost

	TOTAL COST		COST PER KM^2	
	CYP	US$	CYP/km^2	US $/km^2
Intelligraph Consultants	2550	3978	102	159
Agrio Remote Sensing Ltd	4247	6625	170	265
Total For IKONOS	**6797**	**10603**	**272**	**424**
Cost Of Landsat	1870	2917	75	117
Cost Of Local Consultants	1442	2250	57	90
Grand Total Project Cost	**10109**	**15770**	**404**	**631**

10 IMPROVEMENTS NEEDED FOR THE APPLIED METHODOLOGY

10.1 Acquisition Date

The acquisition date of the satellite images is very important in identifying the various crops. The IKONOS satellite images taken on 14th March had the following disadvantages for this project:

- Spring/summer vegetables may be very small (plants not well grown) or may have not been planted still so they do not exist in the images
- Many fields are still covered with fully grown winter weeds. In such cases there is interference with cereals, trees (mainly young plantations full of weeds), fodders (alfalfa and other fodders), vines, scattered olives and almond trees and deciduous fruits.
- Deciduous trees and vines have not yet shown the new growth and foliage and hence cannot be easily detected, mainly when the plots are full of weeds.

If the acquisition date had been towards the end of April, then the advantages would be as follows:

- The weeds would have been eliminated. Farmers by that date, cultivate or spray with herbicides the farm plots for destroying the weeds.
- Most of the spring/summer vegetables will show more clearly in the satellite images.
- Deciduous fruit trees (apples, pears, peaches, plums, walnuts and others) will have full foliage.
- Vines will show full vegetation.

Having a second satellite image, within the same year, then the best month would have been the end of August. Such second image will capture late summer and autumn vegetables, such as:

- Autumn potatoes
- Beans (dry beans) and cow peas
- Groundnuts
- Tobacco
- Late summer vegetables such as tomatoes and water melons

The LANDSAT TM 30m resolution, although it was taken on the 11th May, still the classification results were not very good due to the image resolution.

As indicated before the Landsat TM data do offer more bands that can give to the analyst the ability to add or remove some bands during the classification analysis and retrieve more accurate results. However, the resolution of Landsat TM data could not help in this study area due to the size of cultivated parcels in relation to the resolution.

It is important that the ground truth samples are taken at the same date (approx) with the date the satellite images are taken.

10.2 Resolution of the satellite images

There is no doubt that the higher is the resolution, the better are the classification results. However the cost component of the images is an important parameter to be considered.

Higher resolution satellite images, involves large number of images and hence, higher cost. The 4m resolution is considered the ideal resolution for such project. LANDSAT images 30m resolution to be used for areas outside the Major Government Irrigation Schemes, will not give accurate results. Within the Major Government Irrigation Schemes, land consolidation was applied and the farm plots are significantly bigger, compared to the irrigated farm plots found outside those projects. Irrigation outside the Major Government Irrigation Schemes makes up the 40% of the total all over Cyprus and is practiced in scattered fragmented farm plots. The use of the LANDSAT 30m resolution for the outside areas, as suggested for reducing the cost of the images, will not give good results. The matter has to be studied and evaluated further as regard those areas.

10.3 Ground truth surveys and field checks

Adequate ground truth surveys are needed for getting the necessary information relating the pixel reflectance with the actual crop category. The Study Team feels that the ground truth surveys carried out for the pilot study were inadequate. A second field survey checking was needed after the interpretation and classification of the various land use categories. Such checking will verify the obtained results, feedback additional information for improving the pixel categorization and assist in the accurate calculation of the areas of each category.

It is recommended that the ground truth and field check be carried out as close as possible to the acquisition date of the satellite images.

10.4 Land use sub-categories

In order to receive more accurate results for some crop categories, it is necessary to have **sub-categories** as per the ground truth results and field checks. As an example will be the citrus that may be of different age, intercropped or not, cultivated the soil in between the trees or not etc. Obviously the pixel reflectance will be different in each of the above cases and although all of them are citrus the results will be misleading if only one category is taken with a pixel reflectance or even a threshold is specified. Having a high value of threshold of the pixel reflectance will exclude some plots of the above situation. Similarly having a low value threshold, will include other crop categories, not related to the specific crop. However having sub-categories with the appropriate ground truth and field checking will give more accurate results.

10.5 Vectorizing the farm plots

The vectorization of the maps with all features (farm plots, rivers, roads, dams, etc.), should be properly vectorized and get rid of any gaps, self-intersections, unwanted lines, and information that interfere with the actual situation. Processing of all the information through the GIS should be done with high degree of accuracy for avoiding discrepancies when integrating the maps with the land use categories obtained from the satellite images.

The IntelliGraph Consultants are suggesting the following for improving the Methodology:

1. IKONOS imagery with better horizontal accuracies **CARTERRA™ Precision (**of ± 4m horizontal accuracy) or **CARTERRA™ Precision Plus (**of ± 2m horizontal accuracy) is expected to fit better with the LRO Plans. This has to be examined in relation to cost, minimum area acquisition, time required to acquire the imagery and availability of GCPs (Ground Control Points)

2. On screen digitizing of the IKONOS imagery will produce better results with regard to the present situation of the land use. However, the task of linking/ relating these shapes with the plots, as determined from the LRO plans needs to be evaluated carefully.
3. Discrepancies in relation to the LRO plans need to be resolved in advance of the digitizing process in order to avoid problems like wrong numbering of Sheets/Plans and duplicate plot numbers.

10.6 Object Oriented Classification

A new method, the Object Oriented Classification method, was developed to improve classification analysis using high-resolution data as IKONOS. A detailed description of this new method is given in Section 6 of Annex 2.

11 POSSIBILITY OF USING THE METHOD FOR ASSESSING THE AGRICULTURAL WATER USE

An ultimate use of the method is the assessment of the water use on a yearly basis. In order to be able to reach that stage, it is necessary to have:

- Accurate results on the various crop categories (mainly areas)
- Evapotranspiration data for the various crops-group categories
- Field data on irrigation efficiencies

The present results obtained from the pilot study, on the crop categories, are very poor. A basic parameter in having accurate figures on water use is the ability of having reliable data of land use. It is essential that the method be well improved, before using it for assessing the water use.

During the present study, some actual data on water use were recorded, however such data were inadequate and misleading for three basic reasons:

- The amount of water used, for specific plot was not always measured
- Part of the applied water was from boreholes, not being recorded
- Due to water shortage in the last 3-4 years, the applied volume of water was less than the actual needs. The shortage reached the 45 % in the major government irrigation projects for the year 2000.

Having crop water requirement data from the evapotranspiration study (CROPWAT) and accurate areas on the various crop categories, it may be possible to apply the remote sensing technique for assessing the annual water use.

12 POSSIBILITY OF EXPANDING THE METHOD ALL OVER CYPRUS

At this stage is too early in deciding on the possibility of expanding the method all over Cyprus. Definitely once the method is improved the potential is great. However its expansion will depend on:

- How accurate results of crop category and areas are obtained by the method
- Cost component

It may be possible to apply the method gradually. An area or project could be selected and apply the method in more extensive way at the first stage. During this stage, many problems will be overcome and the method will be improved and further evaluated.

The present cost of the IKONOS 4m resolution (excluding the LANDSAT 30m) is estimated to be 329CYP/km2 or 514US$/km2

Any additional cost due to the new IKONOS data acquisition is expected to be anticipated by the cost reduction due to the experience gained by the companies and other staff.

The NEW IKONOS DATA ACQUISITION pricing is expected to be as follows:

In the event that new data will be used we should take into consideration that the minimum order area for IKONOS data is 100 sq km and the cost is approximately as follows:

GEO products with + - 50 meter error	
GEO 1 meter (color)	$27.50 per sq km
GEO 1 Meter (color) Ortho Kit	$42.00 per sq km
GEO 4 meter (color)	$18.00 per sq km
GEO 4 Meter (color) Ortho Kit	$29.00 per sq km
Reference products with + - 25 metes error	
REFERENCE 1 meter (color)	$68.20 per sq km
REFERENCE 4 meter (Multispectral)	$62.00 per sq km
RRO products with + - 10 metes error	
PRO 1 meter (color)	$107.80 per sq km
PRO 4 meter (Multispectral)	$ 98.00 per sq km
Precision products with + - 4 metes error	
Precision 1 meter (color)	$149.60 per sq km
Precision 4 meter (Multispectral)	$136.00 per sq km
Precision 1m+ 4m Bundle (purchased together)	$204.00 per sq km
Digital TERRAIN / ELEVATION MODEL	
An indication for the cost of a new Elevation Model is	$100.00 per sq km

NOTES:

- Minimum order is 100 sq km
- Prices may change without any notice
- Delivery time for new acquisition is approximately 90 days

- Note that all products except GEO require on ground orthorectification processing that needs additional time other than the 90 days mentioned above based on the size of the AOI
- All products except GEO require that the customer provides the necessary GCPs and/or the Elevation Model as to perform the necessary orthorectification
- More information can be provided on request

Finally, Agrio Remote Sensing Ltd. (the only official distributor of QuickBird data in Cyprus) can also provide on request pricing and specifications for QuickBird data, offering the highest resolution data in the market today.

13 SUGGESTIONS AND RECOMMENDATIONS

The Study Team after studying the results of the remote sensing technique within the pilot survey area, has reached to the following suggestions:

- The method has great potentials for the land and water use assessment.
- It is necessary to improve further the methodology on the steps and procedure as described previously. Many weak points have been identified that can be improved and raise the accuracy of results.
- The budget and time limitations were an obstacle for carrying out further work for improving the applied methodology.
- The results obtained are below level of acceptance, however various factors have to be blamed among those the date of satellite acquisition and the drawbacks of the interpretation technique (inadequate ground truth surveys etc).
- It is suggested to apply the method in another area or project, allocating adequate time and funds. The Kokkinochoria area is recommended to be studied. A phase II can be set up for that purpose. Money spent for such study is not a loss but an investment for training the people and applying the advanced technology. The work is suggested to be carried out in co-ordination with the Department of Agriculture.
- Date of Acquisition: The date of acquisition is the most important factor in the classification. The image of the acquisition should reflect those crops that we are interested in classifying.
- An initial field survey taken in a period as close as possible to the image acquisition date will result to a better understanding of both the study area and the crops to be mapped.
- Growing Period of Crops: The acquisition date of the image should be defined based on the growing period of the crops of interest. A pre study concerning the ideal growing period of the crops of interest is necessary for identifying those crops in the imagery.
- Multiple Acquisitions: In the case of a complex classification (High number of classes, very specific classes) multiple acquisitions might be necessary as to group several crops together that can be then classified with a specific acquisition date.
- Separability: At the acquisition date the crops of interest should have the maximum separability in terms of spectral reflectance. Moreover, the selection of image bands during the actual processing should also aim to preserve the highest possible spectral separability between classes.
- ROI's Training: May be the most critical factor for the reliability of the classification. The number of ROI's selected and the ROI's themselves should reflect the physical reality of the study area. Moreover, the ROI's of each class should represent the overall distribution of the class in the image.
- Data/Resolution: IKONOS 4-meter resolution multispectral data is ideal for a parcel based applications. Each pixel represents 4 square meters, a very convenient size for applications demanding such detail.
- Clear and detail project specifications should be set up.

14 Land use identification techniques suggested by the European Union: Trial application of the Computer-Aided-Parcel-Identification (CAPI) method within part of the Chrysochou Pilot Project area

14.1 Introduction

During the Pilot Project Mr Kyriakos Alexandrou of the Agricultural Department of the Ministry of Agriculture, Natural Resources and Environment suggested applying the **C**omputer-**A**ided-**P**arcel-**I**dentification (CAPI) method to a part of the Pilot Project area. Because most necessary inputs to this method, such as an appropriate satellite image (IKONOS 1m resolution) and a Remote Sensing Analysis of the area (based on an IKONOS 4m resolution image) as well as control areas of land use (Data provided by the Agricultural Department and the Water Development Department-Polis Chrysochou Regional Office) were readily available being parts of the Pilot Project, the effort necessary to perform a CAPI analysis on part of the Pilot Project area was within acceptable limits as regards time and human resources.

It should however be borne in mind that this application of CAPI is not an in-depth study but a quick test to gain knowledge about the method and to assess its applicability and potential. It should therefore not be considered as an integral part of the Pilot Project.

14.2 The CAPI method

The CAPI method, as carried out during this trial application, comprises of the following stages:

1. Parcels of homogeneous land use are digitized/vectorized on-screen from a high resolution satellite image (or aerial photography)
2. Land use classification is carried out by Remote Sensing Analysis (RSA) resulting in polygons of same land use
3. The vectorized land use parcels are overlaid by the RSA results within a GIS
4. Land use parcels that coincide with land use polygons from the RSA are assigned the land use of the RSA-polygon
5. The area for each land use category may be calculated as the sum of the areas of all land use parcels that were assigned the particular category

It becomes clear from the above that CAPI can be used to improve the accuracy of results of a RSA. This is accomplished by using the RSA for the recognition of the land use categories only and by calculating the land use areas from parcels vectorized on-screen that have been assigned the land use categories identified by the RSA.

14.3 Application of the CAPI method to part of the Pilot Project area

From the stages of the CAPI method described in 14.2 above, the IntelliGraph Consultants agreed to carry out the on-screen vectorization of land use parcels for part of the study area. The vectorized land use parcels, which were delivered in a Microstation file format, were imported into MapInfo GIS by the study team. IntelliGraph had vectorized parcels in two parts of the study area, which in the following are referred to as CAPI trial areas: one cluster of parcels in the north-west corner of Polis village (referred to as North-Western CAPI trial area) and one cluster of parcels mainly in the Chrysochou village also covering part of the Polis village (referred to as Southern CAPI trial area). The study team vectorized few additional land use parcels to fill obvious gaps and to obtain a more continuous coverage of the two areas. The vectorized land use parcels and their location within the

Pilot Project area are presented in Figure 2. Table 9 gives the number of parcels in each trial area and the areas covered by the land use parcels.

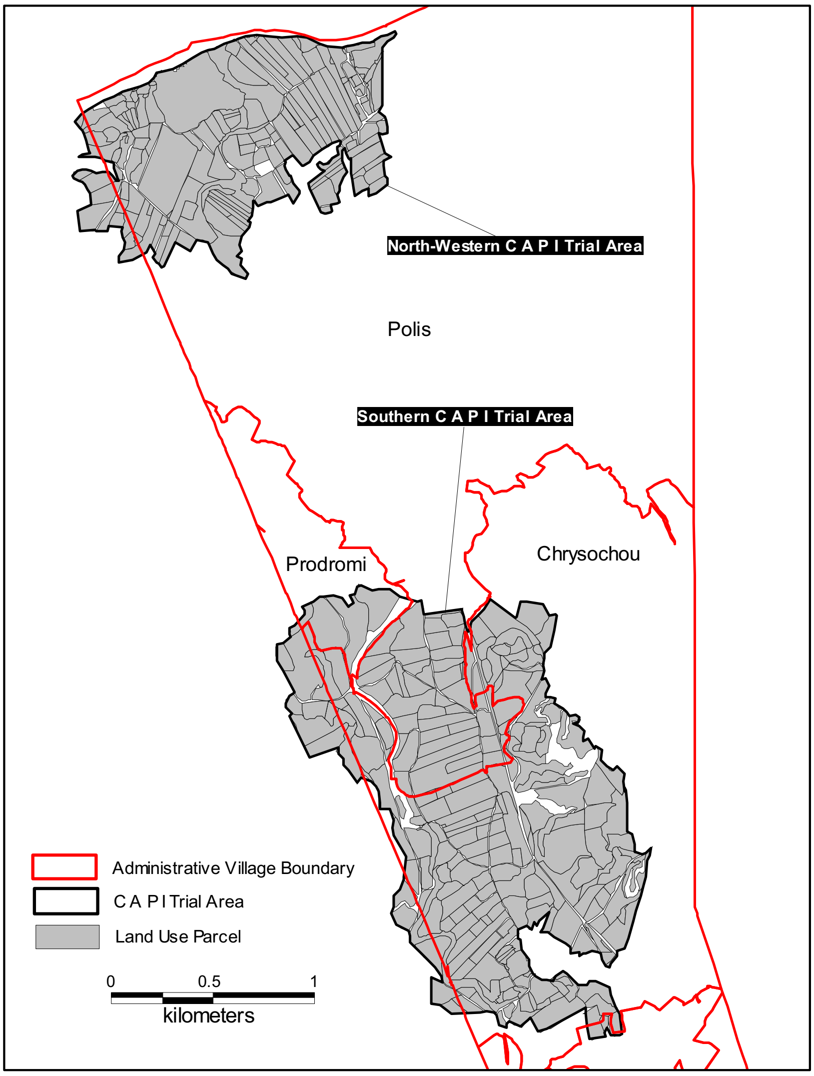

Figure 2: Location of vectorized Land Use Parcels within Project Area

Table 9: Number of and areas covered by vectorized land use parcels

CAPI trial area	Number of land use parcels	Area covered by land use parcels (Decares)
North-Western Area	166	1151
Southern Area	242	2193

It was decided to consider four land use categories (Citrus, Olives, Forest, Grass) within this study, as only these categories cover areas big enough for sound analysis within the two trial areas.

The remote sensing analysis of the IKONOS 4m resolution satellite image resulted in the land use areas given in Table 10.

Table 10: Areas classified by RSA of IKONOS 4m image within the two Trial Areas

Land Use Category	Area (Decares)	
	North-Western Area	Southern Area
Citrus	75.5	151.8
Olives	8.9	19.0
Forest	96.0	-
Grass	269.1	336.3
TOTAL	**449.5**	**507.1**

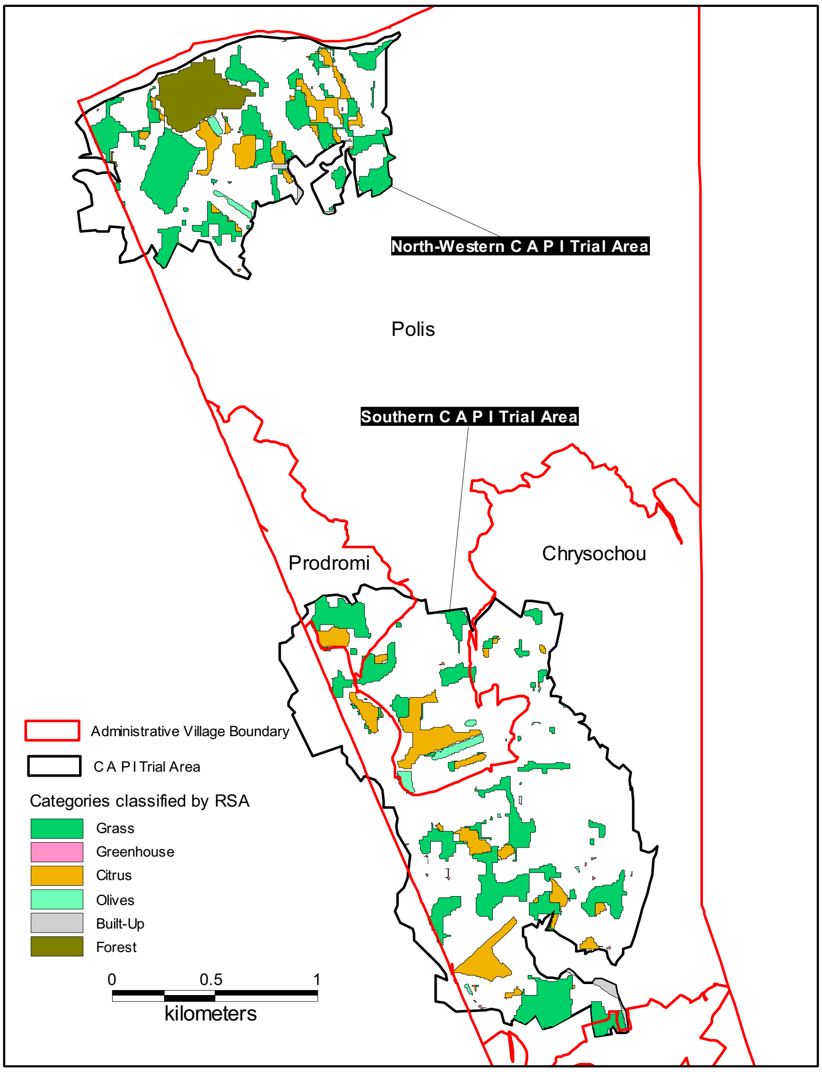

Figure 3: Classified Areas from RSA (IKONOS 4m resolution) within CAPI Trial Areas

Within MapInfo GIS, the vectorized land use parcels were overlaid with the polygons that resulted from the RSA of the IKONOS 4m resolution image and the crop categories of the RSA polygons were assigned to the land use parcels in the following way: Each land use parcel, the centroid of which was located within a polygon from the RSA, was assigned the crop category of the particular RSA polygon. The land use parcels with their assigned land use categories are presented in Figure 4. Table 11 gives the corresponding land use areas.

It has to be mentioned that the centroid of a polygon, as the term is used in this analysis, is not necessarily the center of gravity of the polygon, it is the "central point" of the polygon as used within the MapInfo software.

The technique of assigning the land use category to the land use parcels by the condition that its centroid falls within a polygon classified by RSA is a weak point of the procedure. In some instances throughout the analysis it was noticed that, for a particular land use parcel, a considerable part of the parcel was covered by a land use polygon from the RSA but the parcel's centroid happened to be outside the RSA polygon and thus the land use parcel was not assigned the category. Naturally there might as well be cases where accidentally the centroid of the land use parcel lies within a RSA polygon that covers only insignificant part of the land use parcel but, according to the procedure followed, the whole parcel is assigned the land use category. A better approach would be to assign land use categories according to the amount of overlap of the polygons from the RSA with the land use parcels, where a threshold value would have to be introduced.

Table 11: Areas of land use per crop category after application of CAPI method. Areas calculated from land use parcels with assigned land use category.

	Area (Decares)	
Land Use Category	**North-West Area**	**Southern Area**
Citrus	99.5	181.7
Olives	9.7	35.2
Forest	105.1	0.0
Grass	295.3	449.5
TOTAL	**509.6**	**666.4**

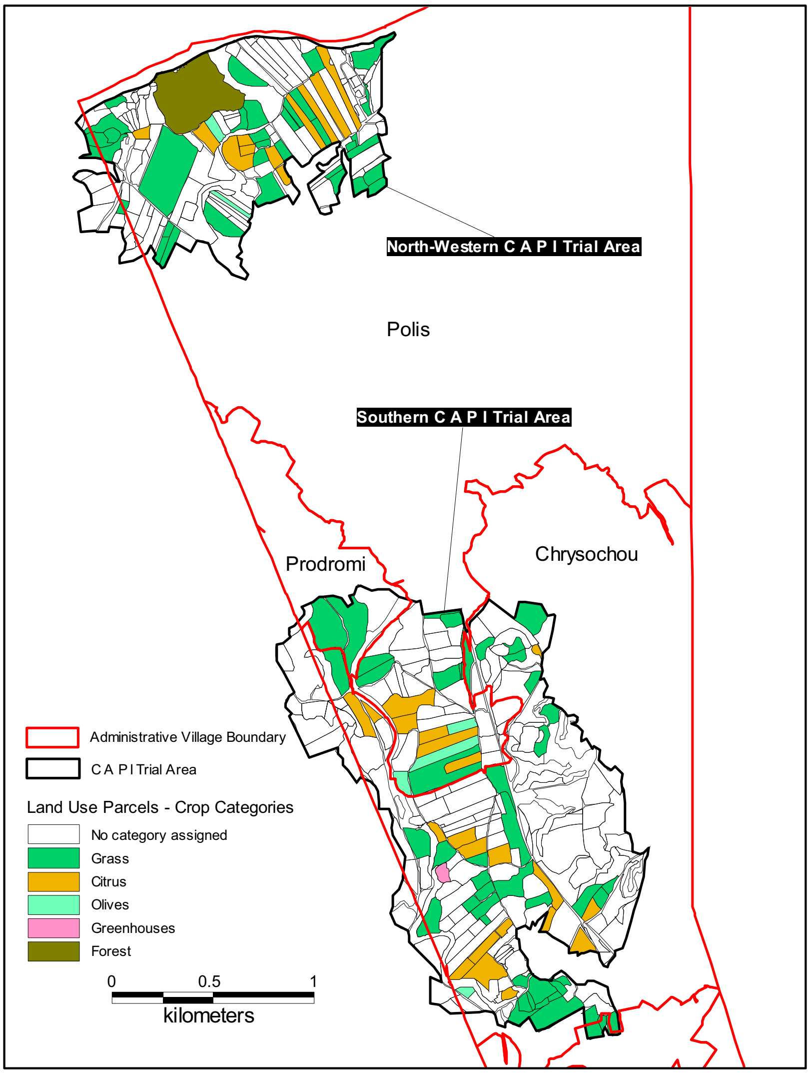

Figure 4: Land Use Parcels with crop categories after assigning crop categories from RSA

The resulting land use areas as given in Table 11 were then compared to the control areas i.e. the cropped areas provided by the Agricultural Department and the Water Development Department-Polis Chrysochou Regional Office. The relevant data as provided by the Agricultural Department appear in Table 12 and Figure 5 whereas data provided by the WDD appear in Table 13 and Figure 6.

