LIFE ENVIRONMENT STRYMON

Ecosystem Based Water Resources Management to Minimize Environmental Impacts from Agriculture Using State of the Art Modeling Tools in Strymonas Basin

LIFE03 ENV/GR/000217

Task 2. Monitoring Crop Pattern, Water quality and Hydrological Regime

Crop pattern identification in Strymonas basin using satellite image analysis
Volume 2 (year 2005)

Period covered by the report: from 1/9/2004 to 31/8/2005

Date of submission of the report: 31/1/2006

THE GOULANDRIS NATURAL HISTORY MUSEUM
GREEK BIOTOPE / WETLAND CENTRE

The present work is part of the 4-years project: "*Ecosystem Based Water Resources Management to Minimize Environmental Impacts from Agriculture Using State of the Art Modeling Tools in Strymonas Basin*" (contract number LIFE03 ENV/GR/000217). The project is co-funded by the European Union, the Goulandris Natural History Museum - Greek Biotope/Wetland Centre (EKBY), the Prefecture of Serres – Directorate of Land Reclamation of Serres (DEB-S), the Development Agency of Serres S.A. (ANESER S.A.) and the Local Association for the Protection of Lake Kerkini (SPALK)

This document may be cited as follows:

Apostolakis A. N. 2006. Crop pattern identification in Strymonas basin using satellite image analysis**.** Volume 2. Greek Biotope/Wetland Centre (EKBY). Thermi, Greece. 32 p.

PROJECT TEAM

Greek Biotope/Wetland Centre (EKBY)

Dimitrios Papadimos (Project Manager)
Iraklis Chalkidis (Agricultural Engineer)
Antonios Apostolakis (Geographic Information System Expert)
Eleni Hatziiordanou (Geographic Information System Expert)

Prefecture of Serres – Directorate of Land Reclamation of Serres (DEB-S)

Christos Metrzianis (Scientific Coordinator)
Athanasios Taousianis (Scientific Coordinator)

CONTENTS

CHAPTER 1

INTRODUCTION

The aim of this work was to estimate the vegetation patterns and areas of the total study area. To achieve this task we used photo interpretation techniques for remote sensing data.

The Life Strymon project overall objective is to promote the sustainable management of surface waters and groundwater in Strymonas River Basin, assisting the implementation of the Water Frame Directive. (Chalkidis, at al. 2004. Water Quality and Hydrological Regime monitoring network.)

The identification and spatial distribution of crops in the Strymonas River Basin in early summer, is indispensable information for wise water usage during the months of July and August. During these months, we have the maximum demand for irrigation water. A detailed water distribution plan must be designed based on the crops water demand and the available water resources.

Remote sensing offers some relative fast and cost effective methods for crop identification using satellite image data. So it covers two major demands of the project: To have the spatial distribution of crops and to have them early in summer so that we can effectively design a water distribution plan.

CHAPTER 2

MATERIALS AND METHODS

The method followed, can be described in the following general steps:

1. Data acquisition
2. Signature collection from the field
3. Data preparation
4. Data processing
5. Extraction of results

2.1 Image acquisition

For the purposes of the Life Strymon project, 8 panchromatic satellite images that cover the whole study area were purchased from SPOT Imagery (Satellite Pour l' Observation de la Terre), under exact acquisition programming request. More precisely, 4 sets of images were purchased, each one including 2 scenes, one from the northeastern part and one from the southwestern part of the study area. SPOT imagery was selected because of the moderate spatial resolution (10m x 10m), reasonable price, data availability and spectral bands.

The image acquisition was programmed for the spring and summer of 2004 and the summer of 2005, in order to avoid cloud and ice coverage. The programming request included detailed descriptions and technical requirements of the imagery needs, such as survey period, survey area and repeated acquisitions at specified time intervals for crop monitoring. Most of the images were acquired by SPOT-4 and some by SPOT-5, depending on the time availability of the satellite's pass at the requested time period. Table 2.1.1 shows technical information and exact acquisition date and time of the satellite images.

Table 2.1.1 Technical information and exact date and time of the acquisition of the eight SPOT images.

Set	Scene	Satellite	Instrument	Resolution	Acquisition date	Acquisition time
1	1	SPOT 4	HRVIR 2	10 m	23-April-2004	09:44:54
1	2	SPOT 4	HRVIR 1	10 m	29-April-2004	09:29:25
2	3	SPOT 4	HRVIR 1	10 m	25-May-2004	09:29:34
2	4	SPOT 4	HRVIR 2	10 m	14-June-2004	09:45:09
3	5	SPOT 5	HRG 2	10 m	14-July-2004	09:41:40
3	6	SPOT 5	HRG 2	10 m	25-August-2004	09:34:04
4	7	SPOT 5	HRG 2	10 m	22-June-2005	09:43:44
4	8	SPOT 4	HRVIR 2	10 m	9-July-2005	09:46:14

All images were preprocessed at Level 1A by SPOT Image France. Thus, a minimum radiometric correction was performed to them. This included the application of a linear model to compensate instrument effects and distortions, which are caused by differences in sensitivity of the elementary detectors of the viewing instrument.

2.2 Image preprocessing

The two SPOT images from set 4 that were used to identify the crop patterns of 2005 were firstly georeferenced to the Greek Geodetic Reference System EGSA΄87[1] using ERDAS IMAGINE version 8.4. “Image to map” and “image to image” coordinate transformations were applied for the georeference, using well defined ground control points from topographic maps (scale 1: 50.000). The first order polynomial method was preferred for the transformations, because of the suitability of this method when dealing with relatively flat areas, such as is the case of the Strymonas River basin. The bilinear interpolation was selected for resampling the images, because of its higher spatial accuracy. Figures 2.2.1 and 2.2.2 show the images which resulted from that procedure (Hatziiordanou at al. 2004. SHYLOC Implementation in Strymonas Basin - Volume 1.)

[1] The Greek Geodetic Reference System (EGSA΄87) is a Tranverse Mercator projection that uses the spheroid of GRS80 and a scaling factor of 0.9996. It is the main reference system that is used in Greece