Table 12: Planted Crop Areas from data from Agricultural Department

	Planted Area (Decares)	
Crop Category	**North-West Area**	**Southern Area**
Citrus	30.4	202.2
Olives (Irrigated and Non-Irrigated)	27.2	14.2

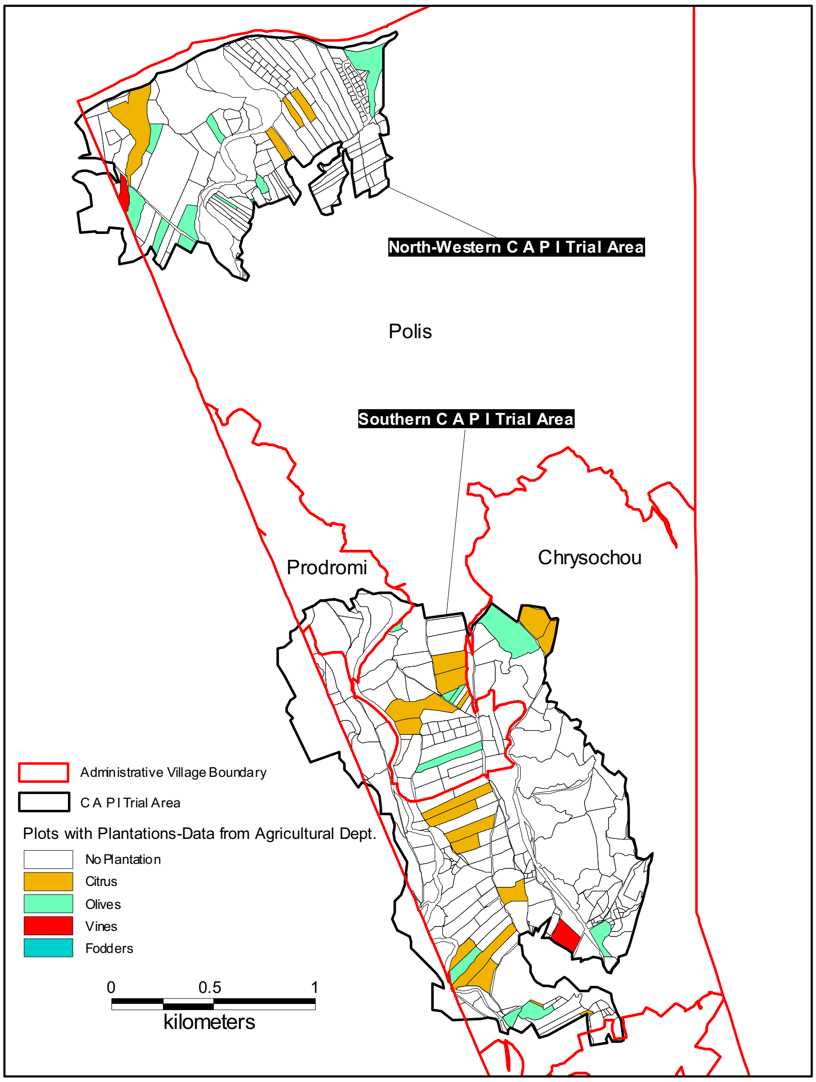

Figure 5: Plots with Plantations – Data from Agricultural Department.
Note: Although entire plots are colored, this only indicates that a plantation exists on the plot; the actual plantation within the plot might, and will in most cases, cover only part of the plot.

Table 13: Planted Crop Areas from data from Water Development Department-Polis Chrysochou

	Area (Decares)	
Crop Category	**North-West Area**	**Southern Area**
Citrus	38.4	251.0
Olives	22.5	30.5

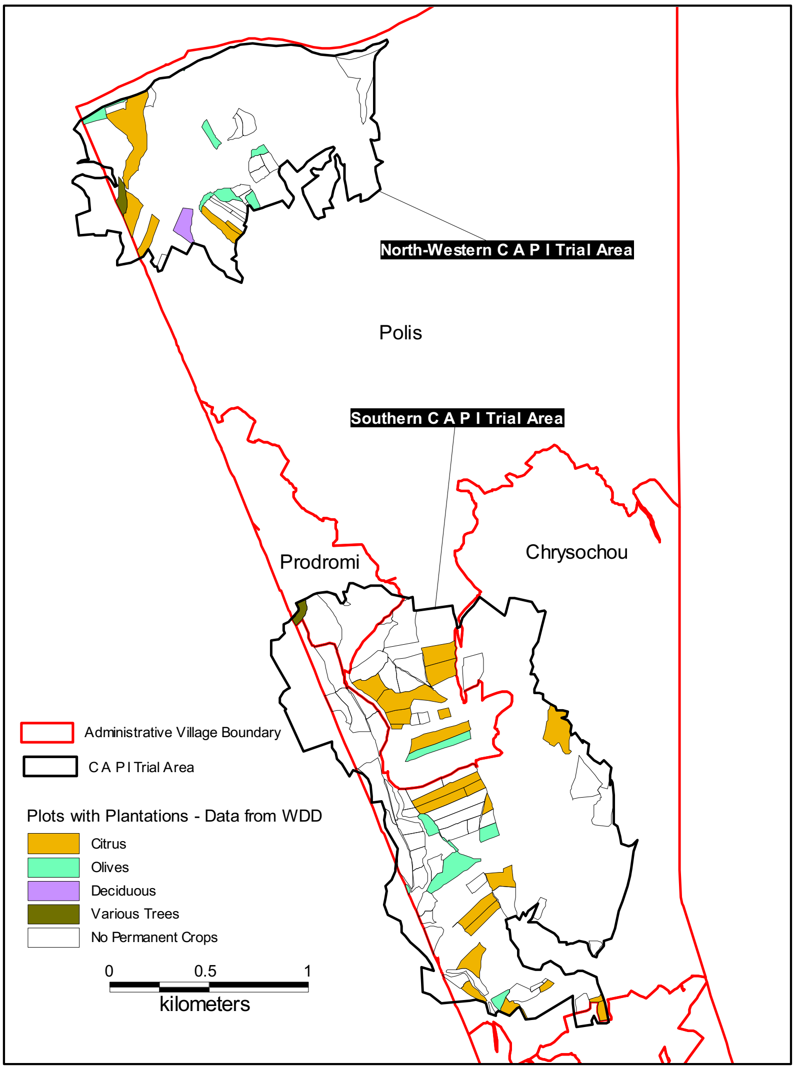

Figure 6: Plots with Plantations – Data from Water Development Department-Polis Chrysochou. Note: Although entire plots are colored, this only indicates that a plantation exists on the plot; the actual plantation within the plot might, and will in most cases, cover only part of the plot.

14.4 Results

The land use areas from the RSA, the areas obtained through the application of the CAPI method as well as the cropped areas for the CAPI trial areas from the Agricultural Department and the Water Development Department are presented in a compact form in Table 14 and Table 15.

Table 14: Planted Crop Areas from the various Sources for the North-Western CAPI Trial Area

	Areas (Decares)			
Crop Category	**RSA (IKONOS)**	**CAPI - Land Use Parcels**	**Data from Agricultural Dept.**	**Data from WDD**
Citrus	75.5	99.5	30.4	38.4
Olives	8.9	9.7	27.2	22.5
Forest	96.0	105.1	-	-
Grass	269.1	295.3	-	-

Table 15: Planted Crop Areas from the various Sources for the Southern CAPI Trial Area

	Areas (Decares)			
Crop Category	**RSA (IKONOS)**	**CAPI - Land Use Parcels**	**Data from Agricultural Dept.**	**Data from WDD**
Citrus	151.8	181.7	202.2	251
Olives	19.0	35.2	14.2	30.5
Forest	-	-	-	-
Grass	336.3	449.5	-	-

From the results in Table 14 and Table 15 it becomes clear that the application of the CAPI method lead to the identification of land use areas 9% to 34% larger than the areas identified by RSA, in both trial areas in all categories considered (Table 16). In the case of olive plantations in the Southern trial area CAPI identified areas 85% larger than the RSA. This figure is doubtful and the reason behind it should be further investigated.

Table 16: Percentage of CAPI identified land use areas, assuming the RSA identified land use areas to be 100%

Crop Category	**North-Western Area**	**Southern Area**
Citrus	132%	120%
Olives	109%	(185%)
Forest	109%	-
Grass	110%	134%

Any comparison of the areas obtained through CAPI and the areas provided by the Agricultural Department and the WDD is to a great extent pointless, as the areas provided by the two departments generally do not agree well enough for proper comparison.

For the instances where a comparison seems possible the results are as follows:

- In the north-western trial area 9.7 decares of olive plantations were identified, which constitutes 36% (compared to 27 decares) and 43% (compared to 23 decares) of the areas provided by the Agricultural Department and the WDD respectively. This result is considered to be poor, as less than half of the plantation areas were recognized.

- In the southern trial area the identified citrus areas (182 decares) reach between 90% (compared to 202 decares) and 73% (compared to 251 decares) of the control areas. This is considered to be a reasonable result.

14.5 Conclusions and Recommendations

The CAPI method as applied to part of the Pilot Project area identified significantly larger land use areas than the Remote Sensing Analysis did.

It was clearly demonstrated that the CAPI method can greatly improve the results of a RSA by accounting for areas of a uniform plantation which have not been identified by the RSA due to deviations from the typical color, pattern etc. of the particular crop category on the satellite image. Cases of such areas are usually found at the borders of plantations.

The applied technique of assigning the land use category to the land use parcels by the condition that its centroid falls within a polygon classified by RSA was identified as a weak point of the procedure. Further work is necessary to develop the best possible technique for this part of the CAPI method, based on the software available.

To some extent the test application of CAPI suffered from the same shortcomings as did the whole Pilot Project, such as the IKONOS satellite image that was not taken during the appropriate period etc. As the categories assigned to the land use parcels come from the land use polygons resulting from the RSA it is clear that any shortcomings of the RSA will be passed on directly to the land use parcels.

Although the results did not allow for proper comparison with the control areas provided by the Agricultural Department and the WDD and although in the instances where some comparison was possible the areas obtained through CAPI did not generally agree well with the areas from the two departments, but having in mind the shortcomings of the RSA which greatly influence the CAPI results, the study team thinks that the method has great potential and it should be applied to another test area to further investigate its capabilities. When choosing the area for any future test application of CAPI it has to be ensured that the actual land use areas are exactly known so to have a solid basis for comparison of the results. Furthermore the general recommendations made in this report on the application of remote sensing techniques have to be considered, in particular the appropriate period for taking the satellite image and as regards the ground truth surveys necessary for the RSA.

As Cyprus aspires to join the European Union, any future work on land use identification using remote sensing techniques (satellite images) should follow the procedures and specifications described by the EU. A summary of these procedures and specifications has been prepared by Mr. Kyriakos Alexandrou, Integrated Administration and Control System Section, Dept. of Agriculture, Lefkosia, Cyprus and is presented in Annex 7.

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ANNEX 1

Multispectral Classification – Pilot Study
Chrysochou River Basin, Pafos – Cyprus
Report on Preparation of Data for GIS Analysis
IntelliGraph Consultants

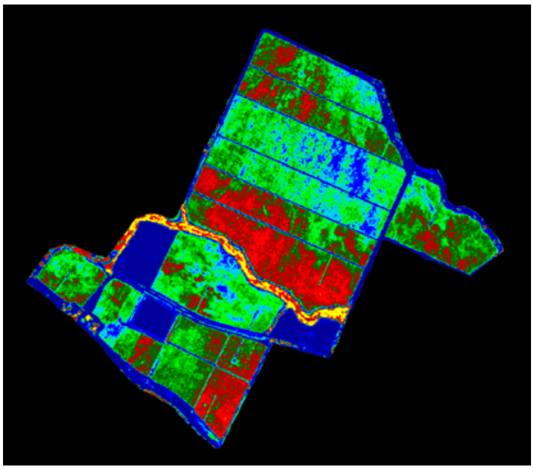
Multispectral Classification

Pilot Study

Chrysochou river basin area, Pafos - Cyprus

REPORT

PREPARATION OF DATA FOR GIS ANALYSIS



Prepared for:

The Department of Water Development,

Ministry of Agriculture, Natural Resource and the Environment

Nicosia, Cyprus

November 1, 2001

Prepared By:

IntelliGraph Consultants

THE ENGINEERING SOFTWARE PROFESSIONALS

PREPARATION OF DATA FOR GIS ANALYSIS

Overview:

We had undertaken the task to integrate the classification data, as prepared by Agrio Remote Sending Ltd. (ARS), together with the cadastral maps of the Region of Interest (ROI). We prepared the result, as an integrated map with information on different layers that can be processed using a GIS software (MapInfo)

Data:

We were provided with the following data:

1. Hard copy cadastral maps of the ROI of Scale 1:5000, Dated 1924. The Department of Lands and Surveys (DLS) provided the plan grid coordinates (four-corners) of each map in UTM (WGS84). Table 2 shows the Sheet numbers and the plan grid coordinates for each map.

2. IKONOS GEO 1 Meter resolution PSM in GeoTIFF format, and IKONOS GEO 4 Meter resolution Multi-spectral in GeoTIFF format.

3. Vector data (DXF files) of the classification analysis in 8 (eight) separate files by ARS. The files are shown below in Table 1. A number was assigned for each classification randomly.

CLASSIFICATION	
CITRUS	1
FOREST	2
OLIVES	3
BUILTUP	4
DAM	5
GREENH	6
SEA	7
GRASS	-

Table 1: Classes extracted from the classification analysis

Resources used:

The following resources were used for the project:

1. Scanner: Large format scanner for scanning in 300 dpi resolution Black/White.
2. Software:

a. MicroStation J and MicroStation V8 for data capture, and
b. MicroStation Descartes for registration/manipulation of the scanned maps.

PLAN	LBC_XC	LBC_YC	RBC_XC	RBC_YC	RTC_XC	RTC_YC	LTC_XC	LTC_YC
XXVI/50	444534,00	3876914,88	446946,92	3876922,48	446941,93	3878530,91	444529,00	3878523,31
XXVI/51	446946,92	3876922,48	449359,84	3876930,08	449354,85	3878538,50	446941,93	3878530,91
XXVI/58	444539,09	3875306,36	446952,02	3875313,96	446946,92	3876922,48	444534,00	3876914,88
XXVI/59	446952,02	3875313,96	449364,94	3875321,56	449359,84	3876930,08	446946,92	3876922,48
XXXV/3	446957,11	3873705,44	449370,03	3873713,04	449364,94	3875321,56	446952,02	3875313,96
XXXV/11	446962,10	3872096,92	449375,03	3872104,52	449370,03	3873713,04	446957,11	3873705,44
XXXV/12	449375,03	3872104,52	451787,95	3872112,01	451782,95	3873720,64	449370,03	3873713,04
XXXV/19	446967,20	3870488,29	449380,12	3870495,89	449375,03	3872104,52	446962,10	3872096,92
XXXV/20	449380,12	3870495,89	451793,04	3870503,49	451787,95	3872112,01	449375,03	3872104,52
XXXV/21	451793,04	3870503,49	454205,96	3870511,09	454200,87	3872119,61	451787,95	3872112,01
XXXV/28	449385,12	3868887,37	451798,04	3868894,97	451793,04	3870503,49	449380,12	3870495,89
XXXV/29	451798,04	3868894,97	454210,96	3868902,57	454205,96	3870511,09	451793,04	3870503,49
XXXV/30	454210,96	3868902,57	456623,88	3868910,17	456618,88	3870518,69	454205,96	3870511,09
XXXV/36	449390,21	3867278,85	451803,13	3867286,45	451798,04	3868894,97	449385,12	3868887,37
XXXV/37	451803,13	3867286,45	454216,05	3867294,05	454210,96	3868902,57	451798,04	3868894,97
XXXV/38	454216,05	3867294,05	456628,97	3867301,55	456623,88	3868910,17	454210,96	3868902,57

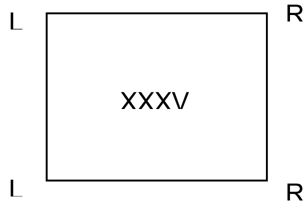


Table 2: Plan Grid Coordinates in UTM/WGS84

Methodology:

The hard copy maps covering the ROI were scanned at a 300dpi resolution. Each map image was imported in MicroStation Descartes. Each map image was registered independently to the corresponding plan grid coordinates as provided by DLS. Matching the four corner points with the corresponding destination points we performed warping of each image using the Projective method. The map images were checked for edge matching with adjacent maps and for possible deviations from the coordinates provided by DLS. The results were satisfactory and a very good fit of the ROI was achieved. Figure 1 shows the overall fit of the map images covering the ROI and Figures 2, 3 and 4 show some of the overlapping regions between adjacent Sheets.

We then imported the IKONOS GEO 1 Meter resolution PSM in GeoTIFF format and the IKONOS GEO 4 Meter resolution Multispectral to overlay the warped map images. We were expecting inaccuracies in matching the two sets of data (ie the data of the warped images and the IKONOS images) because of the fact that IKONOS as a GEO product, as per Space Imaging (SI) specification, the horizontal accuracy is ± 50 meters.

The overlay of the IKONOS GEO 1 Meter resolution PSM image over the warped map images showed that the two sets of data did not have a good matching and that we had inconsistencies in the deviations between the two sets of data. While the three known corner points in both sets of data were suggesting a uniform deviation, the identification of same points in both sets of data, were suggesting a different uniform variation. These inconsistencies are explained as follows:

I. Corner point 3 of Sheet XXVI/51 and corner point 4 of Sheet XXV/52 (same points) were deviating by approximately -27m on Easting and
II. -180m on Northing from the corresponding IKONOS point
III. Similar deviations were observed for corner point 2 of sheet XXXV/3 and corner point 3 of sheet XXXV/11 with the corresponding IKONOS point
IV. Similar deviations were observed for corner point 2 of sheet XXXV/19 and corner point 3 of sheet XXXV/27 with the corresponding IKONOS point
V. Twenty-two identical points located on both the warped map images and the IKONOS image, were deviating by a range of 10-70m on easting and 5-20m on northing respectively.

The above exercise is shown on Figure 1. Points 1,2,3 on Figure 1, as points I, II, III above. The yellow color points are the points located on the IKONOS GEO 1m image and the brown color points are the corresponding points located on the map images.

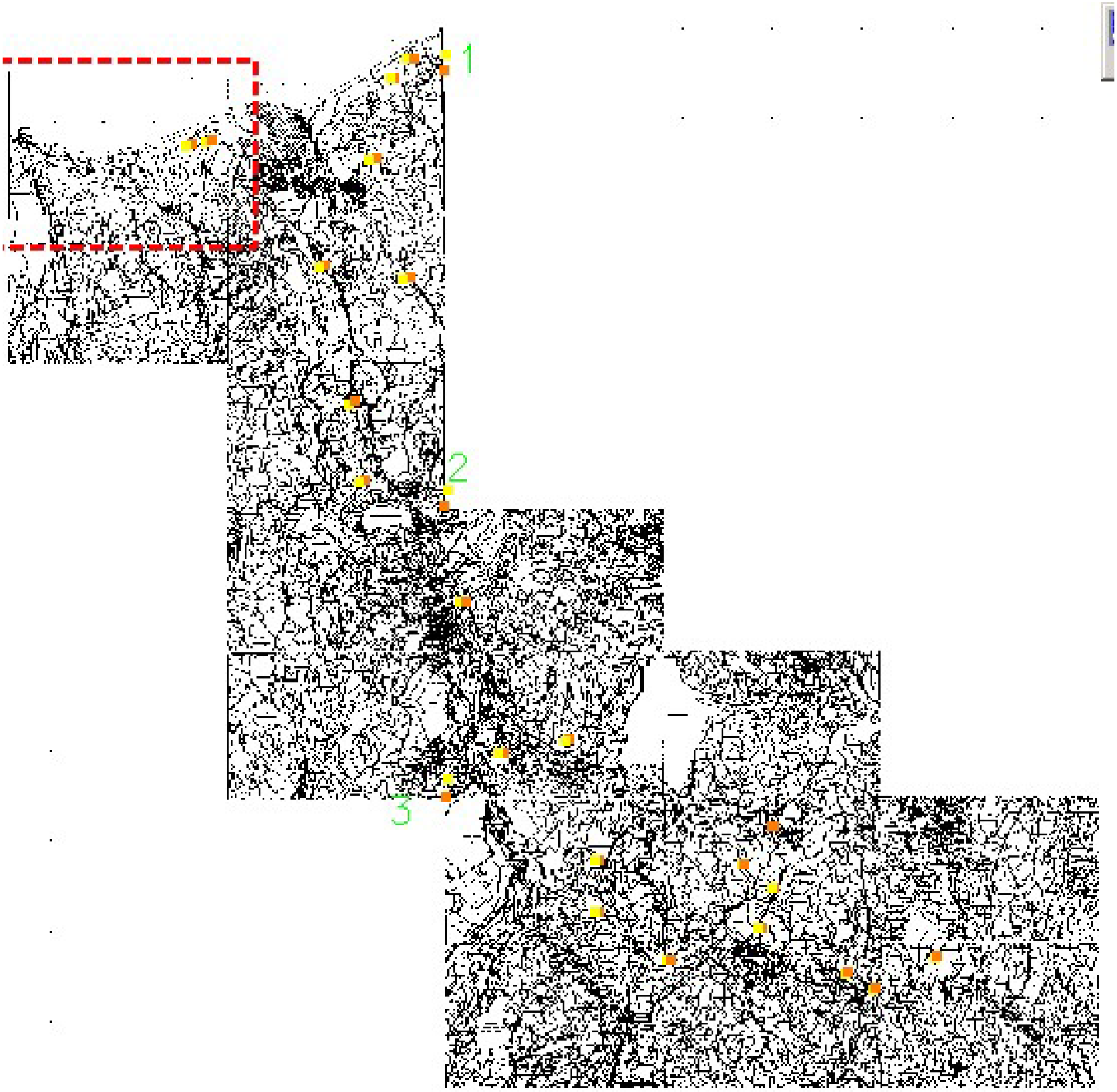


Figure 1: Map images warped forming the ROI. Yellow dots are points identified on IKONOS(1M) and brown dots are the corresponding points on the warped map images

Our original thoughts were to warp the IKONOS image to the correctly registered and warped map images, so that the IKONOS image overlays to the best possible match the warped map images that were geometrically correct. However, after discussions with ARS we decided that no warping of the IKONOS image should be performed, as this warping would produce deformations of the pixels and therefore would jeopardize the quality of the results of the remote sensing classification analysis. Our decision was therefore to register the warped images to the IKONOS 1M image for the best possible match. We first joined the map images together, i.e. we performed mosaicking, so that the sixteen map images could be uniformly warped. Then we identified/located common points (Twenty two pairs of points as per Figure 1) on both images (The warped maps as one file and the IKONOS 1M image) and we warped the mosaic for the best possible overlay.

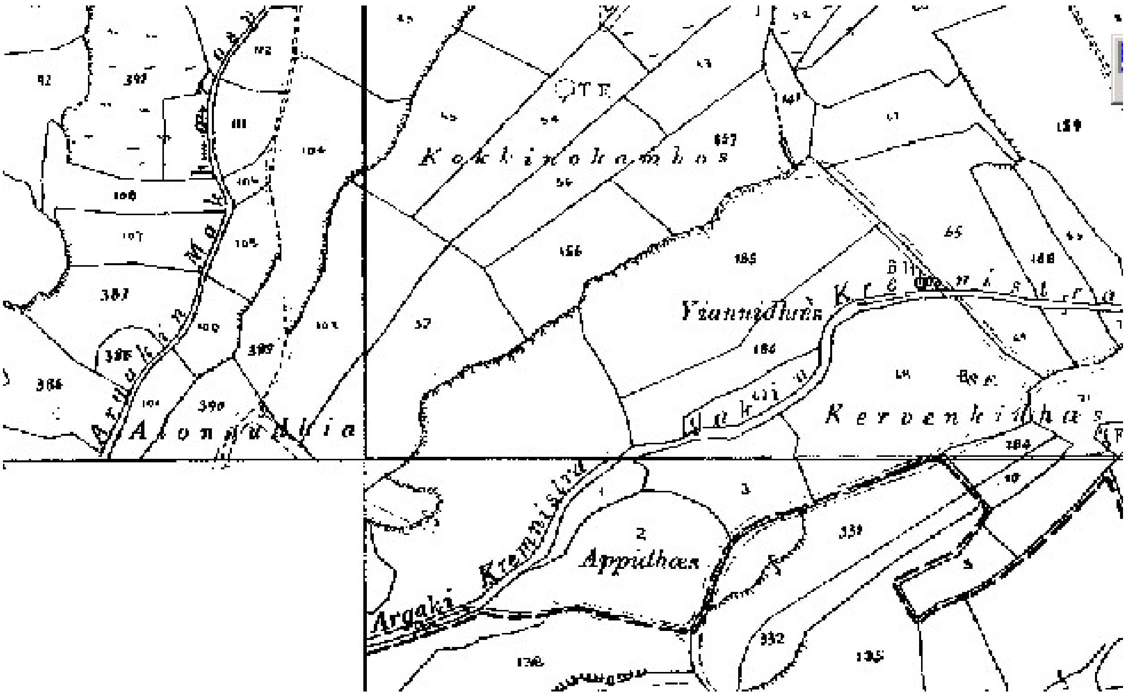


Figure 2: Example 1 of the good edge-matching

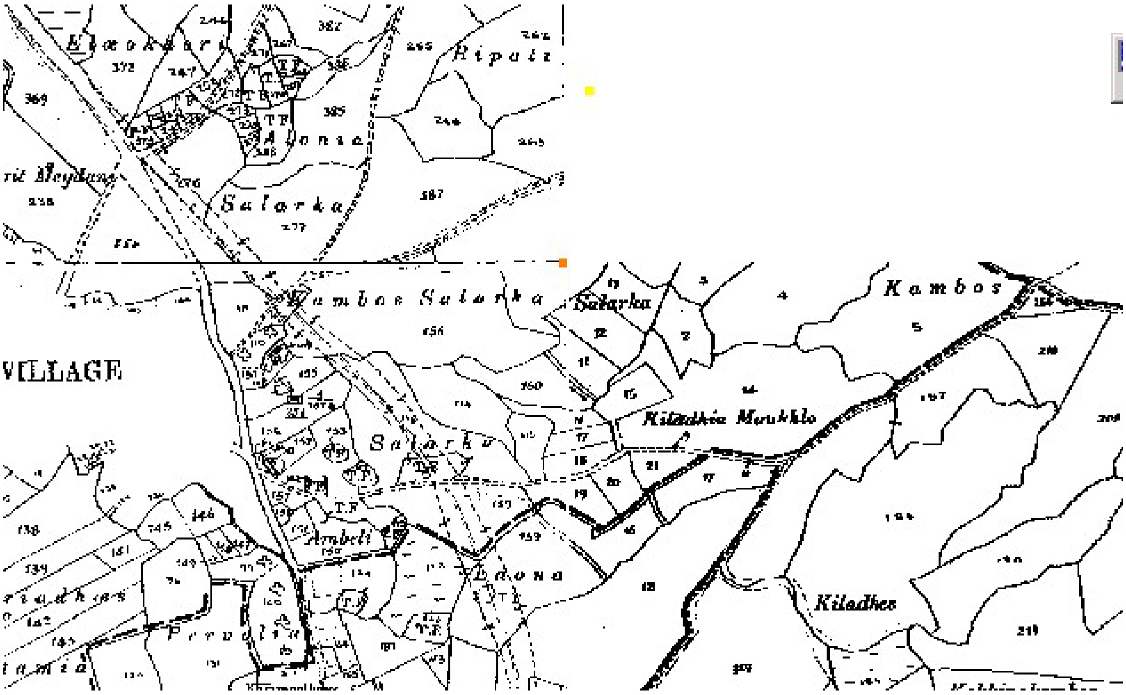


Figure 3: Example 2 of the good edge-matching

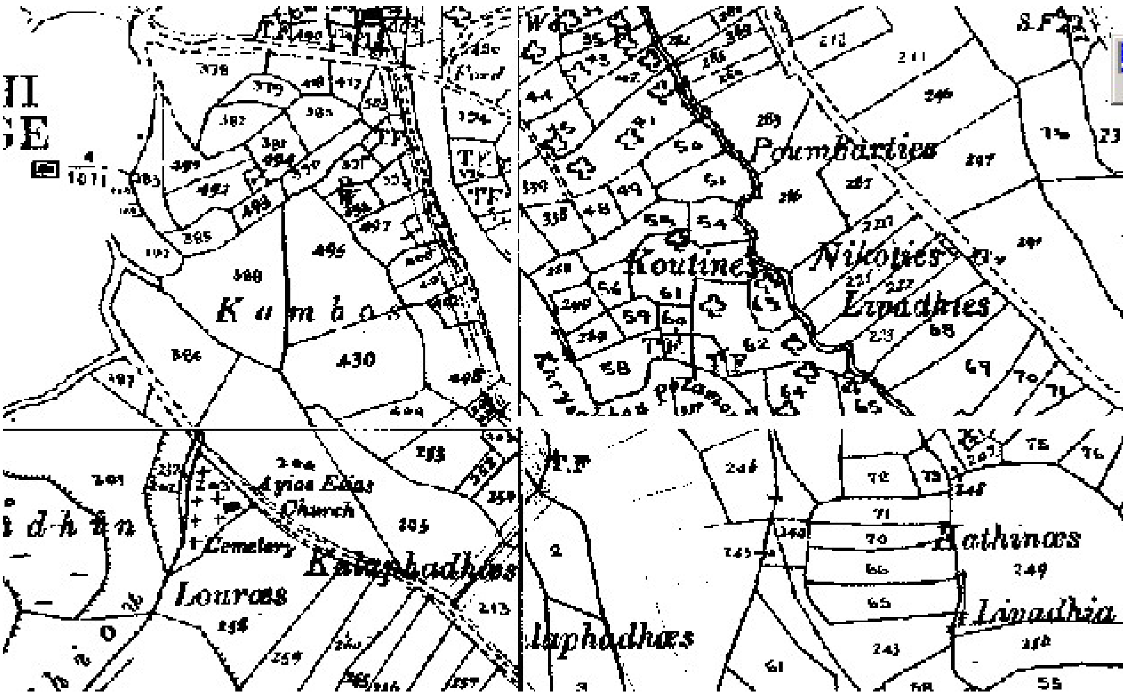


Figure 4: Example 3 of the good edge-matching

There are a number of reasons that the two sets of images (map images and IKONOS image) were expected to deviate, some of which are the following:

1. The IKONOS image as a GEO product, by specification has a $\pm$50m horizontal accuracy. The angle of acquisition and the type of terrain determines the variation of the horizontal accuracy. It is expected that in cases of varying terrain, the variations in horizontal accuracy are not uniform throughout the study area.
2. The Plan Grid coordinates provided by DLS might not be accurate, as the particular area maps are dated 1924
3. The maps provided might not have a consistent and uniform error.
4. The original definition of the ROI might have been defined with a coordinate system other than UTM/WGS84.

Considering the above circumstances, the overlay of the warped maps with the IKONOS 1M image was quite satisfactory. This became obvious as plot corners, intersections and other identifiable points could be seen on both images with very small deviations as they were overlaid.

Having performed all the above adjustments we preceded with the vectorization of the map images for the ROI. The Plots, the Rivers and the Roads were created as closed shapes, so that they could be ready for the GIS processing. Text was placed inside each plot for the Sheet number and the plot number. For the roads we gave the indication RO and for the Rivers the indication RI instead of the plot number. For Plots without plot numbers or for plots with numbers that could not be read, we gave the indication N/A. Sheet number and plot number were all placed in a different level (layer) so that the GIS software would be able to create tables by isolation a particular level (layer).

We then imported the Classification data as provided by ARS. We imported one classification at a time, so that we could easily prepare the data. The DXF data were cleaned from duplicate elements and created into closed shapes with a fill color and each classification was placed into a unique level (layer) in the master file. A shape representing a specific classification area could be:

a. Part of a plot,
b. Including competently more than one plot, or
c. Including parts of more than one plot.

These cases are shown in Figures 5, 6 and 7.

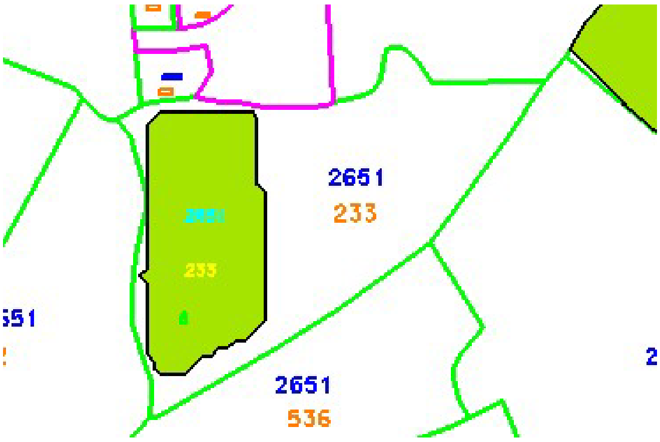


Figure 5: Example of a classification shape inside a plot

Figure 6: Example of a classification shape including many plots

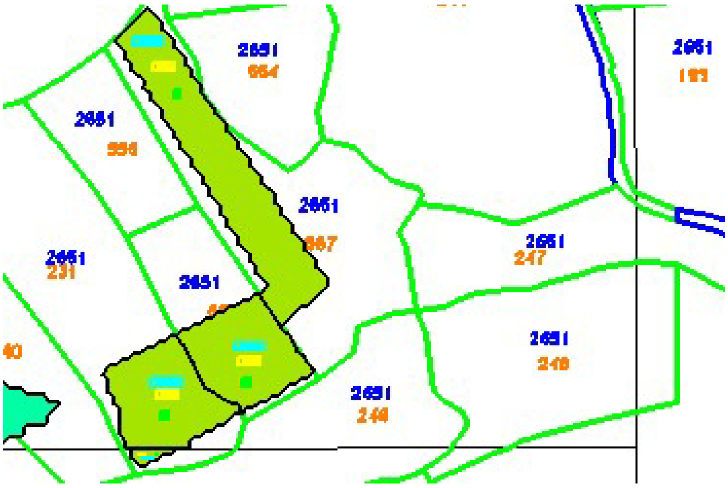


Figure 7: Example of a classification shape including parts of many plots

For cases b and c above, each classification shape was further divided into smaller shapes according to the plot, road and river boundaries and for each new shape the sheet number, the plot number and the classification number were placed inside the shape. All shapes were placed in one separate level (layer) and each of the sheet number, plot number and classification number were placed into a separate level (layer) as well.

As shown on Table 1, the classification number for GRASS was not provided. This is because the classification analysis could not extract results for GRASS. According to ARS, GRASS is a combination of the Fodder and the naturally grown grass with predominant values for the latter. This represented the largest numbers of shapes compared with the other classifications. The GRASS classification is provided in the MicroStation (dgn) file, but only as closed shapes without sheet numbers, plot numbers and classification numbers.

Results:

Having in mind that the data will be further imported for analysis to GIS, we separated the different types of information into different layers. The following information are provided separately in the MicroStation (dgn) file:

1. A layer with all the plots as closed shapes
2. A layer with all the roads as closed shapes
3. A layer with all the rivers as closed shapes
4. A layer with sheet numbers inside the above closed shapes
5. A layer with plot numbers inside the above closed shapes
6. A layer with closed shapes for each classification as provided by ARS
7. A layer with closed shapes for each classification as divided by plot, road and river boundaries
8. A layer for sheet numbers for each of the classification closed shapes as divided by plot, road and river boundaries
9. A layer for plot number for each of the classification closed shapes as divided by plot, road and river boundaries
10. A layer for classification number for each of the classification closed shapes as divided by plot, road and river boundaries

The above distinct separation of the information, will allow GIS to analyse separately the different types of information, i.e. area of plots, number of plots, plots with specific classification, total area for a specific classification, etc).

The content of each layer in the MicroStation Master_Final.dgn +file is provided in Table 3.

LEVEL	COLOR*	WEIGHT	DESCRIPTION
1	0	0	Sheet Number
2	0	0	Sheet Borders
3	0	1	Project Title
4			Legend
10	2	2	Closed shapes of Plots
11	5	2	Closed shapes of Roads
12	1	2	Closed shapes of Rivers
20	1	1	Sheet number inside plots - No sheet number for Roads and Rivers
21	6	1	Plot number inside plots - **RO** was used for Roads and **RI** used for Rivers
24			Classification numbers for SEA areas. **Number 7**: SEA Areas
25	0(0)	1	Closed Shapes of BUILT-UP areas as received from Remote Sensing Analysis
26	0(80)	1	Closed Shapes of BUILT-UP areas
27	27	1	Sheet numbers for BUILT-UP areas
28	28	1	Plot numbers for BUILT-UP areas
29	29	1	Classification numbers for BUILT-UP areas. **Number 4**: BUILT-UP Areas
30	0(0)	1	Shapes of CITRUS areas as received from Remote Sensing Analysis
31	0(6)	1	Closed Shapes of CITRUS areas
32	4	1	Sheet numbers for CITRUS areas
33	7	1	Plot numbers for CITRUS areas
34	24	1	Classification numbers for CITRUS areas. **Number 1**: CITRUS Areas
35	0(0)	1	Shapes of DAM areas as received from Remote Sensing Analysis
36	0(135)	1	Closed Shapes of DAM areas
37	37	1	Sheet numbers for DAM areas
38	38	1	Plot numbers for DAM areas
39	39	1	Classification numbers for DAM areas. **Number 5**: DAM Areas
40	0(0)	1	Shapes of FOREST areas as received from Remote Sensing Analysis
41	0(122)	1	Closed Shapes of FOREST areas
42	42	1	Sheet numbers for FOREST areas
43	43	1	Plot numbers for FOREST areas
44	44	1	Classification numbers for FOREST areas. **Number 2**: FOREST Areas
45	0(12)	1	Shapes of GRASS areas as received from Remote Sensing Analysis
50	0(0)	1	Shapes of GREEN-HOUSES areas as received from Remote Sensing Analysis
51	0(11)	1	Closed Shapes of GREEN-HOUSE areas
52	7	1	Sheet numbers for GREEN-HOUSE areas
53	4	1	Plot numbers for GREEN-HOUSE areas
54	2	1	Classification numbers for GREEN-HOUSE areas. **Number 6**: GREEN-HOUSE Areas
55	0(0)	1	Shapes of OLIVES areas as received from Remote Sensing Analysis
56	0(87)	1	Closed Shapes of OLIVES areas
57	1	1	Sheet numbers for OLIVES areas
58	4	1	Plot numbers for OLIVES areas
59	5	1	Classification numbers for OLIVES areas. **Number 3**: OLIVES Areas
60	0(0)	1	Shapes of SEA areas as received from Remote Sensing Analysis
61	0(1)	1	Closed Shapes of SEA areas
62	3	1	Sheet numbers for SEA areas
63	4	1	Plot numbers for SEA areas

*** All shapes were in outline color 0. The color in parenthesis is the color of the fill of the shapes**

Table 3: Layer content for Master_final.dgn file

Deliverables:

1. One CD Containing:

    a. MicroStation Version J file (Master_final.dgn) with all the vectorized data (Plots, roads, rivers, classifications and text in different layers as described earlier)
    b. A MicroSoft World file (IntelliGraph_data.doc) of this document.

2. Hard copy printouts of:

    a. A1 size plot of the ROI for plots, roads and rivers
    b. 1:10000 plot of the ROI overlaid with the classification analysis (Two parts)
    c. A1 size plot of the ROI overlaid with the classification analysis.

Conclusions/Comments:

1. The original deviations between the IKONOS image and the map images for the possible reasons that we explained earlier were a problem of the project. The warping of the map images to fit the IKONOS resulted in vector data that deviate from the Plan Grid coordinates as given by DLS, but are more accurate to the IKONOS overlay which has its own inaccuracies as explained earlier.
2. There was a lot of laborious work carried out especially in creating closed shapes as the scanned maps were not clear enough in many cases and the boundaries of plots, roads and rivers were not distinct. In total there are over 5600 closed shapes created and over 10000 text strings placed.
3. The Classification data created a lot of unexpected laborious work as in many cases the classification closed shape had to be subdivided in many other closed shapes because it was overlapping a number of different plots, roads or rivers.
4. The scanned maps of 1924 created also a number of problems for the identification of distinct points that could also be located on the IKONOS image. For example, dirt roads of 1924 were now new asphalt roads with different alignment and the built areas of 1924 were definitely different on IKONOS.
5. In general, the workload was much larger than what we expected originally, however we believe that the objective for this project was achieved in the best possible manner.

ANNEX 2

Multispectral Classification – Pilot Study
Chrysochou River Basin, Pafos – Cyprus
Report - IKONOS Satellite Image
ARS Agrio Remote Sensing Ltd.

Multispectral Classification

Pilot Study

Chrysochou river basin area, Pafos - Cyprus

REPORT

Prepared for:

The Department of Water Development,

Ministry of Agriculture, Natural Resource and the Environment

Nicosia, Cyprus

November 1, 2001

Prepared By:

ARS

Agrio Remote Sensing Ltd.

Interpreting Images of the Earth

OUTLINE

1. INTRODUCTION

1.1 Aim of the study

The purpose of the study is to investigate the feasibility, reliability and cost of detailed survey of land and water use with the objective to better access the importance of water withdrawal inside the river basins and its impact on reservoir recharge.

The objective of this study is the classification and interpretation of IKONOS very high-resolution images (VHRI) to map irrigated areas in the Chrysochou river basin by means of a '*supervised classification'*. Remote sensing analysis was used to find out if the following crop classes could be identified using IKONOS imagery:

- **Non irrigated:** open water, build up areas, forests, agriculture, unclassified
- **Irrigated:** almonds, banana, citrus, deciduous trees, fodder, olives, greenhouses, potatoes, vines, vegetables, tobacco.

1.2 Remote Sensing – Methods

Remote Sensing is a technology based on sampling radiation and force fields that seeks to acquire and interpret *geospatial data* to develop information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere. It involves the detection and measurement of photons of differing energies emanating from distant materials, by which these may be identified and categorized by class/type, substance, and spatial distribution.

Image *classification* is the process by which all pixels in a multispectral imagery are automatically categorized into land cover classes. The features are categorized based on the their inherent spectral reflectance and emmitance properties.

A *supervised classification* requires that the analyst has some familiarity with the geographic area in order to correctly identify and locate some of the land cover types for training sites selections. This familiarity can be acquired through fieldwork, analysis of existing maps or personal experience. The analyst develops spectral signatures for known categories, such as urban and forest, and the computer assigns each pixel in the image to the cover type to which its signatures is most similar.

1.3 Description of Study Area

The study area or region of interest (ROI) has a total area of 25 square kilometers; the area is located at the northeast part of the island and includes the town of Polis Chrysochous. The main land use of the area is agriculture and other not irrigated vegetation like grass and bushes. The morphology of the ROI can be described as a watershed area surrounded by hills at the east and west side. At the southern part of the ROI an artificial dam exists, holding the running water of the river Evretos. The far north area ends up with the seacoast of Polis Chrysochous.

2. DATA / PRE-PROCESSING and SURVEY

2.1 Data Selection

The satellite data used for this study were IKONOS multispectral data at a 4-meter resolution. In addition, IKONOS 1-meter true color imagery was used to increase the spatial resolution of the dataset. The following table provides information on the main technical characteristics of the IKONOS satellite.

Launch Date	September 24, 1999 (11:21:08 am PDT)
Resolution	**Ground resolution of each band:** 1-meter panchromatic (nominal at <26deg off nadir) 4-meter multispectral (nominal at <26deg off nadir)
Spectral Bands	
Imagery Spectral Response	**Panchromatic:** 0.45 - 0.90 microns **Multispectral:** #1: Blue 0.45 - 0.52 #2: Green 0.52 - 0.60 #3: Red 0.63 - 0.69 #4: Near IR 0.76 - 0.90
Swath Widths & Scene Sizes	**Nominal swath width:** 13 km at nadir **Areas of interest:** a nominal single image at 13 km x 13 km • strips of 11km x 100 km up to 11 km x 1000 km • image mosaics of up to 12,000 sq. km. • up to two 10,000 square kilometer contiguous areas in a single pass within a region
Metric Accuracy	12-meter horizontal and 10-meter vertical accuracy with no ground control 2-meter horizontal and 3-meter vertical accuracy with ground control These are specified as 90% CE (circular error) for the horizontal and 90% LE (linear error) for the vertical
Orbital Information	
Altitude	423 miles / 681 kilometers
Speed	4 miles per second / 7 kilometers per second
Revisit frequency	2.9 days at 1-meter resolution; 1.5 days at 1.5-meter resolution *These values are for targets at 40 degrees latitude. The revisit times will be more frequent for higher latitudes and less frequent for latitudes closer to the equator.*
Orbit time	98 minutes
Orbit type	sun-synchronous

The specific IKONOS data marketed as ***‘CARTERRA Geo’*** is a geometrically corrected product that has been rectified to a pre-specified ellipsoid and map projection. The rectification process removed image distortions introduced by the collection geometry and re-samples the imagery to a *uniform* ground sample distance and a specified map projection.

Product	Resolution	Accuracy	Spectral Bands (Micrometers)	Dynamic Range
Geo 4m MS	4 meter	+-50m	Red: 0.64-0.72 Green: 0.52-0.61 Blue: 0.45-0.53 Near-Infrared:0.77-0.88	11 bit (2048 levels)
Geo 1m PSM	1 meter	+-50m	Red: 0.64-0.72 Green: 0.52-0.61 Blue: 0.45-0.53	11 bit (2048 levels)

The study area was covered by only one acquisition therefore no image mosaic was necessary as initially indicated in the study proposal. In the event that the study area is larger and not covered by a single acquisition, then two or more datasets can be merged together by using the mosaic technique.

The image of the study area was acquired on **March 14, 2000 08:24 am** by Space Imaging Europe’s receiving station. The classification analysis reflects only those crops that existed during that time.

2.2 Remote Sensing Software

The software used for the image processing and classification analysis was **ENVI** by Research Systems Inc. (www.rsinc.com)

ENVI – the Environment for Visualizing Images is a state-of-the-art image processing software application designed from the ground up to provide turn-key panchromatic, multispectral, and hyperspectral analysis of satellite and airborne remote sensing data as well as single-band, and polarimetric radar data processing. ENVI includes comprehensive tools for image registration, orthocorrection, mosaicking, image classification, integrated GIS features, topographic analysis, and map composition all within an intuitive user interface.

2.3 Data Pre-Processing

1. *Subseting:* A procedure that was applied on the IKONOS 4 m image in order to select a spatial subset of the image based on the boundaries of the study area. The ROI that indicates the coverage of the study area was provided by the WDD and was used as a reference for the selection of the spatial subset of the dataset.

2. *Stretching:* This function was used to adjust the color range of the IKONOS data both for the 4m and the 1m imagery. The stretching adjustments were applied in order to maximize the range of the reflectance values of the image and as a result the enhancement of the spectral variation of the image. The stretching procedure is a very important step before applying any analytical processing such as classification. In addition, stretching will enhance the imagery for presentation purposes like the preparation of hard copy image maps.

2.4 Initial Field Survey

An initial field survey was performed in cooperation with the local office of the Water Development Department at Polis Chrysochous for the inspection of the study area. During the field survey data about the following were collected:

- Identification of different types of crops existing in the region of interest
- Morphology and other earth characteristics of the study area
- Based on the existing archive land use maps kept by the local WDD, an effort was made to identify the different kinds of crops existed on the IKONOS image acquired on March 14, 2000.

During this initial survey difficulties have appeared in identifying crops on the site, since some of the crops were seasonal and did not exist at the time of survey or the acquisition date.

The following table provides detail information in the identification of classes:

CLASSES	Sample Selected At field survey?	Identified on 1m IKONOS Image	Identified on 4m IKONOS Image	Approximate Growing Period	Classified	Comments
IRRIGATED						
Almonds	No	No	No	Feb –Mar	No	No Leaves at the time of acquisition
Bananas	No	No	No	April	No	Not existed in study area
Citrus	Yes	Yes	Yes	March-April	Yes	
Deciduous trees Walnuts	Yes	Yes	Yes	April	No	No Leaves at the time of acquisition
Fodder	Yes	Yes	Yes	March –Nov.	Yes	
Olives	Yes	Yes	Yes	April –May	Yes	

Greenhouses	Yes	Yes	Yes	--	Yes	
Potatoes	No	No	No	Aug.-Oct.	No	No potatoes at the time of acquisition
Vines	No	Yes	Yes	April	No	No Leaves at the time of acquisition
Vegetables	No	No	No	--	No	No vegetables at the time of acquisition
Tobacco	No	No	No	April –May	No	No tobacco at the time of acquisition
NON IRRIGATED						
Open water	N/A	Yes	Yes	--	Yes	
Build areas	N/A	Yes	Yes	--	**Yes**	
Forests	N/A	Yes	Yes	--	**Yes**	
Agriculture	N/A	Yes	Yes	--	**Yes**	
Other (unclassified)	N/A	Yes	Yes	--	**Yes**	

During the field survey the following crop types were excluded from the classification, as indicated above:

1. Deciduous (*walnut* and *vines*) were excluded because during the acquisition date these crops were at the very initial stage of the growing period (no leaves existed) and therefore were not able to be classified as vegetation.

2. *Bananas* plantations did not appear at the study area at all.

3. *Potatoes*, vegetables and tobacco did not exist in the study area during the acquisition date.

4. One small field was identified in the survey for *almonds.* However, the growing status of the leaves was not satisfactory and reliable to represent this type of crop in the classification.

5. Usually to distinguish different crops the time factor must be considered and it is recognized the most efficient way to find out different crops as their growing periods can be quite different. In particular, since the archive image used was acquired in early spring, the fields of the study area were mostly covered by natural growing grass. As a result, the highly dense areas covered with grass were interfering with other crops like fodder that had similar spectral signatures. Therefore, the two classes were merged together.

6. During the classification procedure an effort was made to eliminate the negative effects of shadows, which interfered with the shadows occurring from crops especially the class of olives. The distribution of olives in the study area was not dense. Shadows with similar spectral characteristics were occurring and our concern was to preserve all the regions covered by olives and unavoidably present some shadows as olives due to the similarity in spectral response.

7. The reflectance value of the shadows within the crops fields should be included in the spectral signature of the class of the specific crop. The NIR band very useful in such cases and the use of NIR band helped to distinguish the shadows caused by the morphology of the area and the shadows caused by crops. A separate class was created to classify areas covered by shadows due to morphology.

8. An additional class for 'Unclassified' was selected to aid the classification algorithm to better classify any pixels other than those of the desired crop classes. This class was then merged with the unclassified pixels of shadows that were generated by classification algorithm.

The final crops that were classified in the study area are listed below:

- Citrus
- Fodder / Grass
- Olives
- Greenhouses

Additional classes were defined to enhance the classification quality (accuracy) as follows:

- Water Sea
- Water Dam
- Forest
- Build Up Areas
- Shadows
- Unclassified (bare land, other natural growing vegetation)

3. IMAGE CLASSIFICATION

3. 1 Classification Procedure

Image classification is the process by which all pixels in a multispectral imagery are automatically categorized into land cover classes. The features are categorized based on the their inherent spectral reflectance and emmitance properties.

There are two main categories of classification: supervised and unsupervised.

- **Unsupervised:** The computer groups pixels in categories of like signatures and then the user identify what those cover types actually are.

- **Supervised:** Supervised classification is much more effectual in terms of accuracy in mapping substantial classes whose validity depends largely on the cognition and skills of the image analyst. Classes were recognized in the imagery from prior knowledge such as personal experience with the region, by identifying classes using thematic maps and an actual on-site visit. This allowed us to choose and set up discrete classes (thus supervising selection) to which identifying category names were then assigned.

  (*Training sites* were areas representing each known land cover category that appear fairly homogeneous on the image (as determined by similarity in tone or color within shapes delineating the category), were located and circumscribed by polygonal boundaries drawn on the image display. For each class outlined, mean values and variances of the DNs for each band used to classify were calculated from all pixels enclosed in the site(s) (more than one polygon was established for each class). When DNs were plotted as functions of the band sequence (increasing with wavelength), the result was a *spectral signature* or spectral response curve for that class. Classification then proceeded processing in which every pixel was compared with the various signatures and assigned to the class whose signature came closest.

3.2 Common Supervised Classification Algorithms

- The *Minimum Distance Means* classifier calculates the distance of a pixel's reflectance values to the spectral mean of each signature file, and then assigns the pixel to the category with the closest mean.

- The *Parallelepiped* classifier creates 'boxes' using minimum and maximum reflectance values within the training sites. If a given pixel falls within a signature 'box', or band space, it is assigned to that category.

- During the *Maximum Likelihood* classifier, the distribution of reflectance values in a training site is described by a probability density function, developed on the basis of Bayesian statistics (probability). This classifier evaluates the probability that a given pixel will belong to a category and classifies the pixel to the category with the highest probability of membership.

3.3 Supervised Classification Steps

There are three main steps in the supervised classification:

1. Locate representative samples of each type that can be identified in the image (called training sites or Region of interest ROI's). Then digitize polygons around each training site assigning a unique identifier to each cover type.

2. Extract from the pixels in the training sites numerical descriptions of the spectral characteristics of land cover types. The numerical descriptions generally include the mean, standard deviation, minimum value, total number of pixels etc.

3. Classify the entire image by considering each pixel, one by one, comparing its particular signature with each of the known signatures. The values (are) assigned to each pixel are the values of the class that has the most similar signature. Decision about how similar the signatures are to each other are made through statistical analysis.

3.4 Selection and Training of Regions of Interest (ROI's)

The ROI's are small areas selected by the user to represent a specific class. In the classification procedure ROI's are polygons holding information about the spectral signature range of a particular class. Based on the ROI's pattern the classification algorithm will identify areas similar to the ROI's and will assign them to the particular class.

The objective of the *training* procedure is to evaluate the quality (representability) of the ROI's of each class. This process is necessary and critical in defining criteria by which spectral patterns are recognized for each class. Spectral signature ranges for each ROI were extracted based on the combination of two methods.

- *Parametric*: Based on statistical parameters that assume a normal distribution (mean, covariance matrix).

- *Nonparametric*: Not based on statistics but on discrete objects (polygons i.e ROI's) in feature space.

During the training and selection of ROI's the objective was to pick homogeneous areas for each spectral class. The *region growing* technique was used to reduce the variability within the class. During this technique, necessary adjustments were made to the statistical parameters (variance, total number of pixels) in order to define the final range of the spectral signature. The final selection of ROI's was determined based on a satisfactory ROI's separability.

3.5 Classification Applied

The supervised classification method applied was the *Maximum Likelihood* classification. This method assumes that the statistics for each class for each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless a probability threshold is selected all pixels are classified.

Each pixel is assigned to the specific class that has the highest probability (maximum Likelihood). A threshold of 0.75 was selected as the most appropriate figure to control the overall distribution of the pixels.

4. POST CLASSIFICATION PROCESSING

4.1 Confusion Matrix

The accuracy of the classification results is very important for the classification procedure. Using the ENVI statistical method of *confusion matrix* an assessment of the classification results was made.

The *confusion matrix* is the contingency matrix of the classified image extracted by using the ground truth ROI's. The confusion matrix is calculated by comparing the location and class of each ground truth pixel with the corresponding location and class in the classification image. Each column of the confusion matrix represents a ground truth class and the values in the column correspond to the classification image's labeling of the ground truth pixels. Based on the confusion matrix the following statistical figures about the classification results are calculated:

- Overall Accuracy: The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels. The ground truth image or ground truths ROIs define the true class of the pixels. The pixels classified correctly are found along the diagonal of the confusion matrix table. The total number of pixels is the sum of all the pixels in all the ground truth classes.

- Kappa coefficient: The kappa coefficient (k) is another measure of the accuracy of the classification. It is calculated by multiplying the total number of pixels in all the ground truth classes (N) by the sum of the confusion matrix diagonals, subtracting the sum of the ground truth pixels in a class times the sum of the classified pixels in that class summed over all classes, and dividing by the total number of pixels squared minus the sum of the ground truth pixels in that class times the sum of the classified pixels in that class summed over all classes.

- Commission: Errors of commission represent pixels that belong to another class that are labeled as belonging to the class of interest. The errors of commission are shown in the rows of the confusion matrix.

- Omission: Errors of omission represent pixels that belong to the ground truth class but the classification technique has failed to classify them into the proper class. The errors of omission are shown in the columns of the confusion matrix.

- Producer Accuracy: The producer accuracy is a measure indicating the probability that the classifier has labeled an image pixel into Class A given that the ground truth is Class A.

- User Accuracy: The user accuracy is a measure indicating the probability that a pixel is Class A given that the classifier has labeled the pixel into Class A.

Overall Accuracy = (13790/14521) 94.9659%
Kappa Coefficient = 0.9281

Ground Truth (Pixels)

Class	Citrus	Olives	Water Dam	Green Houses	Sea	Shadows	Fodder	Forest	Build Up Area	Total
Unclassified	95	1	4	0	0	185	148	0	148	581
Citrus	973	0	0	0	0	0	2	0	0	975
Olives	0	28	0	0	0	8	0	0	0	36
Water Dam	0	0	5565	0	0	0	0	0	0	5565
GreenHouses	0	0	0	36	0	0	0	0	0	36
Sea	0	0	0	0	214	0	0	0	0	214
Shadows	8	0	0	0	0	858	0	0	0	866
Fodder / Gras	91	4	0	0	0	37	600	0	0	732
Forest	0	0	0	0	0	0	0	149	0	149
Build Up Area	0	0	0	0	0	0	0	0	5367	5367
Total	1167	33	5569	36	214	1088	750	149	5515	14521

Ground Truth (Percent)

Class	Citrus	Olives	Water Dam	Green Houses	Sea	Shadows	Fodder	Forest	Build Up Area	Total
Unclassified	8.14	3.03	0.07	0	0	17	19.73	0	2.68	4
Citrus	83.38	0	0	0	0	0	0.27	0	0	6.71
Olives	0	84.85	0	0	0	0.74	0	0	0	0.25
Water Dam	0	0	99.93	0	0	0	0	0	0	38.32
GreenHouses	0	0	0	100	0	0	0	0	0	0.25
Sea	0	0	0	0	100	0	0	0	0	1.47
Shadows	0.69	0	0	0	0	78.86	0	0	0	5.96
Fodder / Gras	7.8	12.12	0	0	0	3.4	80	0	0	5.04
Forest	0	0	0	0	0	0	0	100	0	1.03
Build Up Area	0	0	0	0	0	0	0	0	97.32	36.96
Total	100	100	100	100	100	100	100	100	100	100

Class	Commission	Omission	Commission	Omission
	(Percent)	(Percent)	(Pixels)	(Pixels)
Citrus	0.21	16.62	2/1167	194/1167
Olives	22.22	15.15	8/33	5/33
Water Dam	0	0.07	0/5569	4/5569
GreenHouses	0	0	0/36	0/36
Sea	0	0	0/214	0/214
Shadows	0.92	21.14	8/1088	230/1088
Fodder / Gras	18.03	20	132/750	150/750
Forest	0	0	0/149	0/149
Build Up Area	0	2.68	0/5515	148/5515

Class	Prod. Acc.	User Acc.	Prod. Acc	User Acc.
	(Percent)	(Percent)	(Pixels)	(Pixels)
Citrus	83.38	99.79	973/1167	973/975
Olives	84.85	77.78	28/33	28/36
Water Dam	99.93	100	5565/5569	5565/5565
GreenHouses	100	100	36/36	36/36
Sea	100	100	214/214	214/214
Shadows	78.86	99.08	858/1088	858/866
Fodder / Gras	80	81.97	600/750	600/732
Forest	100	100	149/149	149/149
Build Up Area	97.32	100	5367/5515	5367/5367

4.2 Analysis of Statistics for the Classification Results

The *overall accuracy* of the classification represents the number of pixels that were classified correctly, according to the training sites (ROIs). Another measure of the accuracy of the classification is the *kappa coefficient*.

The figures: *Overall Accuracy* = 94,9659% and *Kappa Coefficient* = 0,9281, can be considered as very high for classification standards. The above figures were achieved due to the following reasons:

- The IKONOS imagery used is a very high-resolution data; therefore each pixel is very consistent.
- The area of the classification is relatively small and the analyst has an overview ability of the area. As a result, the final selection of the training sites reflects the variety of classes in the whole extent of the study area.
- The polygons of the ROI's selected, were very small and their content homogeneous.

The final classification results were extracted progressively after a number of different approaches on the selection of training areas as well as the parameters of the classification algorithm.

It should be noted that the *overall accuracy* does not necessarily indicate the quality with which the classification results represent the physical reality of the study area. The *overall accuracy* of the classification, evaluates the correlation of the ROI's selected with the final classification results.

Additional comments on the confusion matrix based on the interference between the classes are:

- Water Dam, Sea, Greenhouses and Forest were very distinct classes. The ranks of separability from other classes were very high thus they did not interfere with other classes. It should be noted that the greenhouses and forest literally are not classes that can be separated easily. However, in the specific study area their coverage is very small (almost 1,3% of the total study area) and the ROI's selected were almost identical with the cover area of the classes.

- The fodder/grass class had a very low separability and interfered with the citrus (12.5%), shadows (5%) and olives (0,05%). If the image acquisition date was determined according to the growing periods of the crops then the fodder/grass class could have been classified easier and the fodder and grass could have been distinguished as two separate classes.

- Olives had a very low separability with the class of shadow and 22% of the training sites of olives have been assigned to the class of shadow.

- Citrus and fodder/grass are classes very difficult to be classified especially in March. Several approaches were made to classify with satisfactory results the two classes. Eventually, the result had a very low interference of fodder/grass within the citrus class, and a high interference of the citrus class within the fodder/grass class (12.5%).

4.3 Majority/Minority Analysis

Majority analysis was used to change suspicious pixels within a large class to that class. A kernel size was defined and the center pixel in the kernel was replaced with the class value that the majority of the pixels in the kernel has. On the other hand, minority analysis is used to replace the center pixel in the kernel with the class value that the minority of the pixels in the kernel has.

4.4 Clumping Classes

Classified images often suffer from a lack of spatial coherency (spaces and holes within a class). The clump technique was used to clump adjacent similar classified areas together using morphological operators.

4.5 Sieving Classes

This technique was applied to solve the problem of isolated pixels occurring in the classified images. Sieving classes removed isolated classified pixels using blob grouping. The sieve classes method looks at the neighboring 4 or 8 pixels to determine if a pixel is grouped with pixels of the same class.

4.6 Export of classification in to vectors.

Classification to Vector was used by ENVI to convert the classification results to ENVI polygon vector layers (.evf files) and eventually DXF files. A vector layer for each class was created.

4.7 Creation of Image Maps

Image maps were created using ENVI. Grid lines were overlaid on the 1 meter and 4 meter resolution image. Grids based on map-coordinate and latitude/longitude based (for georeferenced images). The IKONOS Georeferenced images had grids that are based on geographic coordinates (latitude/longitude). The grid spacing was specified in projection units, based on the reference pixel given in the image header file. The grid coordinates were then labeled with the appropriate map coordinates. The images were then annotated with the appropriate text and exported to high resolution photographic plotters to create a hard copy of the imagery.

5. CONCLUSION / RECOMMENDATIONS

Remote sensing analysis using very high-resolution imagery (VHRI) is a complex and sensitive procedure. Insignificant factors can have critical influence on the overall success of the classification. Several factors should be considered and properly managed in order to have acceptable and reliable results.

For the specific study the following factors had a significant role for the overall classification result.

- Date of Acquisition: The image acquisition of the study area was made on March 14, 2000 and the classification analysis reflected those crops that existed during that time. An initial field survey taken in a period as close as possible to the image acquisition date will result to a better understanding of both the study area and the crops to be mapped.

- Growing Period of Crops: The acquisition date of the image should be defined based on the growing period of the crops of interest. A pre study concerning the ideal growing period of the crops of interest is necessary for identifying those crops in the imagery.

- Multiple Acquisitions: In the case of a complex classification (High number of classes, very specific classes) multiple acquisitions might be necessary as to group several crops together that can be then classified with a specific acquisition date.

- Separability: At the acquisition date the crops of interest should have the maximum separability in terms of spectral reflectance. Moreover, the selection of image bands during the actual processing should also aim to preserve the highest possible spectral separability between classes.

- Field Survey: The initial field survey performed aims to the identification of samples for crop classes but also to provide the analyst with a basic understanding about the study area, a factor that can influence the classification procedure.

- ROI's Training: May be the most critical factor for the reliability of the classification. The number of ROI's selected and the ROI's themselves should reflect the physical reality of the study area. Moreover, the ROI's of each class should represent the overall distribution of the class in the image.

- Determination of classes: The number of classes does not necessarily have to be the same with the classes of interest. Additional classes can be selected to force the behavior of the classification towards the anticipated result. By doing this, the probability of assigning the right pixels in the right class will increase.

- Classification Algorithm chosen: Even though most supervised classification methods can be suitable for such applications, the most appropriate is the *Maximum Likelihood* classification method because it uses statistical models for the distribution of pixels.

- Dynamic Range: Using 11 bit data (2048 shades of gray per pixel), the classification analysis demands more advanced techniques in order to distinguish the different crop categories. Due to the fact that the range of reflectance values is 2048 in comparison with other datasets such as Landsat or SPOT having a range of 256 reflectance values the variation within a single class is much higher. Therefore, the selection and the training of pixels that were used for the classification is an extremely sensitive procedure in terms of spectral accuracy.

- Data/Resolution: IKONOS 4-meter resolution multispectral data is ideal for a parcel based applications. Each pixel represents 4 square meters, a very convenient size for applications demanding such detail.

Remote Sensing provides repetitive, consistent and accurate view of the earth. This information is invaluable in monitoring earth and the effect of human activities. The pilot project has demonstrated that the methodology using a study area sampling with fieldwork and remote-sensing techniques can produce reliable statistics about the vegetation distribution in the area of interest. From the information about the vegetation and in particular the crop types a reliable estimate about the irrigated and non-irrigated areas can be extracted.

The overall outcome of the classification analysis indicates that the use of 4 meter resolution IKONOS data provide a very good possibility to perform the desired classification. Another positive point to mention is the re-usable knowledge base. The benefit of the re-usable knowledge base is an enormous gain in performing such additional studies.

Having in mind all the parameters involved in the completion of this study such as the size of the study area, the time for completion and the acquisition date of the imagery used, and the fact that this is a fully automated procedure, there is no doubt that this study gives encouraging results as to proceed with serious evaluation and consideration of similar studies at different regions under more favorable conditions.

6. Object Oriented Image Classification a Revolutionary new approach for the analysis of high-resolution data.

While remote sensing made enormous progress over the last years in terms of improved resolution, a vast majority of applications like a classification, rely on basic image processing concepts developed in the 70s: per-pixel classification. It is argued that this methodology does not make use of any spatial concepts. Especially in high-resolution images it is very likely that neighboring pixels belong to the same land cover class as the pixel under consideration.
New developed algorithms and software launch a totally new approach to the classification of high resolution data. In traditional image and raster analysis, the "unit of analysis" is the pixel . Image classification involved the mathematical grouping of pixels that were "alike" in the spectral values present at each pixel in the various bands. When applied to earlier remotely sensed datasets (such as Landsat data), this approach worked reasonably well, but there were problems. When new, higher-resolution data sources became common like IKONOS, the problems became more evident.

Consider a tree in a forest for a example. If you're attempting to map vegetation types with the Landsat sensor, the pixel size is (about) 30 meters, and this is relatively well sized for variations in canopy. Consider, however, the same area imaged by IKONOS with one-meter pixel size. A single tree canopy will be imaged in many different pixels, some at the top, some along the side in shadow and some on the side in bright sunshine. Different parts of a single wheat field will have different spectral properties reflecting more or less vigorous vegetation. What previously was measured as homogenized into a single pixel now is captured in many different pixels with different spectral properties.

Traditional pixel-based classification methods aren't effective with new higher-resolution data.
In response to these growing problems that underlie all pixel-based approaches a newly developed patent algorithm is taking a different approach to classification. It first attempts to identify small adjacent groups of pixels that are relatively homogenous in their multidimensional spectral properties using image segmentation.

The algorithm performs a first automatical processing - segmentation - of the imagery. This results to a condensing of information and a knowledge-free extraction of image objects. The formation of the objects is carried out in a way that an overall homogeneous resolution is kept. The segmentation algorithm does not only rely on the single pixel value, but also on pixel spatial continuity (texture, topology). The formatted objects have not only the value and statistic information of the pixels that they consist. They carry also texture, form (spatial features) and topology information in a common attribute table. The user interacts with the procedure and based on statistics, texture, form and mutual relations among objects defines training areas.

After basic object segmentation is completed, it's possible to apply supervised classification in which image objects of known classes are selected and others of similar properties are automatically detected. Such grouping takes advantage of the object's physical and spectral properties. The approach is similar to a traditional nearest-neighbor method used in our project, but it uses "fuzzy" methods. Alternatively, users can create a rule base to apply prior rules to the classification--fuzzy memberships are used to classify the objects.

Both approaches manage to condense the image information into meaningful pixel aggregation. Spatial hierarchy features that can managed by the use of fuzzy membership functions, multilevel segmentation and context classification are tools that give great advantage to the DEFiNiENS (Germany) eCognition method against traditional pixel based classification methods.

The existence of meaningful objects that contain information about their geographic location and orientation makes it possible to automatically incorporate the spectral and spatial information that they poses into a decision making system.

The possibility to create finer objects that respect the boundary of their "superobjects" provide the means to detect non homogeneous sites inside a class of classified objects. This multilevel approach is welcomed by scientific fields that have to do with the monitoring of natural landscapes or agricultural areas. In this frame precision farming benefits to a great extent from the object oriented classification method.

Object Oriented classification provides an accessible, truly revolutionary approach to classification to address the most difficult problems in image classification.

GLOSSARY

ACCURACY - refers to the reference placement of the image during registration in relation to its actual ground location. Accuracy is often represented as a statistical “error” such as CE90. See “Error” for more details. CARTERRA™ - Space Imaging uses CARTERRA™ as a brand name for products produced and services provided.

CLASSIFICATION - quantitative method that classifies or identifies objects or patterns on the basis of their multispectral values; the normal output is analogous to an image map requiring no visual interpretation.

CLOUD COVER PERCENTAGE - Cloud cover is measured by the percentage of an image obscured by clouds. Space Imaging will make best efforts to obtain coverage that meets customer requirements. Some geographic areas are more prone to clouds and haze than others, which will impact the time it takes to collect a particular area of interest.

COLOR - there are three “types” of color products available: Natural, False Color (Infrared), and Multispectral.

- Natural: also known as “true” color, is composed of three primary colors of the visible spectrum (blue, green, red (0.4-0.7 micrometers)). When properly exposed/processed, the color rendition closely approximates the original scene as viewed by the human eye, thus the term Natural Color.

- False Color (Infrared): when an image is processed, the resulting colors will be unnatural or false for most objects. Because of this, color-infrared film is sometimes called false-color film. For example, vigorous vegetation is displayed in intense red/pink tones rather than green.

- Multispectral: imagery that is simultaneously collect-ed in multiple wavelengths (bands) with a single sensor that operates in the visible and infrared spectral regions. This usual-ly uses less than 10 spectral bands (more than 10 spectral bands is referred to as hyperspectral).

DATA - refers to remotely sensed images that can be produced as photographic or digital products.

DATUM - Geodetic datums help to define the curvature of the earth to allow for position calculations. A datum is essentially a correction to the chosen ellipsoid utilizing ground control. As with FORMAT, our products support a variety of the most frequently used datums, such as WGS84 and NAD83.

ERRORS - Horizontal accuracy (represented as CE90) is a horizontal measurement on the ground defining the radius of a circle within which an object of known coordinates should be found on an image. The probability of a point in the image meeting the recorded accuracy is 90% for CE90. This parameter is expressed in meters.

Vertical accuracy (represented as LE90) is the accuracy at which elevation of a point in the image can be determined. The probability of a point in the image meeting the recorded accuracy is 90% for LE90. This parameter is expressed in meters.

FORMAT- Our image data is offered in different formats depending upon what kind of image application software requirements you have. The formats available for each sensor are included on each product page. Examples of formats are:

GeoTIFF - TIFF with geographic coordinates included in file header.

TIFF - Tag Image File Format. The most common image file format used by commercial GIS software.

GEORECTIFIED - the photogrammetric adjustment of one or more images relative to each other and to an absolute (fixed) ground reference system. An image or vector layer that is georectifiedis tied to a geographic reference system such that each pixel or point chosen can be identified by geographic coordinate (latitude and longitude).\

GEOGRAPHIC INFORMATION SYSTEM (GIS) - an organized collection of computer hardware, software and digital geographic data designed to provide multiple layers of geographically-referenced information. GIS databases are used to efficiently capture, store, update, manipulate, analyze and display all forms of georectified information.

LATITUDE/LONGITUDE - Latitude is the angular distance, measured in degrees, north or south from the equator. Longitude is the distance east or west on the Earth’s surface measured as an arc of the equator (up to 180 degrees) between the meridian passing through a particular place and the prime meridian, passing through Greenwich, England. Look up the data availability in your area of interest by providing a Lat/Long on the web “Search Archive” or learn what Lat/Long covers your area of interest. This will assist fulfillment when ordering.

METADATA - For formats other than NITF, the metadata is supplied as separate files on the delivered media. The metadata contains the information needed to ingest the image/data into a GIS software. If there are problems reading the imagery, the solution may lie in the metadata.

MULTISPECTRAL- This is a color image with multiple spectral bands (often including infra-red channels) which allows analysis on different combinations of bands (by using appropriate GIS software). Multispectral data is used to interpret features revealed by spectral data (agricultural stress, environmental impacts, etc.). When viewing an enhanced image is the intended use rather than analysis, products identified as “Color” are preferable to multispectral.

ORTHORECTIFICATION - Orthorectified images are the most position-accurate products offered. The orthorectification process removes image distortions introduced by the collection geometry and the terrain, and resamples the imagery to a uniform ground sample distance and user-specified map projection.

PANCHROMATIC - This is a black-and-white image. If visual sharpness is most important, panchromatic or pan-sharpened (with color) is the best product to purchase.

PAN-SHARPENED - Color images with 1-meter pixels created by merging the 1-meter Pan with the 4-meter Multispectral product of the same area.

PIXEL (derived from “picture element”)- a data element having both spatial (texture) and spectral properties. The spatial (texture) variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values) and the spectral variable defines the intensity of the spectral response for that cell/pixel in a particular band.

PROJECTION- See MAPPROJECTION.

RESOLUTION - a measure of the smallest linear separation between two objects that can be resolved by the sensor. For example, the smallest detectable, albeit unidentifiable, feature that the IKONOS 1-meter sensor can detect is 1 meter in diameter in photographs and 1 meter square in digital data.

ROI – Region Of Interest

SUPERVISED CLASSIFICATION-Digital-information extraction technique in which the operator provides training-site information that the computer uses to assign pixels to categories.

SYSTEM CORRECTED-Data is geometrically adjusted for the spacecraft’s orientation and predicted position (i.e., North= “up”). System corrected data is useful when accurate base maps are not available

TERRAIN CORRECTED - These products use precision corrected processing, and also incorporate digital terrain models (DTMs) into the correction process. Elevation models allow terrain relief distortions (from mountains, hills and valleys) to be removed on a pixel by pixel basis. Terrain correction is recommended for all images where relief differences exceed 500 feet.

UTM - Universal Transverse Mercator projection. A global map projection especially useful for navigation because it preserves angles and compass headings. Area and distance distortions are small.

UNSUPERVISED CLASSIFICATION -Digital information extraction technique in which the computer assigns pixels to categories with no instructions from the operator

ANNEX 3

Multispectral Classification – Pilot Study
Chrysochou River Basin, Pafos – Cyprus
Report - Using Landsat TM data
ARS Agrio Remote Sensing Ltd.

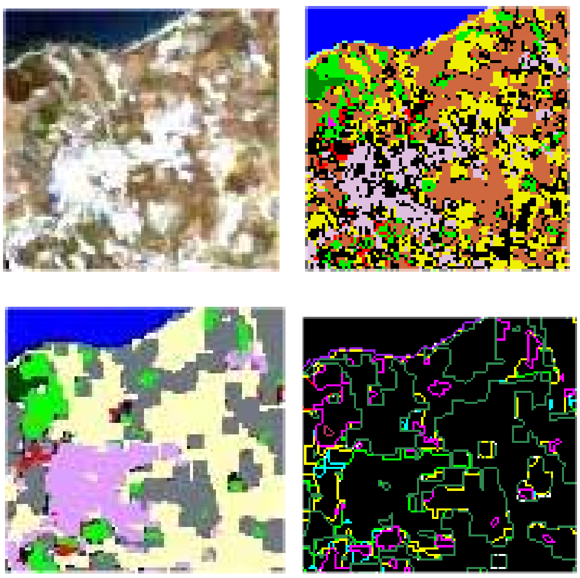
Multispectral Classification

Pilot Study

Chrysochou river basin area, Pafos - Cyprus

Using Landsat TM data

REPORT



Prepared for:

The Department of Water Development,

Ministry of Agriculture, Natural Resource and the Environment

Nicosia, Cyprus

November 30, 2001

Prepared By:

ARS

Agrio Remote Sensing Ltd.

Interpreting Images of the Earth

OUTLINE

1. INTRODUCTION

1.1 Aim of the study

The purpose of the study is to investigate the feasibility, reliability and cost of detailed survey of land and water use with the objective to better access the importance of water withdrawal inside the river basins and its impact on reservoir recharge.

The objective of this study is the classification and interpretation of Landsat TM data to map the Chrysochou river basin by means of a '*supervised classification'*. Remote sensing analysis was used to find out what classes could be identified using Landsat TM data.

The following classes could be identified in the area of interest:

Forest, Build Up Areas, Water Dam, Fields (bare reddish soil), Citrus, Grass (natural growing and any other mixed vegetation), Vines, White bare land, Water Sea

True Color Landsat TM Image

1.2 Remote Sensing – Methods

Remote Sensing is a technology based on sampling radiation and force fields that seeks to acquire and interpret *geospatial data* to develop information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere. It involves the detection and measurement of photons of differing energies emanating from distant materials, by which these may be identified and categorized by class/type, substance, and spatial distribution.

Image *classification* is the process by which all pixels in a multispectral imagery are automatically categorized into land cover classes. The features are categorized based on the their inherent spectral reflectance and emmitance properties.

A *supervised classification* requires that the analyst has some familiarity with the geographic area in order to correctly identify and locate some of the land cover types for training sites selections. This familiarity can be acquired through fieldwork, analysis of existing maps or personal experience. The analyst develops spectral signatures for known categories, such as urban and forest, and the computer assigns each pixel in the image to the cover type to which its signatures is most similar.

1.3 Description of Study Area

The study area or region of interest (ROI) has a total area of 25 square kilometers, The area is located at the northeast part of the island and includes the town of Polis Chrysochous. The main land use of the area is agriculture and other not irrigated vegetation like grass and bushes. The morphology of the ROI can be described as a watershed area surrounded by hills at the east and west side. At the southern part of the ROI an artificial dam exists, holding the running water of the river Evretos. The far north area ends up with the seacoast of Polis Chrysochous.

2. DATA / PRE-PROCESSING and SURVEY

2.1 Data Selection

The satellite data used for this study was a Landsat TM multispectral data at a 30-meter resolution. The following table provides information on the main technical characteristics of the Landsat TM satellite.

Launch Date	March 1, 1984
Resolution	**Ground resolution of each band** (meters): Band 1 30 Band 2 30 Band 3 30 Band 4 30 Band 5 30 Band 6 120 Band 7 30

Spectral Bands	
Imagery Spectral Response	Landsat 5 — **Wavelength** (micrometers) — **Resolution** (meters) Band 1 — 0.45-0.52 — 30 Band 2 — 0.52-0.60 — 30 Band 3 — 0.63-0.69 — 30 Band 4 — 0.76-0.90 — 30 Band 5 — 1.55-1.75 — 30 Band 6 — 10.40-12.50 — 120 Band 7 — 2.08-2.35 — 30
Swath Widths & Scene Sizes	**Nominal swath width:** 185 x 170 km
Dynamic Range	256 gray levels (8 bits)
Orbital Information	
Altitude	705 km
Revisit frequency	provide a 16-day, 233-orbit cycle with a swath overlap that varies from 7 percent at the Equator to nearly 84 percent at 81 north or south latitude
Orbit type	sun-synchronous

The image of the study area was acquired on **May 11, 2000** by Eurimage SpA receiving station. The classification analysis reflects only those crops that existed during that time.

2.2 Remote Sensing Software

The software used for the image processing and classification analysis was **ENVI** by Research Systems Inc. (www.rsinc.com)

ENVI – the Environment for Visualizing Images is a state-of-the-art image processing software application designed from the ground up to provide turn-key panchromatic, multispectral, and hyperspectral analysis of satellite and airborne remote sensing data as well as single-band, and polarimetric radar data processing. ENVI includes comprehensive tools for image registration, orthocorrection, mosaicking, image classification, integrated GIS features, topographic analysis, and map composition all within an intuitive user interface.

2.3 Data Pre-Processing

1. *Resampling*: Image Re-Sampling was performed on the whole Landsat TM image provided. This procedure is a preprocessing method that was used to enhance the spatial resolution of the image from 30 meters to 25 meters.

2. Rectification / Registration: This procedure was made to georeference the image with an existing geographic reference system. The image was registered based on the UTM Projection, Zone #36 North.

3. *Stretching:* This function was used to adjust the color range of the Landsat TM data. The stretching adjustments were applied in order to maximize the range of the reflectance values of the image and as a result the enhancement of the spectral variation of the image. The stretching procedure is a very important step before applying any analytical processing such as classification. In addition, stretching will enhance the imagery for presentation purposes like the preparation of hard copy image maps.

4. *Filtering:* Convolution filtering is a common mathematical method of implementing spatial filters to imagery. By using this method, each pixel value is replaced by the average over a square area centered on that pixel. Specifically, the Median filtering was used to smooth the image, while preserving edges larger than the kernel dimensions. ENVI's Median filter replaces each center pixel with the median within the neighborhood specified by the filter size.

5. *Subseting:* A procedure that was applied on the LANDSAT TM image in order to select a spatial subset of the image based on the boundaries of the study area. The ROI that indicates the coverage of the study area was provided by the WDD and was used as a reference for the selection of the spatial subset of the dataset.

2.4 Initial Field Survey

An initial field survey was already performed in cooperation with the local office of the Water Development Department at Polis Chrysochous for the inspection of the study area for the pilot study using IKONOS data. Using the information from the initial field survey and the experience gained during the project using IKONOS data, the following classes were selected:

- Forest,
- Build Up Areas
- Water Dam
- Fields (bare reddish soil)
- Citrus
- Grass (natural growing and any other vegetation)
- Vines
- White bare land
- Water Sea

The above classes were selected in an attempt to achieve the optimum classification results. If the classes were defined in such a way that they were not spectrally distinct, low classification accuracies could result. This is a common difficulty when using many classes. In contrast, using fewer classes may result in a class that contains a wide range of spectral patterns. This also results in low classification accuracy, because the large variance of such a class is likely to include spectral patterns that the analyst would prefer to include in other classes.

3. IMAGE CLASSIFICATION

3. 1 Classification Procedure

Image classification is the process by which all pixels in a multispectral imagery are automatically categorized into land cover classes. The features are categorized based on the their inherent spectral reflectance and emmitance properties.

- **Supervised:** Supervised classification is much more effectual in terms of accuracy in mapping substantial classes whose validity depends largely on the cognition and skills of the image analyst. Classes were recognized in the imagery from prior knowledge such as personal experience with the region, by identifying classes using thematic maps and an actual on-site visit. This allowed us to choose and set up discrete classes (thus supervising selection) to which identifying category names were then assigned.

  Training sites were areas representing each known land cover category that appear fairly homogeneous on the image (as determined by similarity in tone or color within shapes delineating the category), were located and circumscribed by polygonal boundaries drawn on the image display. For each class outlined, mean values and variances of the DNs for each band used to classify were calculated from all pixels enclosed in the site(s) (more than one polygon was established for each class). When DNs were plotted as functions of the band sequence (increasing with wavelength), the result was a *spectral signature* or spectral response curve for that class. Classification then proceeded processing in which every pixel was compared with the various signatures and assigned to the class whose signature came closest.

3.2 Supervised Classification Steps

There are three main steps in the supervised classification:

1. Locate representative samples of each type that can be identified in the image called training sites or Region Of Interest (ROI's). Then digitize polygons around each training site assigning a unique identifier color to each cover type.

2. Extract from the pixels in the training sites numerical descriptions of the spectral characteristics of land cover types. The numerical descriptions generally include the mean, standard deviation, minimum value, total number of pixels etc.

3. Classify the entire image by considering each pixel, one by one, comparing its particular signature with each of the known signatures. The values are assigned to each pixel are the values of the class that has the most similar signature. Decision about how similar the signatures are to each other are made through statistical analysis.

3.3 Selection and Training of Regions of Interest (ROI's)

The ROI's are small areas selected by the user to represent a specific class. In the classification procedure ROI's are polygons holding information about the spectral signature range of a particular class. Based on the ROI's pattern the classification algorithm will identify areas similar to the ROI's and will assign them to the particular class.

The objective of the *training* procedure is to evaluate the quality (representability) of the ROI's of each class. This process is necessary and critical in defining criteria by which spectral patterns are recognized for each class.

During the training and selection of ROI's the objective was to pick homogeneous areas for each spectral class. The selection of ROI's was made on a true color combination image using bands 3,2,1. The final selection of ROI's was determined based on a satisfactory ROI's separability.

3.4 Classification Applied

The supervised classification method applied was the *Maximum Likelihood* classification. This method assumes that the statistics for each class for each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless a probability threshold is selected all pixels are classified.

Each pixel is assigned to the specific class that has the highest probability (maximum Likelihood). A threshold of 0.82 was selected as the most appropriate figure to control the overall distribution of the pixels. The procedure was performed using all seven bands of the Landsat TM data to maximize the efficiency of the classification algorithm.

4. POST CLASSIFICATION PROCESSING

4.1 Confusion Matrix

The accuracy of the classification results is very important for the classification procedure. Using the ENVI statistical method of *confusion matrix* an assessment of the classification results was made.

The *confusion matrix* is the contingency matrix of the classified image extracted by using the ground truth ROI's. The confusion matrix is calculated by comparing the location and class of each ground truth pixel with the corresponding location and class in the classification image. Each column of the confusion matrix represents a ground truth class and the values in the column correspond to the classification image's labeling of the ground truth pixels. Based on the confusion matrix the following statistical figures about the classification results are calculated:

- Overall Accuracy: The overall accuracy is calculated by summing the number of pixels classified correctly and dividing by the total number of pixels. The ground truth image or ground truths ROI's define the true class of the pixels. The pixels classified correctly are found along the diagonal of the confusion matrix table. The total number of pixels is the sum of all the pixels in all the ground truth classes.

- Kappa coefficient: The kappa coefficient (k) is another measure of the accuracy of the classification. It is calculated by multiplying the total number of pixels in all the ground truth classes (N) by the sum of the confusion matrix diagonals, subtracting the sum of the ground truth pixels in a class times the sum of the classified pixels in that class summed over all classes, and dividing by the total number of pixels squared minus the sum of the ground truth pixels in that class times the sum of the classified pixels in that class summed over all classes.

- Commission: Errors of commission represent pixels that belong to another class that are labeled as belonging to the class of interest. The errors of commission are shown in the rows of the confusion matrix.

- Omission: Errors of omission represent pixels that belong to the ground truth class but the classification technique has failed to classify them into the proper class. The errors of omission are shown in the columns of the confusion matrix.

- Producer Accuracy: The producer accuracy is a measure indicating the probability that the classifier has labeled an image pixel into Class A given that the ground truth is Class A.

- User Accuracy: The user accuracy is a measure indicating the probability that a pixel is Class A given that the classifier has labeled the pixel into Class A.

Overall Accuracy = (2951/3062) 96.3749 %
Kappa Coefficient = 0.9406

Ground Truth (Pixels)

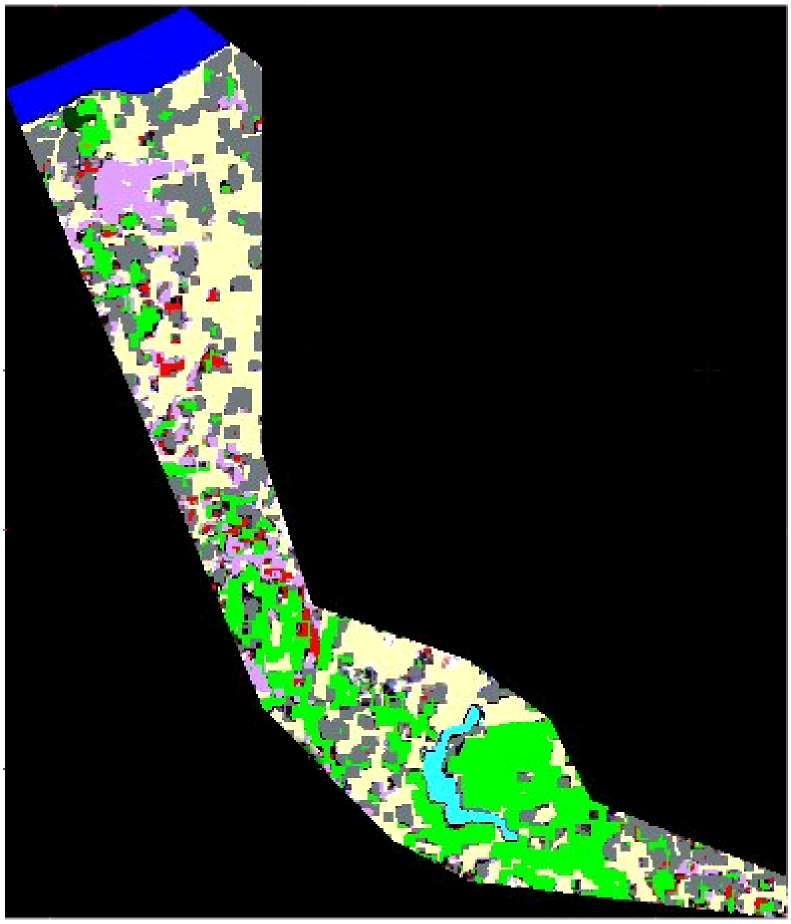
Class	Forest	Build Up Area	Water Dam	Fields	Citrus	Grass	Vines	White bare land	Water Sea	Total
Unclassified	0	7	0	0	1	2	0	30	1	41
Forest	32	0	0	0	0	0	0	0	0	32
Build Up Area	0	138	0	2	0	0	0	3	0	143
Water Dam	0	0	110	0	0	0	0	0	0	110
Fields	0	0	0	111	0	0	0	0	0	111
Citrus	0	0	0	0	28	0	0	0	0	28
Grass	0	0	0	0	30	410	0	0	0	440
Vines	0	0	0	0	0	0	10	0	0	10
White bare land	0	33	0	1	0	1	0	292	0	327
Water Sea	0	0	0	0	0	0	0	0	1820	1820
Total	32	178	110	114	59	413	10	325	1821	3062

Ground Truth (Percent)

Class	Forest	Build Up Area	Water Dam	Fields	Citrus	Grass	Vines	White bare land	Water Sea	Total
Unclassified	0	3.93	0	0	1.69	0.48	0	9.23	0.05	1.34
Forest	100	0	0	0	0	0	0	0	0	1.05
Build Up Area	0	77.53	0	1.75	0	0	0	0.92	0	4.67
Water Dam	0	0	100	0	0	0	0	0	0	3.59
Fields	0	0	0	97.37	0	0	0	0	0	3.63
Citrus	0	0	0	0	47.46	0	0	0	0	0.91
Grass	0	0	0	0	50.85	99.27	0	0	0	14.37
Vines	0	0	0	0	0	0	100	0	0	0.33
White bare land	0	18.54	0	0.88	0	0.24	0	89.85	0	10.68
Water Sea	0	0	0	0	0	0	0	0	99.95	59.44
Total	100	100	100	100	100	100	100	100	100	100

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)	Prod. Acc. (Percent)	User Acc. (Percent)	Prod.Acc. (Pixels)	User Acc. (Pixels)
Forest	0	0	0/32	0/32	100	100	32/32	32/32
Build Up Area	3.5	22.47	5/178	40/178	77.53	96.5	138/178	138/143
Water Dam	0	0	0/110	0/110	100	100	110/110	110/110
Fields	0	2.63	0/114	3/114	97.37	100	111/114	111/111
Citrus	0	52.54	0/59	31/59	47.46	100	28/59	28/28
Grass	6.82	0.73	30/413	3/413	99.27	93.18	410/413	410/440
Vines	0	0	0/10	0/10	100	100	10-Oct	10-Oct
White bare land	10.7	10.15	35/325	33/325	89.85	89.3	292/325	292/327
Water Sea	0	0.05	0/1821	1/1821	99.95	100	1820/1821	1820/1820

Class	Square Kilometers
Forest	0.065000 Km²
Build Up Area	1.706 Km²
Water Dam	0.413750 Km²
Fields	5.431 Km²
Citrus	0.581250 Km²
Grass	5.954 Km²
Vines	0.006250 Km²
White bare land	7.971 Km²
Water Sea	1.609 Km²



Classified Landsat TM imagery

Classification Map Keys – sq Km

- Forest – 0.065000 Km^2
- Build Up Area – 1.706 Km^2
- Water Dam – 0.413750 Km^2
- Fields – 5.431 Km^2
- Citrus – 0.581250 Km^2
- Grass – 5.954 Km^2
- Vines – 0.006250 Km^2
- White Bare Land – 7.971 Km^2
- Water Sea – 1.609 Km^2

4.2 Analysis of Statistics for the Classification Results

The *overall accuracy* (96,3749%)of the classification represents the number of pixels that were classified correctly, according to the training sites (ROIs). Another measure of the accuracy of the classification is the *kappa coefficient (*0,9406).

The final classification results were extracted progressively after a number of different approaches on the selection of training areas as well as the parameters of the classification algorithm.

It should be noted that the *overall accuracy* does not necessarily indicate the quality with which the classification results represent the physical reality of the study area. The *overall accuracy* of the classification, evaluates the correlation of the ROI's selected with the final classification results. Training data are usually collected from a few accessible sites, leading to difficulties in generating a representative sample. In addition, when the scale of vegetation pattern is fine in comparison with pixel size, the selection of pixels that unambiguously represent a single class may be impossible.

Additional comments on the confusion matrix based on the interference between the classes are:

- Water Dam, Sea, Forest and vines were very distinct classes. The ranks of separability from other classes were very high thus they did not interfere with other classes. It should be noted that vines and forest literally are not classes that can be separated easily. However, in the specific study area their coverage is very small (almost 1,3% of the total study area) and the ROI's selected were almost identical with the cover area of the classes.

- Citrus and grass are classes very difficult to be classified, the result was to have a very low interference of citrus within the grass class, and a high interference of the grass class within the citrus class (50.85%).

- Some classes, which are similar spectrally, were identifiable using locational information. For example, white bare land and build up areas are bright in all bands, and were only partially separable using spectral information. A considerable interference of white bare land within the build up area was noted (18.54%) in contrast with a low interference of build up areas within white bare land (0.92%).

4.3 Clumping Classes

Classified images often suffer from a lack of spatial coherency (spaces and holes within a class). The clump technique was used to clump adjacent similar classified areas together using morphological operators.

4.4 Sieving Classes

This technique was applied to solve the problem of isolated pixels occurring in the classified images. Sieving classes removed isolated classified pixels using blob grouping. The sieve method looks at the neighboring 4 or 8 pixels to determine if a pixel is grouped with pixels of the same class.

4.5 Export of classification in to vectors.

Classification to Vector was used by ENVI to convert the classification results to ENVI polygon vector layers (.evf files) and eventually DXF files. A vector layer for each class was created.

4.6 Creation of Image Maps

Image maps were created using ENVI. Grid lines were overlaid on the Landsat 25 meter resolution image. Grids were based on map-coordinate and latitude/longitude coordinate system. The grid coordinates were labeled with the appropriate map coordinates and annotated with the appropriate text to be exported to high-resolution photographic paper to create a hard copy of the imagery.

5. CONCLUSION / RECOMMENDATIONS

Satellite Landsat TM data is increasingly seen as an inexpensive and consistent data source for mapping and monitoring large areas. Such imagery can be used for classification purposes to create general land use maps. Classification analysis using Landsat TM data has the advantage of the seven available spectral bands but is sometimes limited by the spatial resolution of 30 meters depending on the application requirements.

Furthermore, insignificant factors can have critical influence on the overall success of the classification, thus several factors should be considered and properly managed in order to have acceptable and reliable results.

For the specific study the following factors had a significant role for the overall classification result.

- The Landsat imagery has a considerably low resolution (25m for the specific project after resampling) and therefore it is very difficult to distinguish/identify different types of small-cultivated plots.

- Data/Resolution: Landsat TM has limited capabilities in identifying/analyzing parcel based applications, especially in Cyprus where agricultural parcels are very small (sometimes less than one pixel). Each pixel represents 30 square meters not a convenient pixel size for applications demanding such detail.

- Using Landsat TM data the visual control over the training of ROIS's is limited. Mainly because of the low spatial resolution and the heterogeneous content of each pixel (i.e a single Landsat TM pixel can represent more than one class).

- Growing Period of Crops: The acquisition date of the image should be defined based on the growing period of the crops of interest. A pre study concerning the ideal growing period of the crops of interest is necessary for identifying those crops in the imagery.

- Separability: At the acquisition date the crops of interest should have the maximum separability in terms of spectral reflectance. Moreover, the selection of image bands during the actual processing should also aim to preserve the highest possible spectral separability between classes.

- Field Survey: The initial field survey performed aims to the identification of samples for crop classes but also to provide the analyst with a basic understanding about the study area, a factor that can influence the classification procedure.

- ROI's Training: May be the most critical factor for the reliability of the classification. The number of ROI's selected and the ROI's themselves should reflect the physical reality of the study area. Moreover, the ROI's of each class should represent the overall distribution of the class in the image.

- In Landsat TM the spectral distribution of 7 bands gives great analytical capabilities and flexibility in identifying earth surface characteristics.

- Dynamic Range: Using Landsat's 8 bit data (256 shades of gray per pixel), the classification analysis requires more conventional/standard techniques in order to distinguish different classes. Due to the fact that the range of reflectance values is 256 in comparison with other datasets (i.e. IKONOS - 2048 reflectance) the variation within a single class is less and the information that can be extracted is limited.

Remote Sensing provides repetitive, consistent and accurate view of the earth. This information is invaluable in monitoring earth and the effect of human activities. This pilot project has demonstrated that the methodology using Landsat TM data, the specific study area with fieldwork and remote-sensing techniques can produce reliable statistics about general land cover/use in the area of interest.

Considering, all the parameters involved in the completion of this study such as the size of the study area, the acquisition date of the Landsat TM imagery used, and the fact that this was a fully automated procedure, there is no doubt that encouraging results are presented to proceed with serious evaluation and consideration of similar studies at different regions with more favorable conditions.

6. COMPARISON OF IKONOS AND LANDSAT TM DATA ANALYSIS

Classification of agricultural crops can be achieved through the use of multispectral data. Both IKONOS and Landsat TM data can be used to perform classification analysis for land use applications.

Using data by IKONOS enables the analysis to take advantage the very high-resolution pixel size (at 4 meters and 1 meter) an ideal pixel size for parcel-based applications. Moreover, the dynamic range available at 11 bits (2048 shades of gray) provides a unique and powerful advantage for preserving the complex spectral response of the earth surface characteristics. In addition, the near infrared spectral information allows users to accurately differentiate vegetation features and conditions, identify land use areas and easily delineate land and water boundaries. Finally, IKONOS can collect data of the same area on a regular basis enabling users to monitor and support projects that need frequent updates.

On the other hand the use of Landsat data provides lower spatial resolution (30 meters) but higher spectral capabilities with the 7-band range. Landsat data are provided only in 8 bits (256 shades of gray) of dynamic range, which reduces considerably the clarity of the data.

Having in mind the above technical characteristics, the time of acquisition, the study area and the specific requirements of the project, different number of classes have been defined for each case as presented in the following table - together with square kilometers covered by each class:

IKONOS		**LANDSAT TM**	**SQ KM**
Forest,	0.106176 Km²	Forest,	0.065000 Km²
Build Up Areas	0.739456 Km²	Build Up Areas	1.706 Km²
Water Sea	1.727 Km²	Water Sea	1.609 Km²
Water Dam	0.459232 Km²	Water Dam	0.413750 Km²
Citrus	0.433488 Km²	Citrus	0.581250 Km²
Olives	0.062272 Km²	Vines	0.006250 Km²
Green Houses	0.095584 Km²	Grass (natural growing and any other vegetation)	5.954 Km²
Grass (natural growing and any other vegetation)	3.233 Km²	Fields (bare reddish soil)	5.431 Km²
Unclassified (bare land, other natural growing vegetation)	N/A	White bare land	7.971 Km²
Shadows	N/A		

The aim in both studies was to have identical classes as to easily compare the results of the classification analysis. However, as explained above for some classes it was not possible to follow the same classification definitions.

Forest, Build Up Areas, Water Sea and Water Dam were identified and classified in both studies.

Using Landsat data the only crop classes that were identified and mapped were citrus and vines. On the other hand using IKONOS data 4 different distinct crop classes (citrus, fodder/grass, olives and greenhouses) were identified and classified.

Vines were not classified using IKONOS data due to the acquisition date of the image and the growing period of this class. However, using Landsat TM data acquired about 3 months later, and having in reference the clearly defined training sites of vines during the on-site survey and IKONOS reference, vines were classified.

Olives were not classified using Landsat data. Training data collected for olives, lead to difficulties in generating a representative sample. The scale of vegetation pattern in comparison with pixel size (25 m) was very low to represent olives in a single class.

In the initial study using IKONOS data, white bare land and other not relevant classes such as shadows and other type of vegetation were merged together with the system defined unclassified class to focus on the requested classes for the study. In the Landsat classification, classes such as Grass (natural growing and any other vegetation), Fields (bare reddish soil) and White bare land were preserved to enhance the classification mapping.

Concluding, both platforms IKONOS and Landsat TM can be used to perform classification mapping depending on the project requirements. Landsat TM data can be used for general large-scale applications where high detail analysis is not necessary. On the other hand IKONOS data can be used in both large and small-scale applications and can provide very detail analysis in terms of spatial resolution.

ANNEX 4

Maps:

Annex 4-1: Plots with Citrus Plantations from Field Survey – WDD Polis Chrysochou

Annex 4-2: Plots with Citrus Plantations from Agricultural Dept.

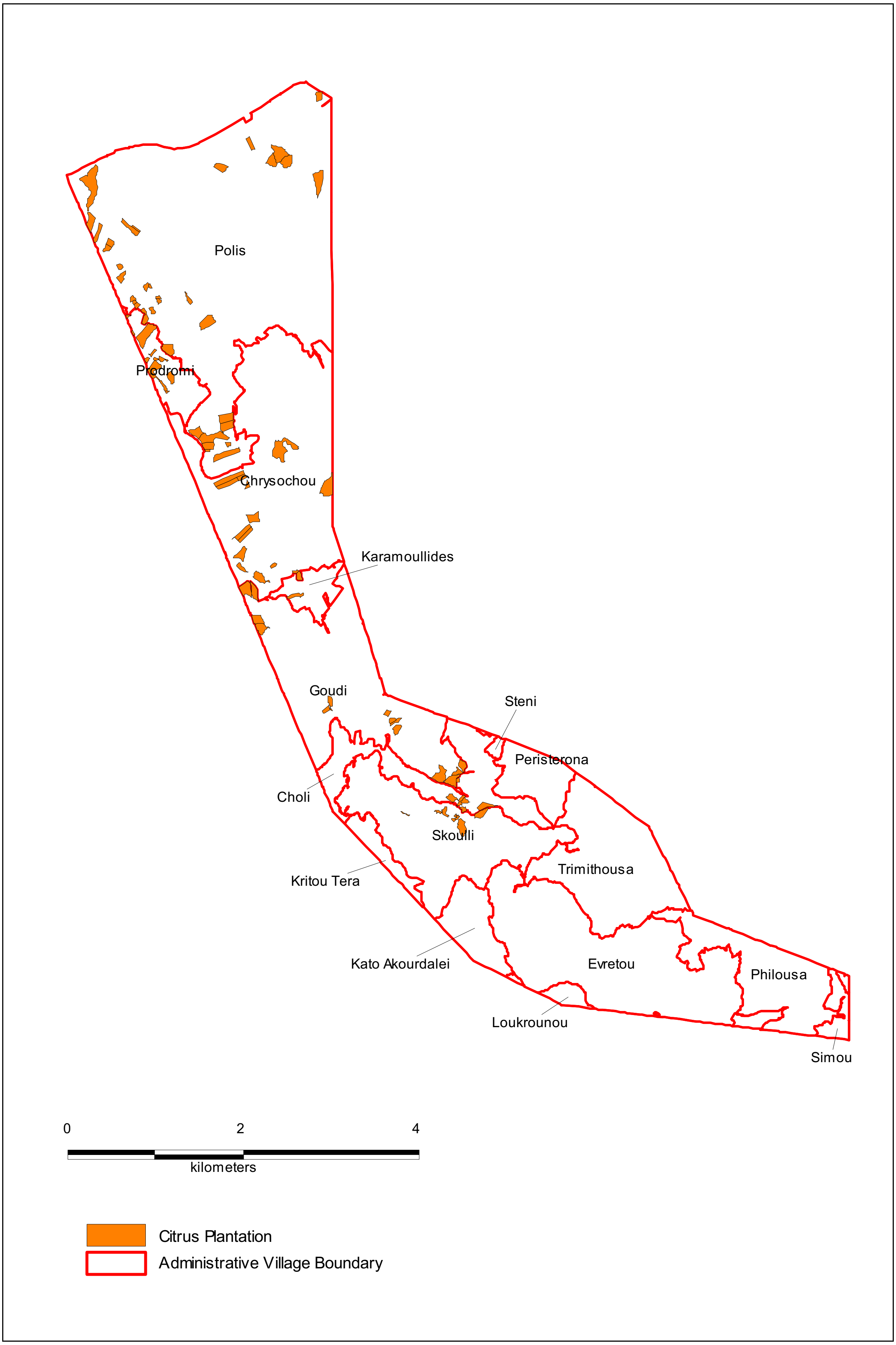
Annex 4-3: Citrus Plantation Areas from IKONOS RSA

Annex 4-4: Citrus Plantation Areas from Landsat RSA

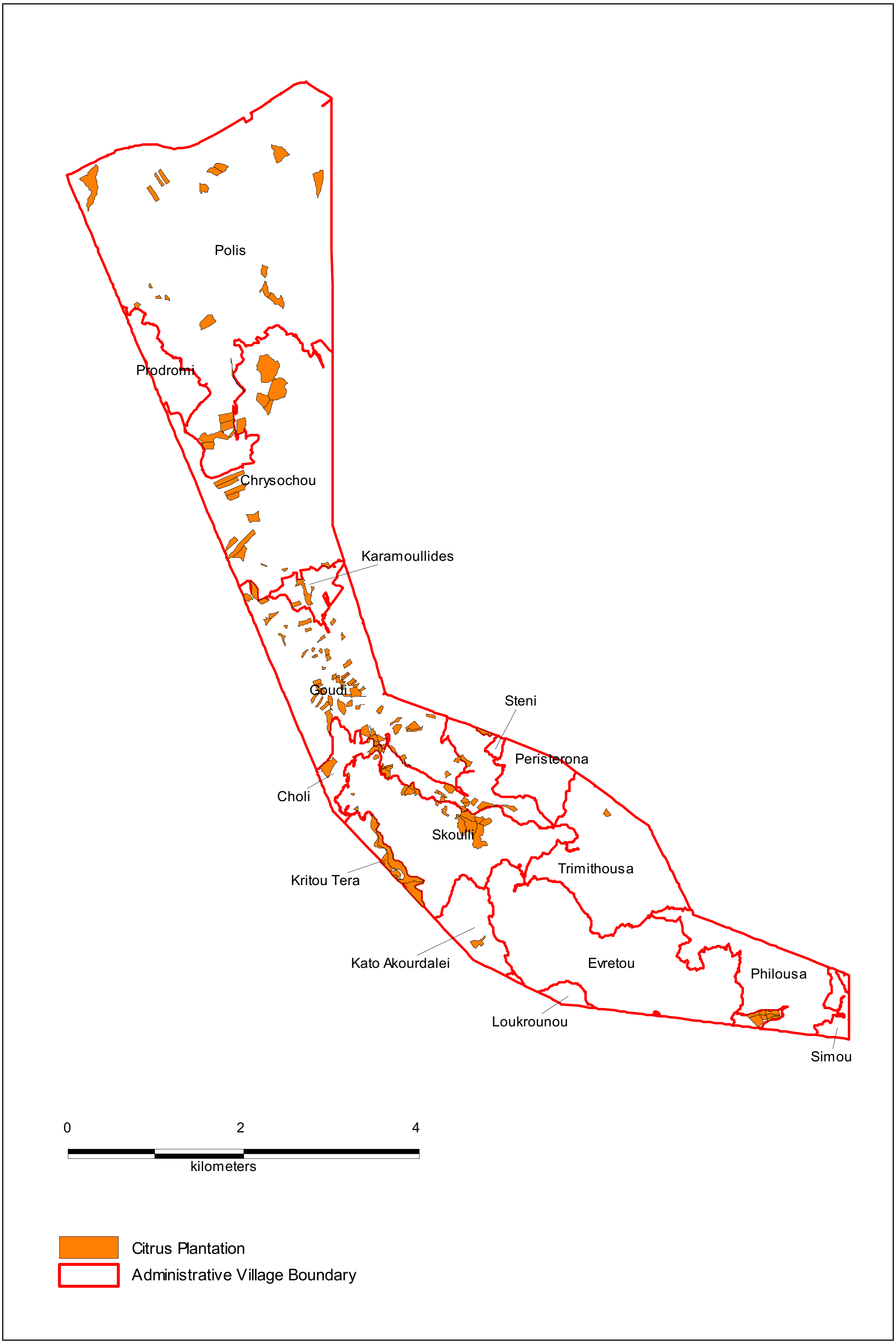
Annex 4-5: Plots with Olive Plantations from Field Survey – WDD Polis Chrysochou

Annex 4-6: Plots with Olive Plantations from Agricultural Dept.

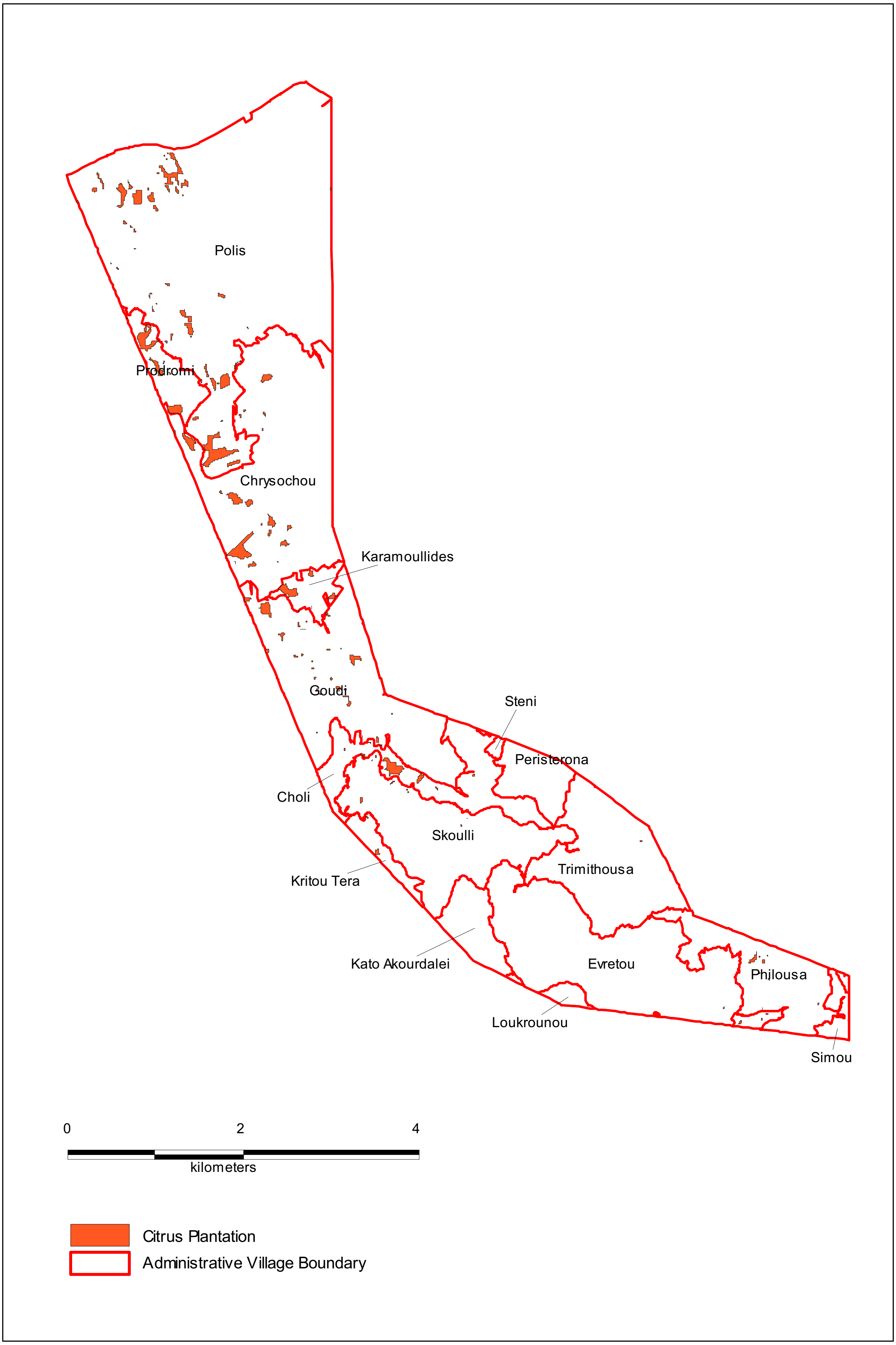
Annex 4-7: Olive Plantation Areas from IKONOS RSA



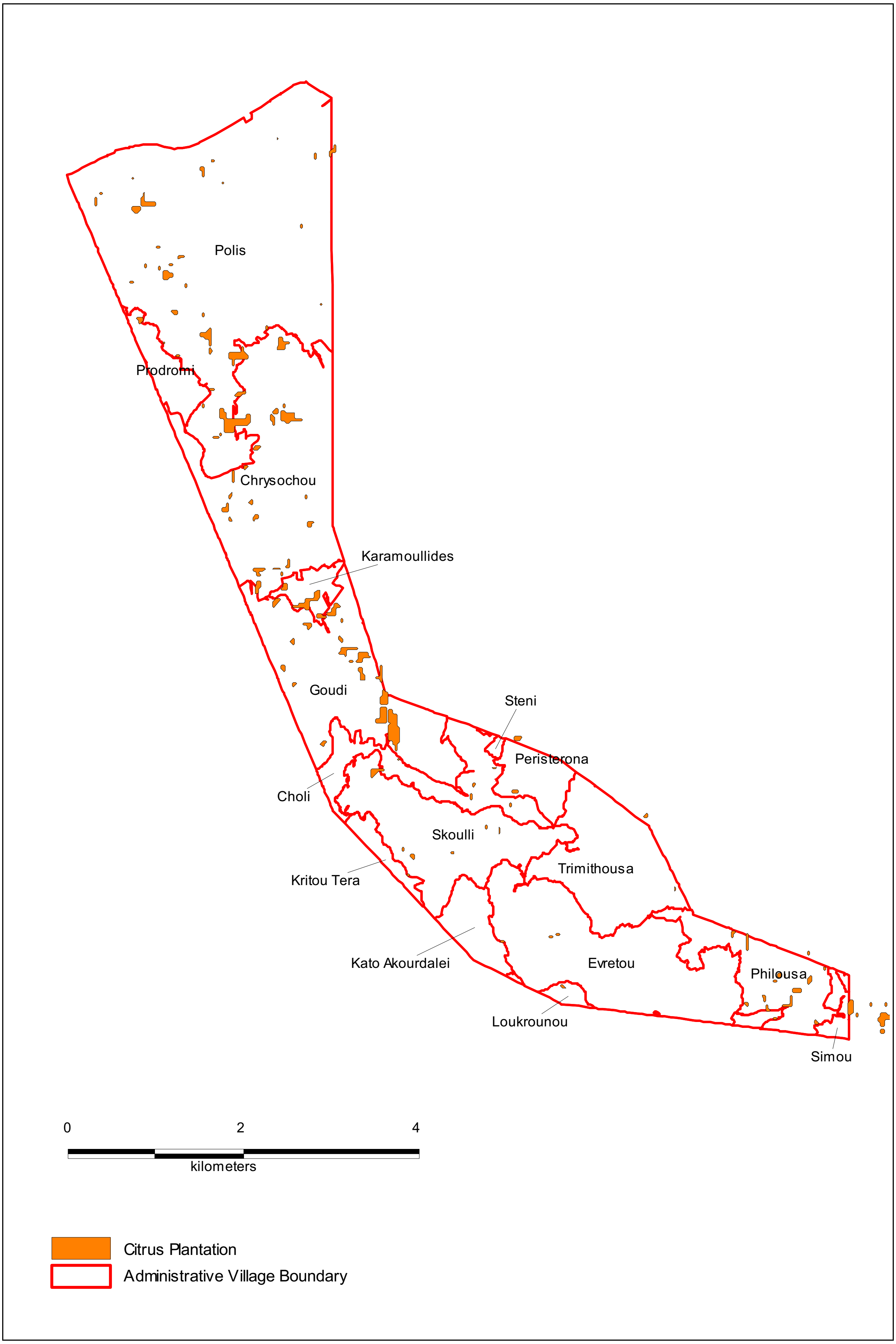
Annex 4-1: Field Survey – WDD Polis Chrysochou: Plots with Citrus Plantations



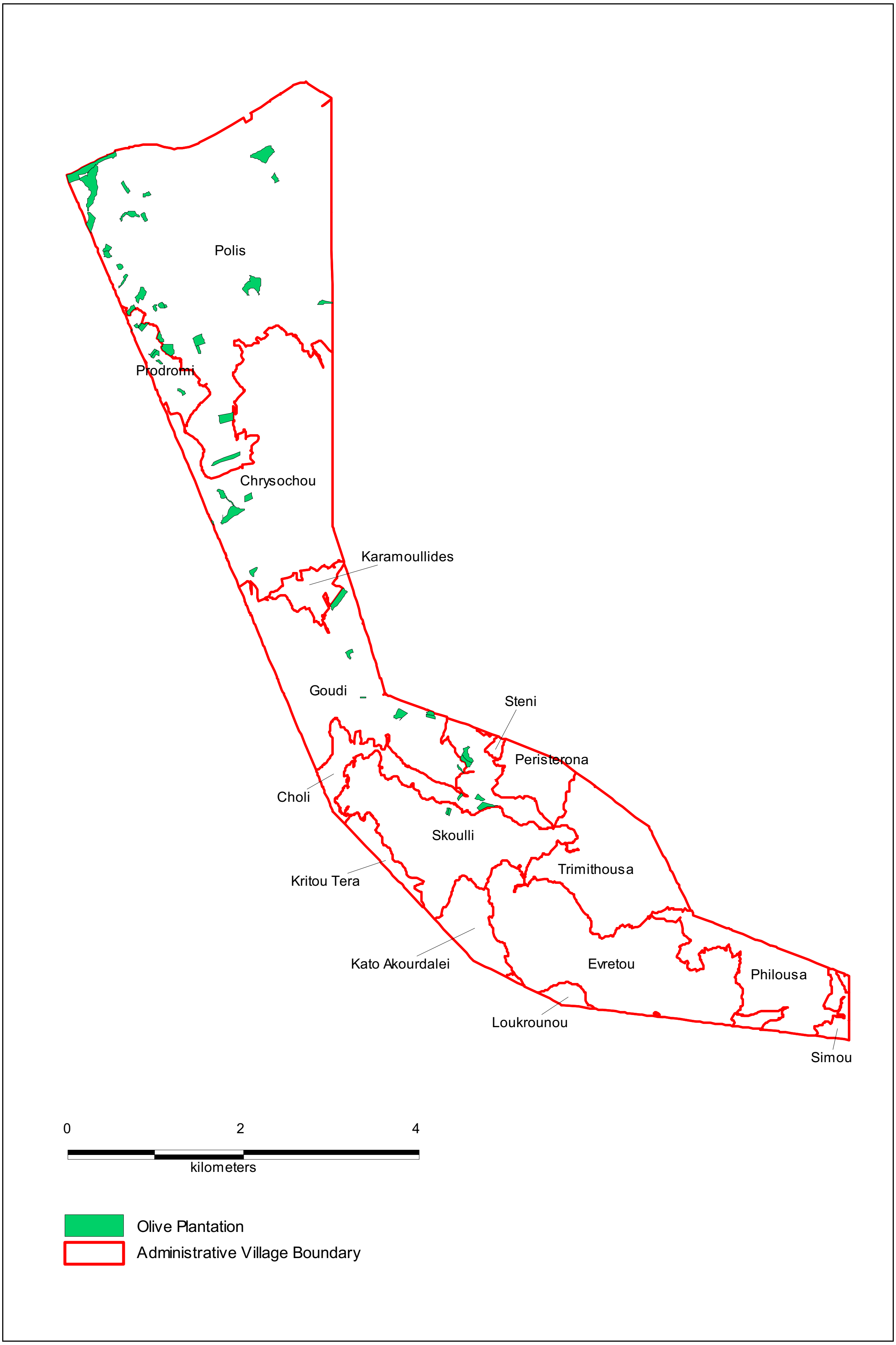
Annex 4-2: Data from Agricultural Department: Plots with Citrus Plantations



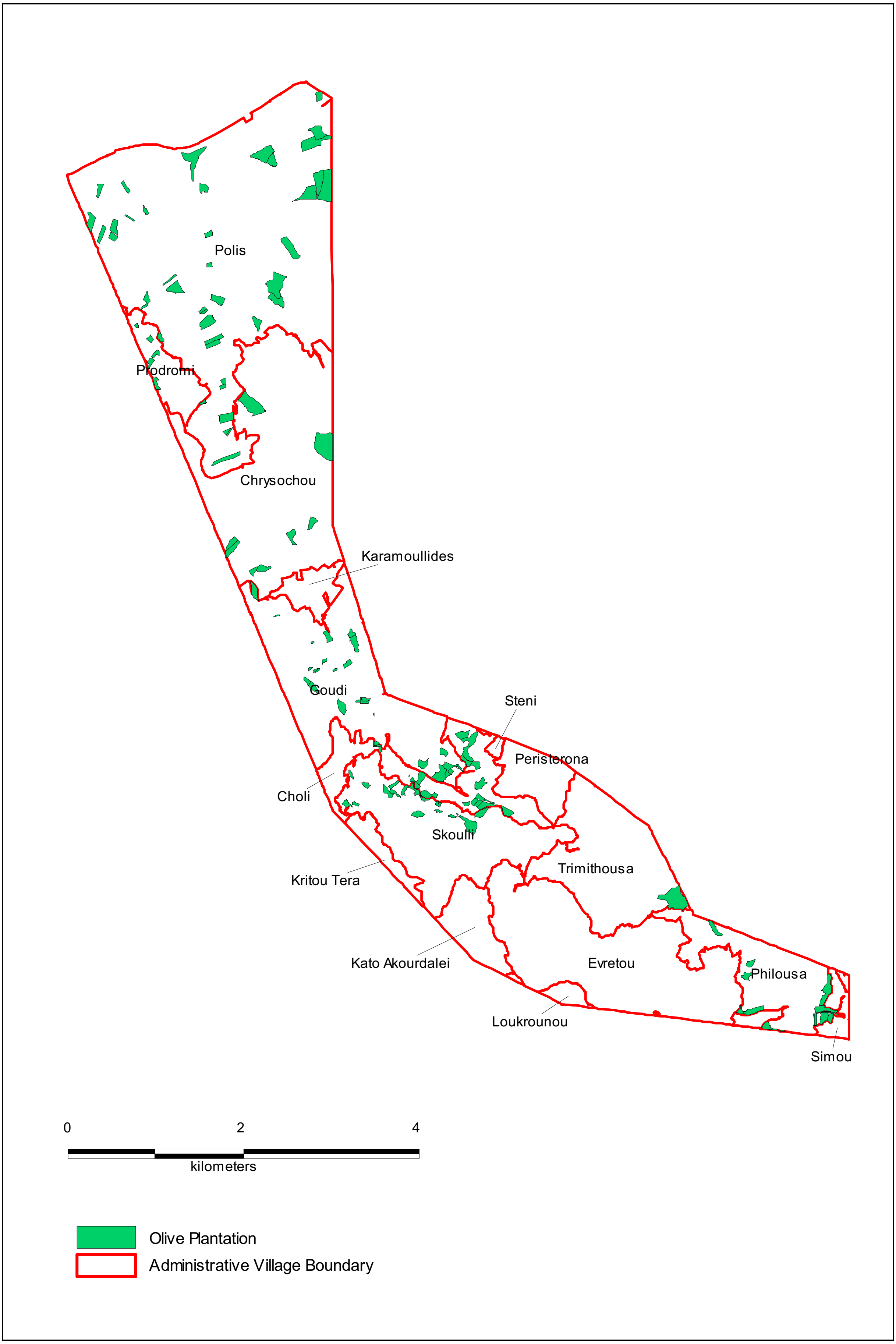
Annex 4-3: IKONOS Satellite Image Analysis: Citrus Plantation Areas



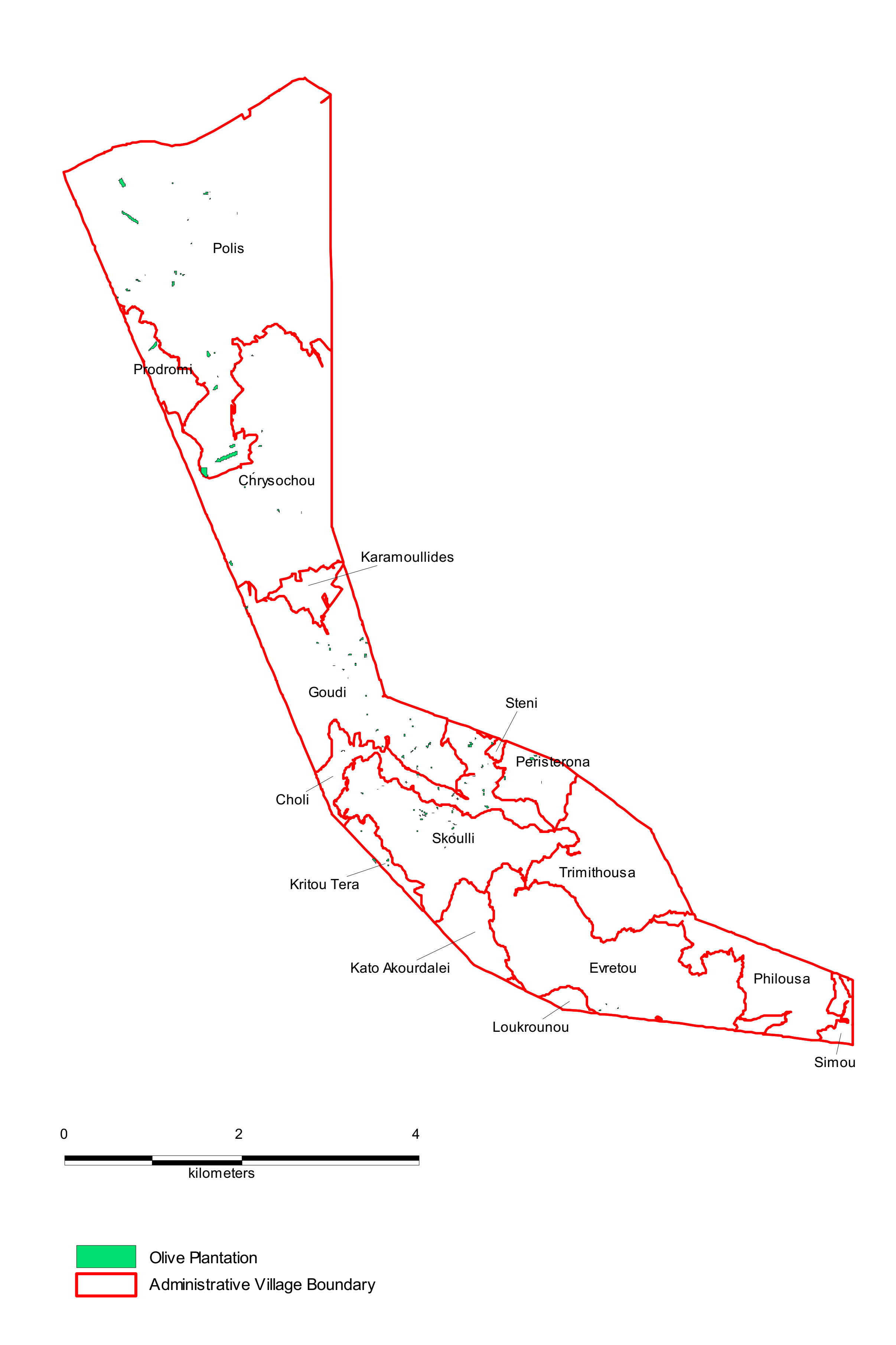
Annex 4-4: Landsat Satellite Image Analysis: Citrus Plantation Areas



Annex 4-5: Field Survey WDD Polis Chrysochou: Plots with Olive Plantations



Annex 4-6: Data from Agricultural Department: Plots with Olive Plantations



Annex 4-7: IKONOS Satellite Image Analysis: Olive Plantation Areas

ANNEX 4

ANNEX 5

Tables presenting the areas of classified crop categories:

Annex 5-1: Cropped Areas for various classified crop categories as obtained from the various sources of data

Annex 5-2: Citrus Areas as obtained from the various sources of data per village boundary

Annex 5-3: Olive Areas as obtained from the various sources of data per village boundary

Annex 5-1

Cropped Areas for various classified crop categories as obtained from the various sources of data

Source of Data		WDD Polis-Chrysochou	Data from Agricultural Dept.	IKONOS RSA	LANDSAT RSA
Land Use Category - Areas in decars (1 decar = 1000m^2)	Citrus	732	900	424	509
	Deciduous	11	32		
	Olives (Irr&Non-Irr)	141	177	58	
	Various Trees	49			
	Vines (Irr&Non-Irr)		216		5.6
	Vegetables	117			
	Tobacco	76			
	Potatoes	26			
	Fodders		14		
	Built-Up			773	1596
	Water-Dam			0.32	407
	Water-Sea			1731	1581
	Forest			201	65
	Grass			3478	5791
	Greenhouse			92	
	White Bare Land				7773
	Fields				5122
TOTAL		**1152**	**1339**	**6757**	**22850**

Annex 5-2
Citrus Areas as obtained from the various sources of data per village boundary

VillageName	VillageCode	WDD - Polis	Agr. Dept	IKONOS *	Landsat
Choli	6338	27	69	29	6
Chrysochou	6341	149	177	91	97
Evretou	6313				2
Goudi	6345	80	238	39	184
Karamoullides	6340	6	15	24	4
Kato Akourdaleia	6334		7		1
Kritou Tera	6336		50	3	1
Loukrounou	6339				2
Peristerona	6321				4
Philousa	6315			6	28
Polis	634301	297	233	174	117
Prodromi	634302	105		50	5
Simou	6310		28	1	15
Skoulli	6337	68	76	3	16
Steni	6368		3		
Trimithousa	6314		4		3
Total		**732**	**900**	**420**	**484**

Note: Areas are given as decars (1 decar = 1000m2)

***) Areas of the IKONOS RSA integrated with the vectorized farm plots**

Annex 5-3
Olive Areas as obtained from the various sources of data per village boundary

VillageName	VillageCode	WDD - Polis	Agr. Dept	IKONOS*	Landsat
Choli	6338	8	25	5	
Chrysochou	6341	12	7	2	
Evretou	6313				
Goudi	6345	10	20	6	
Karamoullides	6340				
Kato Akourdaleia	6334				
Kritou Tera	6336				
Loukrounou	6339				
Peristerona	6321			2	
Philousa	6315		30		
Polis	634301	96	78	33	
Prodromi	634302	13	5	3	
Simou	6310				
Skoulli	6337	3	12	4	
Steni	6368				
Trimithousa	6314		0.4		
Total		**142**	**177**	**55**	**-**

ANNEX 5

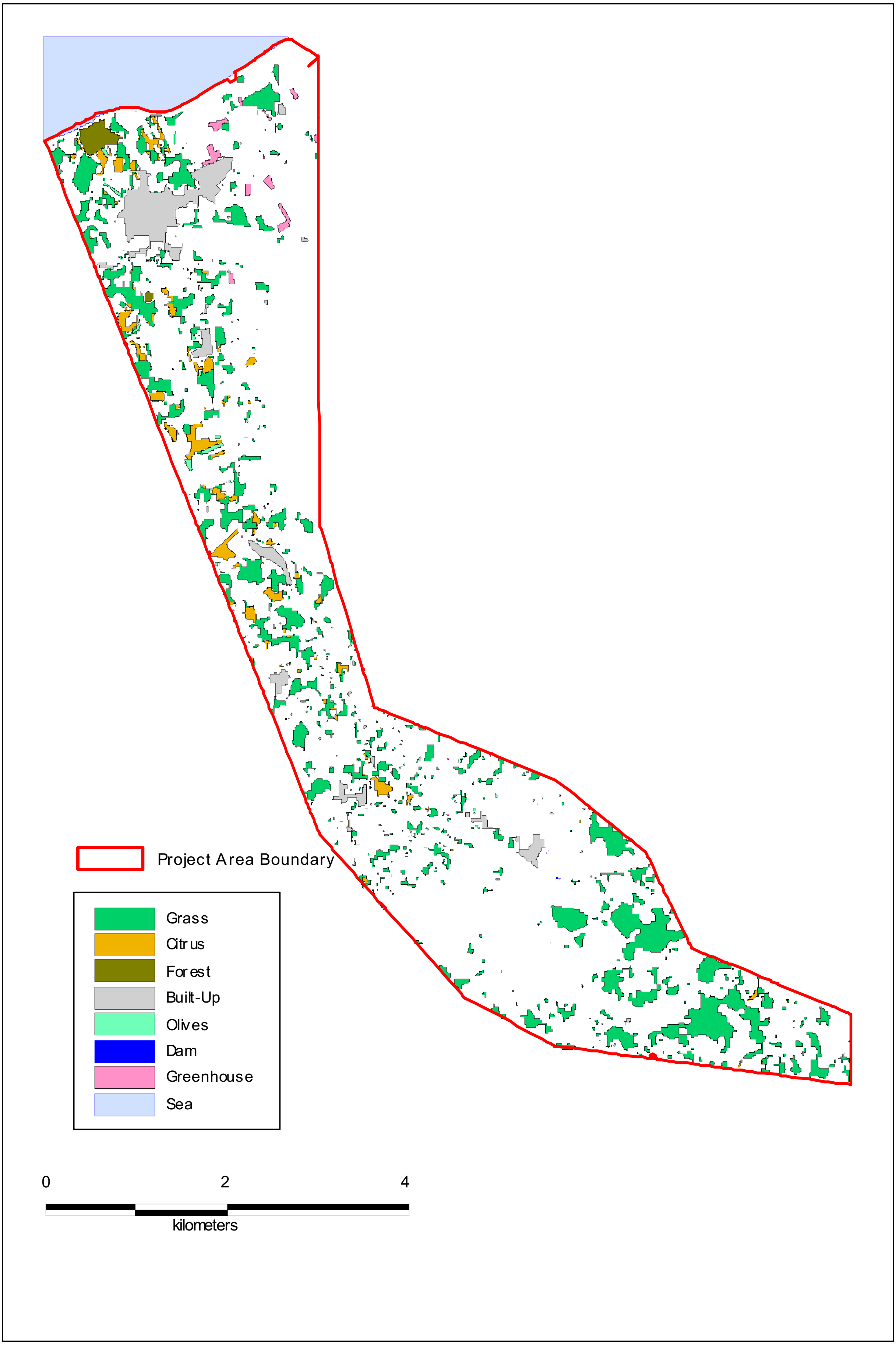
ANNEX 6

Maps showing:

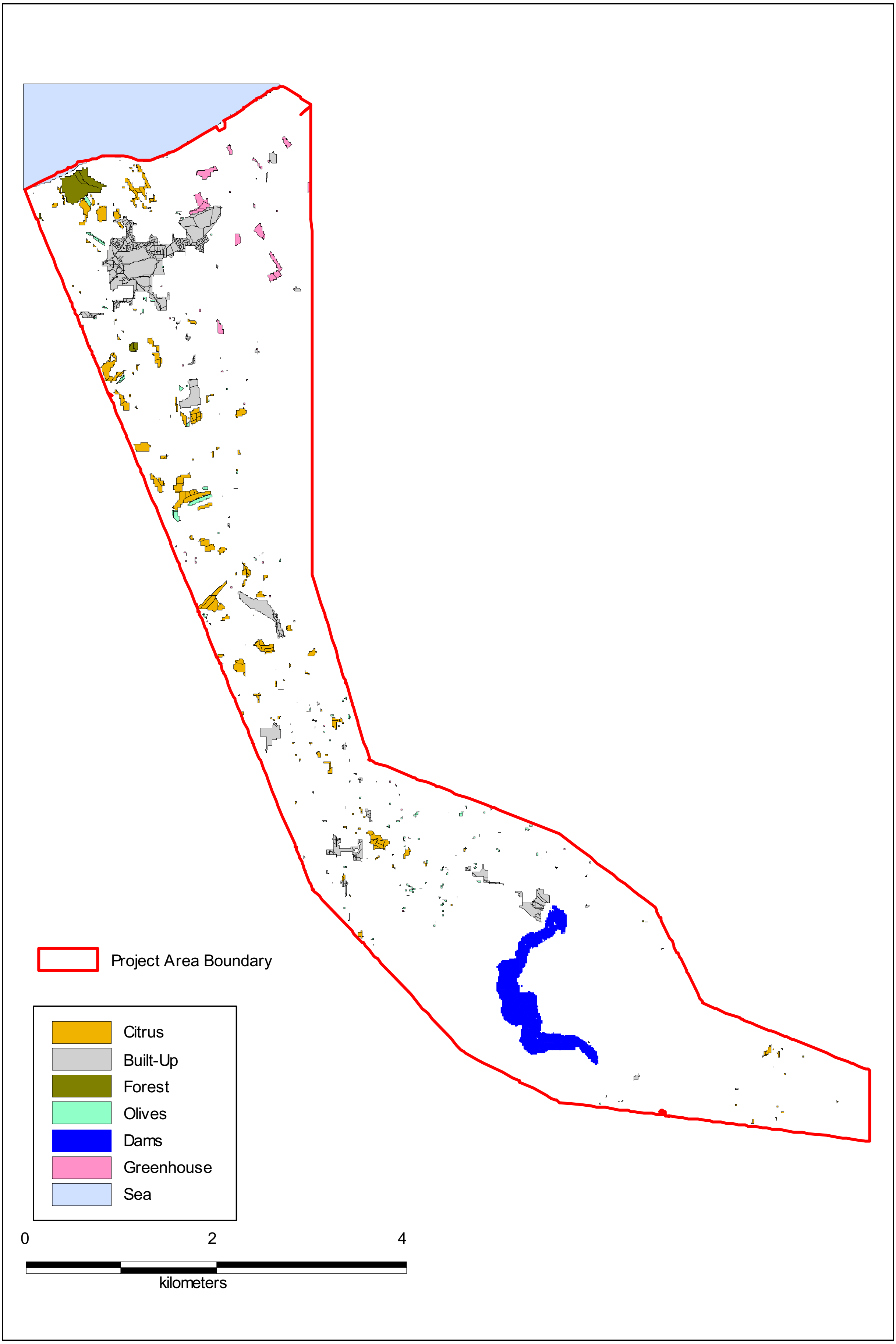
ANNEX 6-1: Classified Areas from IKONOS RSA

ANNEX 6-2: Classified Areas from IKONOS RSA integrated with the vectorized farm plots

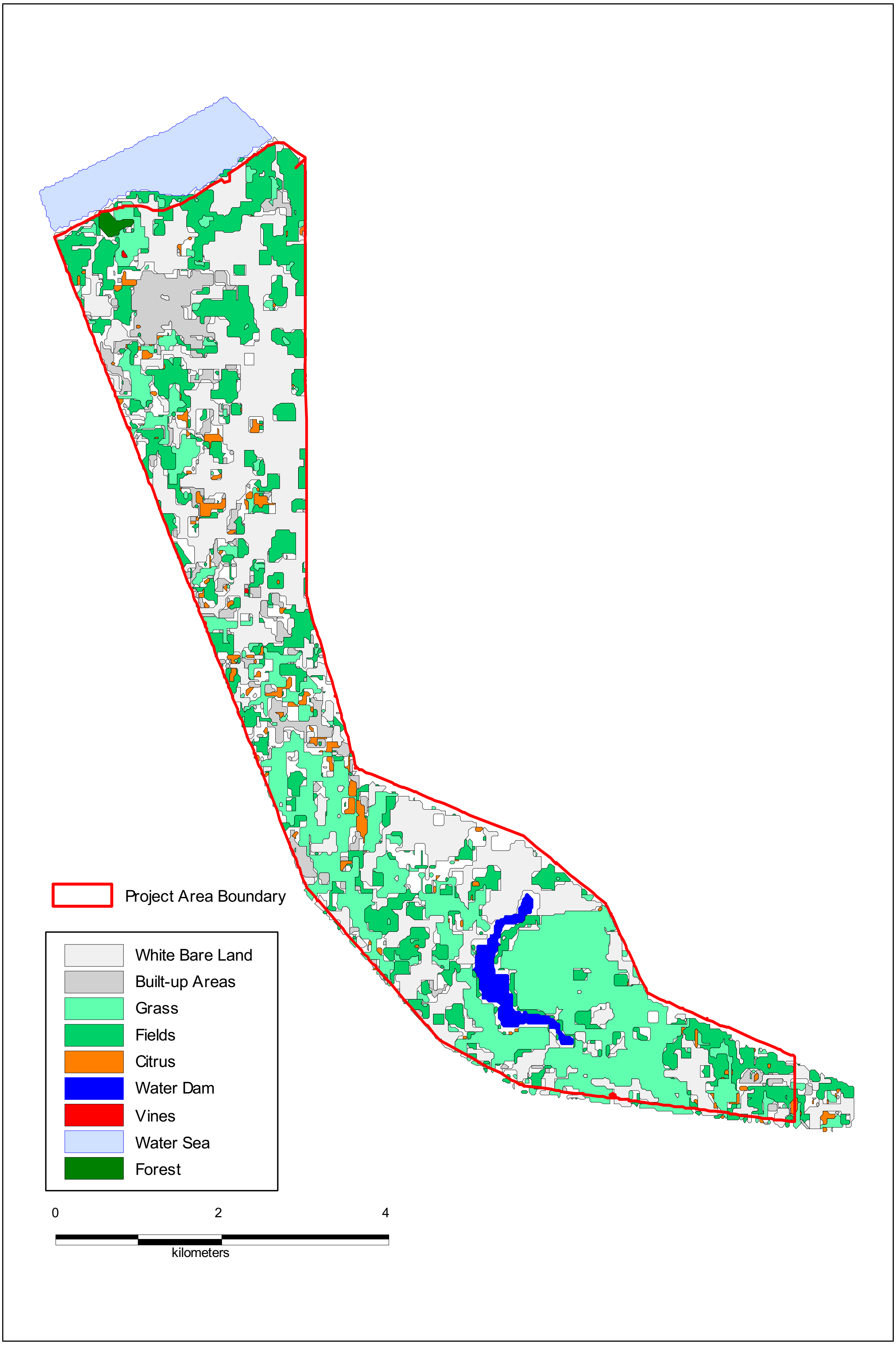
ANNEX 6-3: Classified Areas from Landsat RSA



ANNEX 6-1: Classified Areas from IKONOS Remote Sensing Analysis



ANNEX 6-2: Integration of the Classified Areas from IKONOS RSA with the vectorized Farm Plots



ANNEX 6-3: Classified Areas from Landsat Remote Sensing Analysis

ANNEX 6

ANNEX 7

Agricultural Parcel Identification System

prepared by Kyriakos Alexandrou
Integrated Administration and Control System Section,
Dept. of Agriculture, Lefkosia, Cyprus

ANNEX 7

Agricultural parcel Identification System

1. Pre-processing of images

1.1 Geometric correction

1.1.1 The prescription does not impose a methodology for geometric correction of imagery, but gives recommendations and guidelines in line with it's Quality Assurance (QA) Strategy. The philosophy is to have a set of suitable control procedures, which result in a satisfactory product.

1.1.2 The QA strategy of the EC includes: ITT Technical Specifications and Tender Evaluation; Quality Control (QC) of input data and QC during the geometric correction work (e.g. producing Quality Control Records, QCRs); and finally, an external QC, the measurement of geometric error in the output images.

1.1.3 The allowed geometric error in the output images (and associated Digital Elevation Models, DEMs) are expressed as a maximum permissible "absolute" Root Mean Square Error (RMSE) tolerance of check points, and are stated in the Technical Specifications. The geometrically corrected products and associated DEMs are assessed separately in the three geometric perspectives RMS*E*x, RMS*E*y, and RMS*Ez* 3 .

1.1.4 A product determined outside the tolerance will be returned to the contractor for examination, correction and redelivery.

1.1.5 The above Quality Assurance philosophy is described in more depth in the "Guidelines for Quality Checking of Geometrically Corrected Remotely Sensed Imagery" [Ref. 2], as is the whole process of geometrically correcting aerial or satellite (optical, radar) imagery. Such guidelines have been set up by the EC in order to establish robust methods for effective quality assurance of image geometry for applications related to the management, monitoring and control of agricultural subsidies. A latest version of these guidelines may be retrieved from the Web site hosted by the JRC: http://mars.aris.sai.jrc.it/control/. It must be clear, however, that in the end *the contractor alone is responsible for the accuracy of his produc*t.

1.2 Geometric Correction of Aerial Photography

1.2.1 The high resolution inherent in the aerial photography used in the Parcel Identification Systems (PIS) and/or in the RS Control normally implies ortho-correction. This type of correction eliminates displacements due to image geometry and topographic relief and will produce a resulting image having the same geometric properties as a map projection.

1.2.2 Ortho-imagery produced for the RS Control and/or the IACS (PIS) systems is quality assessed in the same way (see § 2.1.3). The geometric tolerances are however, at present, different depending on whether or not the ortho-photography produced in the RS Control is to be integrated in the IACS (PIS) system, which has a higher accuracy requirement.

1.2.3 In the case of 1:40 000 scale source aerial photos, the required tolerance, as stated in the Technical Specifications, is based on the ASPRS map accuracy standard for 1:10 000 scale maps

(ASPRS 1989 4 , FGDC 1998) and it is known to be achievable if the data capture and processing specification given in the guide-lines are followed.

1.2.4 The RMSE tolerance of the orthophoto product puts requirements on the *input dat*a, on the *ground reference dat*a, on the *DEM* and on *each step of the ortho-correction proces*s, all briefly discussed below.

1.2.5 The input data includes correct choice of film and camera, type of flight navigation adopted, overlap of photography, and scanning issues.

1.2.6 The ground reference data includes Ground Control Points (GCPs), maps, and checkpoints. GCPs need to be chosen of adequate accuracy from the right source (e.g. field surveyed with Differential Global Positioning System, or scaled from maps) and in correct number and distribution, to ensure that the RMSE requirement is not exceeded. Normally GCPs should be *well-defined points* and have accuracy better than half the tolerable RMSE. Furthermore, check points (points used for checking that have not been used in the geometric correction process) should be at least 3 times more accurate than the tolerable RMSE. If a map is used for the acquisition of such points, it should be of a scale satisfying the accuracy requirements.

1.2.7 The DEM used in the ortho-photo production should have height accuracy as stated in the *Technical Specifications* (see also §2.1.3). It is recommended to use automatic stereo-correlation techniques for its generation with subsequent cleaning. The grid spacing is specified according to output scale and terrain but normally a factor of 20 times the output pixel size is sufficient.

1.2.8 Finally, all steps in the ortho-photo correction workflow (e.g. interior orientation, relative orientation, absolute orientation and resampling methods) need to be carefully monitored in order not to exceed the RMSE tolerance.

1.2.9 The Contractor is responsible for performing internal QC, which will result in Quality Control Records (QCRs). The EC may analyze these and check conformity to specifications (and in some cases also, per-form checks on sample intermediate products). One of the most important of these are ground reference check points (coordinates, source, planimetric and vertical quality of point, distribution, and graphic/text description).

1.2.10 The rectified product may finally be checked in an independent external QC. This is carried out on 5-10% of the ortho-image files, on a systematic basis in order to cover the entire block. Additional blocks will also be selected, possibly on a random basis but also potentially to provide closer inspection in areas where problems are anticipated (block borders, or areas where terrain variation is high). A result calculation will be made both at block level and at project level and determine product acceptance. The basis for calculating final image accuracy lies in the identification of checkpoints on image (at least 25 check points per block are required or 9 per photo if working on single photos) and the calculation of the discrepancy for each checkpoint together with an overall RMSE. These calculated values are then com-pared to the tolerable RMSE. Where the calculated RMSE is greater than the tolerable RMSE, the block fails and will be examined, corrected and redelivered by the contractor. Should more than 5% of the blocks that are subject to external QC fail, then all products will be returned to the contractor for further QA.

1.3 Geometric Correction of Optical Satellite Imagery

1.3.1 The characteristics of the optical satellite imagery used in the RS Controls may imply either ortho-correction using orbit/flight parameters and terrain information or a polynomial warp depending on absolute RMSE tolerance. Resolution, terrain variation and view angle influence the geometric correction method as follows :

- resolution < 10m and terrain variation > 250m over the whole image normally implies ortho-correction;
- any resolution and view angle at center of image > 15° from nadir normally implies ortho-correction;
- other terrain and/or sensor configurations normally imply polynomial warp.

1.3.2 The RMSE tolerance on the geometrically corrected product puts requirements on *input dat*a, on *the ground referenc*e, the *DE*M, and on *each step in the geometric correction proces*s, all briefly discussed below.

1.3.3 *Input dat*a: Detailed Input Data Quality Assessment (IDQA) is not required with regards to geometric consistency of satellite imagery; nevertheless, it must be readable, must allow for GCP placement and be of correct format (including view angle, orbit information etc. if ortho-correction is to performed). If the DEM used for ortho-correction is externally procured it must be of sufficient detail, complete, continuous and without any gross anomalies. It should have a height accuracy as stated in the Technical Specifications (see also §2.1.3), and the grid size should be no more than 250 m (preferably 100 m).

1.3.4 *Ground Referenc*e: For satellite images, where the final product need not exceed a quality of RMS*Ex* or RMS*Ey* of 10 m, the most cost-effective option for ground control is topographic mapping. The number of GCP's should be more than 15 per image and should be well distributed (e.g. in a 4x4 grid dividing the image with additional points chosen as near to each corner/edge as possible). The discussion on the accuracy of the GCPs, the checkpoints, and map scale is similar to the one for aerial photography given above. The map scale used should preferably be 1:25 000 or larger.

1.3.5 *The proces*s: The assumption is made that several images are to be corrected covering one target area. Therefore the image with the highest resolution (the "master image") may be corrected first and all the other images may then be registered to this image. However, if this method is applied, the contractor must ensure that the "master image" is corrected with a degree of accuracy that permits subsequent imagery also to meet the "absolute" tolerance specification.

1.3.6 As in the case of aerial photos, the Contractor is responsible for performing internal QC of optical satellite imagery which will result in QCRs. The department may analyze these and check conformity to specifications (and in some cases also, perform checks on sample intermediate products). One of the most important of these are ground reference check points (coordinates, source, planimetric and vertical quality of point, distribution, and graphic/text description).

1.3.7 The rectified product may finally be checked in an independent external QC. This will be carried out on a sample of images (several from same site, and at least one for each type of satellite image corrected). The sample must include the master image if others have been registered to it. The sample site will preferably be located in an area with terrain variation exceeding 100m within 1 km. A result calculation will be made both at image level and at site level and will decide upon product acceptance. The basis for calculating a final image accuracy is similar to the one described above for aerial photography, however the check-points will in the case of satellite imagery be at least 25, positioned as close as possible to intersections. It is recommended to refer solely to the absolute RMSE results for evaluating the quality of image rectification, even for subsequent images in the series. Where, at the end of the external QC, the calculated RMSE is greater than the tolerable RMSE, the image fails and will be examined, corrected and redelivered by contractor. Should two or more images of a site fail, then all products will be returned to the contractor for further QA.

1.4.1 Ortho-correction 5 is required for SAR imagery in all cases where terrain height variation exceeds 50 m over the whole image.

1.4.2 The grid size of the DTM used for SAR ortho-correction should be 50 m or better.

1.4.3 Ortho-correcting SAR data requires the use of separate software modules (usually available as extensions to image processing software or as stand-alone solutions); i.e. it cannot be carried out with ortho-correction software for optical imagery, due to the radically different image formation process.

1.4.4. It is recommended to use nearest-neighbor resampling in SAR geocoding to preserve the radiometry of the original input image.

1.5 Radiometric correction (optical)

Given the variability of the local atmospheric conditions from one day to the next, it is not advisable to apply to the images an atmospheric correction, which is based on meteorological statistics. However, other radiometric correction procedures, like those for variations in sun angle, permit to standardise radiometric properties of multi-temporal data sets and to integrate images acquired by different sensors.

1.6 Radiometric correction (SAR)

1.6.1 *Calibratio*n: SAR images can be easily calibrated. Calibration allows a quantitative evaluation of the backscattering signatures, which is especially important to assess the influence of environmental conditions (e.g. wetness of the soil). For each of the ERS PRI and RADARSAT fine mode products, the data providers supply documentation on the radiometric calibration procedure. If calibration is not performed, SAR signatures can still be used to interpret crop types, for example using supervised classification.

1.6.2 *Speckle filtering* is beneficial to reduce the perceptibly noisy character of SAR data. SAR speckle filtering modules are available in most images processing software, in some cases as part of separate SAR modules. It is advisable to use a so-called GMAP filter, which best retains edge and line features. The settings of the GMAP speckle filter usually include "window size" and "number of (equivalent) looks" (NoL). The window size of the filter depends on the average size of the field in the scene. It is suggested to use small windows (3x3 or 5x5) for areas with small fields, and larger window (7x7 or 9x9) for areas with large fields. The NoL is determined by the resolution of the sensor and SAR processing settings. Changing the value of the window size and NoL for the same SAR image yields different speckle filtering results. Since the scene properties (e.g. field size, shape of boundaries, etc.) are important, it is advisable to run a few tests with the speckle filtering, preferably on several selected sub-scenes, to determine the most appropriate filter settings. These setting should then be used for each additional SAR image for that scene.

In can be beneficial to block average the original input data to improve performance of the speckle filter-ing operation. Block averaging usually results in a higher NoL. In the case of ERS PRI data, a 2x2 block averaging will result in a 25 m pixel spacing product. In the case of RADARSAT fine mode data, a 3x3 block averaging leads to an 18.75 m pixel spacing. Note that block averaging needs to be performed on intensity values, and not on the digital numbers stored in the input image, in order to retain radiometric conformity of the block averaged product. The combined use of multiple images in a time-series is yet an-other technique that can enhance the performance of speckle filters. Speckle filtering, if necessary preceded by block averaging, should be applied *before* geocoding is performed.

2. Ground Data Collection

2.1 As land use statistics are not required for the EAGGF controls, a ground survey can be made using "transects". A sufficient number of parcels to survey should be fixed, covering all land uses and farming practices of the site, so providing a suitable training set for the automatic classification or for photo-interpretation. It would also be useful to extract from the dossiers parcels of the uncommon crops. This would allow all crops to be present in the parcel sample. If the processing of applications submitted for the 2000 campaign has already been initiated when the ground survey is organized, one could envisage to include already identified "problem" plots into the sample. This is a way to combine the ground data collection and the rapid field visits.

2.2 It would also be useful to schedule the ground survey and a multi-spectral window opening during the same period, in order to obtain simultaneous information from the ground and the satellite. The planning of the survey should be a compromise between the crop calendar and the dates planned for photo interpretation. If necessary two surveys done on different dates should be considered, especially if the control is done in two phases (see §8). An a-priori stratification would help to locate the areas of interest.

3. Locating and digitising the declared parcels

3.1 Parcels to digitise

3.1.1 Double digitization should be avoided as much as possible. Some Administrations require this from the contractor, because their own digitization is available too late. A careful planning of the preparatory work could perhaps avoid this drawback, without endangering the necessary confidentiality on the location of the control sites.

3.1.2 All parcels of the farm should be listed in the declaration, even though some of them will not be eligible for subsidy. A farmer may declare a plot, but not apply for subsidy for this plot, in order to qualify as "small", or the crop is not eligible (sugar beet, potatoes, etc.). It is recommended also to digitize these plots. This is, in effect, the only method, which makes it possible to perform cross-checks, for example that the sum of the areas declared tallies or that the same plot is not declared eligible by another farmer. Digitizing all parcels is also required, if it is envisaged to re-use the digitized parcels limits.

3.1.3 The parcels digitized but not eligible for subsidy are simply stored in the database. They can be classified but do not have to be photo-interpreted. They will only be processed if a problem is revealed: double declaration, area or limit incompatibility, etc. It is also important that they be displayed as a background on the field control documents delivered to the Administration.

3.2 Digitizing

Digitizing is one of the most time-consuming tasks of the Control with Remote Sensing. In cases where the delivery of the applications has been scheduled late in the season, it is in general advantageous to use the cartographic information of the previous year to begin this work.

3.3 Updating

After receipt of the current year's declarations, the plot limits shall be updated according to the information provided in the new application.

4. Editing the parcel limits from the images

4.1 Once digitized, the plot limits are overlaid onto the images and, if necessary, the vectors are readjusted (edited or "validated") manually, preferably using ortho-images or, if appropriate, panchromatic SPOT or IRS images. The most effective method is to be able to handle either all the vectors or each plot separately. The readjusting phase is necessary to enable the photo-interpreter to devote time only to land use determination at the Computer Assisted Photo-Interpretation (CAPI) stage. This is necessary primarily for automatic classification so that the digitized plot vector data superimposes perfectly with the series of images used for the classification.

4.2 In all cases, the method of data processing must permit cross-checking in each control site, so revealing any problems of limits between adjacent parcels of different dossiers, or allow the readjustment of the geometry of the neighboring cadastral maps, etc.

4.3 Even if ortho-photo flights are not planned for the current year, it would be useful, at least for the areas with small parcels, to check if recently acquired high quality aerial photographs are available.

5. Area calculation

5.1 Direct determination of areas from the maps attached to the application must be avoided, as the digitized boundaries are only to be used as a guide for localization on the image. Also, many of these maps contain considerable inherent physical errors (due to photocopying, for example). Similarly, the digitization of the plot limits directly from the satellite image, without precise cartographic reference, is definitely not advised, except in the case of *"îlot*s" (parcel blocks), where it is not possible to work otherwise.

5.2 The areas should be measured from the digitized plot limits, using precise and recent cartographic references, after validation on the satellite images, or possible modification at the time of the photo-interpretation. Moreover, the areas should be measured from the vector data and not by counting the pixels. An assessment of the digitizing error will be useful where tolerances at the parcel level are used.

6. Determination of land use

The identification of land use can be done either entirely by CAPI, or by a combination of automatic classification followed by CAPI.

6.1 Automatic classification

6.1.1 Image classification can be used purely as a guide to help the interpreter at the CAPI stage or as a means of automatically identifying mismatches in the land use of a parcel. The use of automatic classification should be reserved for areas where the size and the shape of the parcels make it possible to obtain a sufficient number of pure pixels within the parcel boundaries. Automatic classification should be used only for the predominant crop groups and for homogeneous land use (i.e. not for fallow land or set-aside, which may have different land covers). Automatic classification should preferably be performed with multi-channel imagery, rather than single channel imagery. Multi-channel imagery can consist of single-date multi-spectral data sets, multi-date (selections of) multi-spectral data, or any other combination of spectral or fused (e.g. PAN and multi-spectral, or SAR and multi-spectral) data sets. The use of very high-resolution ortho-images for automatic classification should be considered with care, as the high level of detail in this kind of imagery tends to result in increase heterogeneity inside field boundaries.

6.1.2 In the course of the Control program, a number of methods for automatic classification have been pro-posed. These range from simple pixel based unsupervised classifications to supervised parcel-based classifications. Since the work carried out under the Control program allows for the inclusion of detailed *a priori* information (e.g. parcel boundaries, results from field surveys, application data) the European Commission recommends the use of supervised classifications, since they generally allow both the parameterization of the classification to selected crop classes and a consistent *a posteriori* evaluation of the classification re-sults. In a pixel based automatic classification, commission to (or omission from) a class is carried out per pixel. After that, a relative pixel count within the parcel boundary determines whether that parcel belongs to the land use class or not. For instance, if 75% of pixels inside the boundary belong to class "wheat", the parcel may be accepted, to have been classified as wheat (after which comparison to the declared crop class can be made). Since at this stage, parcel boundaries are supposed to have been adjusted to the right parcel outline (e.g. based on ortho-imagery or recent PAN images), the other classes are usually due to spectral confusion. This, on its turn, may be due to within-parcel variability of the multi-channel signature, spectral heterogeneity of the class, the quality of the original data, the selection of the channels, or the parameter.

For example, a grassland parcel that is partly cut may appear in two distinct classes due to differences in vegetation coverage. Parcel based classifications typically aggregate the multi-channel data for all pixels within the parcel boundary first (usually after exclusion of a pixel buffer around the parcel boundary) and then perform the classification. Thus, only if the aggregated multi-channel signature fulfils the commission criterion of the classification will the parcel be labeled with the reference class. Also in this case, omission can be due to similar factors as in the pixel-based classification. For instance, a oil seed rape parcel that is not already flowering, where most others are, may be omitted from the class “oil seed” if the classification has been parameterized to detect “flowering oil seed” due to the availability of an optical image that is acquired at flowering stage.

6.1.3 For either of the two supervised classification methods (pixel based or parcel based), training data are needed to ‘seed’ the classifier. Data from field surveys at the early stage of the contractor’s work (e.g. for training of CAPI staff) are usually best suited to this purpose, since they form an independent data set from the application data. Field surveys should be aimed at providing a representative set of known locations for the main cultivations and land use classes, and preferably covering the characteristic terrain conditions in the site. Ideally, a subset of the survey data are used for training, while the remainder is used to evaluate the quality of the classification.

If only limited training data from field surveys are available, an alternative source of training data may be drawn from the application data. The use of this alternative should be considered with care. The Commission recommends restricting this method to the major crops, for which a large number of parcels have been declared. The selection of the application data sample is based on the plausibility that the majority of the declared parcels are correct. A statistical outlier analysis may be used to reduce the risk of selecting into the sample parcels with signatures that deviate from the common signature (and are, therefore, likely candidates for further CAPI analysis).

6.1.4 For any classification result, the classification accuracy should be analyzed in at least two ways:

- A classical evaluation of commission and omission errors in the form of an statistical confusion matrix analysis (or coefficient analysis). This is usually a good indicator for the quality of the classification, and can be used to quantify classification performance for different channel or class combinations. This analysis is equally applicable to pixel based and parcel based classifications.
- A sample of automatically classified parcels (of e.g. 5-10%) should be analyzed using CAPI to determine possible anomalies in committed parcels and to highlight the reasons why certain parcels may be omitted. Omitted parcels are usually committed to another class, which make a cross-analysis possible.

6.1.5 Automatic classification’s main purpose is to optimize the CAPI work.

A reliable classification result permits the contractors to concentrate CAPI on parcels for which the classification result does not correspond to the declared class or land-uses that have not been included in the classification. In case automatic classification is used in the control program, it is of the utmost importance that the contractor fully de-tails the methodology used and includes an analysis of the classification results obtained. It is, furthermore, required that the contractor flags automatically classified parcels, which have not also been subject to CAPI, with a special code.

6.1.6 A parcel has to pass to the CAPI stage, if it has not been classified or if the classification does not correspond to the declared Land use. Examples of such cases are (but not limited to):

- the corresponding radiometric classes have not been identified during the classification (e.g. rare type of crop);
- for pixel based classifications: the relative pixel count of correctly classified within the parcel has not reached the pre-defined limit (e.g. 75% or other choice);
- for parcel based classification: the classification does not correspond to the declaration;
- the parcel is declared as set-aside.

6.2 CAPI

6.2.1 The CAPI stage makes it possible to make a decision on all declared parcels that were not classified automatically. Similar to the parcel editing stage (see §5), it should be possible to edit each parcel individually, so permitting it to be modified, moved or subdivided. It must also be possible to check that no other parcels totally or partially overlap with it.

6.2.2 During the photo-interpretation stage the interpreter must be able to simultaneously display at least 4 images (3 multi-spectral and one panchromatic image or the aerial photography, or a classification) and also the vector and alphanumeric data for each application. In case image data with more than 4 bands (e.g. SPOT XI, IRS-1C and LANDSAT TM) are used, it is advisable to select the band combinations that contain the most significant information. This usually includes the near-infrared band, the mid (or short-wave) infrared and one of the visible bands. The most significant bands can be selected from a simple correlation or principal component analysis. Alternatively, if less than 4 input images are used to check the crop type, the remaining views can be used to display alternative band combinations of the same image. Since images are all ortho-corrected, the use of multi-temporal combinations of selected image bands (e.g. all NIR, or all SWIR) is another option. The use of multi-temporal index images (e.g. NDVI image) is yet another possibility.

6.2.3 Where *"îlots"* are used and the crops within the *"îlo*t" are not located, the operator must "re-construct" the crop plan within the *"îlo*t". It is then necessary to photo-interpret partially "blindly", which slows down the task considerably. In this case, one must be able to flag the parts of the *"îlo*t" already processed. The sum of the areas of the different land uses found may not exceed the total surface declared for that *"îlo*t".

6.2.4 It is advisable to plan the use of radar data well in advance and in view of the specific requirements for processing the data and limitations for identifying crops. In order to substitute one optical image by radar imagery, several radar images may be necessary to obtain significant results. In general, land-use determination shall be done by photo-interpretation. The most practical solution would be to produce a multi-temporal radar classification for the photo-interpreter, displayed in a separate window.

6.3 Interpretation of SAR data

6.3.1 For proper use in a CAPI environment, at least two (2), but preferably three (3) SAR images should be combined in an image composite. In some cases, a single SAR image combined with co-registered optical image channels may provide a workable solution. If only 2 SAR images are available, a composite can be generated with a difference image as the third band. This, however, implies that the 2 images have been calibrated.

6.3.2 In general, SAR backscattering of agricultural crops is dependent on the depth and status of the crop canopy and characteristics of the (underlying) soil. Since soil moisture conditions have a significant impact on backscattering, site conditions at the time of acquisition must be known, for example from meteorological records. Wet conditions are usually preferable for SAR image quality, especially when early season images are used (March to May). Also note that the local incidence angle, which is determined by the nominal incidence angle of the SAR sensor and the local slope, has a noticeable effect on the backscattering signature. Information on the local slope can be derived from the DTM.

6.3.3 Image interpretation may benefit from accumulated knowledge on SAR signatures analysis for crops that is available in the literature. Experience with long term SAR data series has shown that SAR data use can be especially beneficial for separating cereals, oil seed rape, grass land and the several types of summer crops.

7. Two-phase controls

7.1 In this process, which is applicable where the "summer" (i.e. spring-sown) crops are important, the dossiers are separated into three categories according to whether they comprise of (1) only winter crops, (2) only summer crops, or (3) both. Two methods are possible for the third category, which implies that the results shall be delivered to the Administration in two phases. This should be agreed between the Administration and the contractor.

7.2 The first category (only winter crops) will normally be processed and delivered first, so as to provide the Administration with the first results before crops are harvested. Conversely, the second category (only summer crops) will be delayed whilst waiting for a summer image, and the results delivered thereafter.

7.3 Regarding the third category, it will be photo-interpreted for winter crops with the first category. Where possible, a plausibility analysis will be made for the summer crops (for example bare soil expected for these crops).

7.3.1 It may be agreed that the field checks of this category will only be directed towards parcels of winter crops. In this case, the results of these checks are sent to the contractor, who will integrate them into the control process for the summer crops, in order to enable him to give a complete diagnosis for the file. Conversely, early field checks can cover all the plots, including those of summer crops, non-or partially photo-interpreted, so as to conclude this dossier without compelling the contractor to process it twice.

7.3.2 Alternatively, rapid field visits may be systematically organised for the parcels declared sown to summer crops in the "mixed" dossiers.

7.4 Similarly, it is possible to extract from the sample the applications on which clear errors of area were demonstrated (see §5.4.3 of the *Technical Specification*s). This decision can be made early from the pan-chromatic image. This also makes it possible to check these applications on-the-spot, without waiting to photo-interpret the land use. If the declared land use is checked on-the-spot, these applications do not have to pass through the photo-interpretation stage.

7.5 These various possibilities permit early controls and a more even spread of the field checks. It also improves the quality of the diagnosis, due to the use of an image planned especially for the summer crops.

7.6 If these options are chosen, they must be discussed and arranged with the Administration, especially for the production of the field documents. Should complete dossiers be verified in the field, care must be taken to give the inspectors field documents where all parcels of those dossiers have already been located.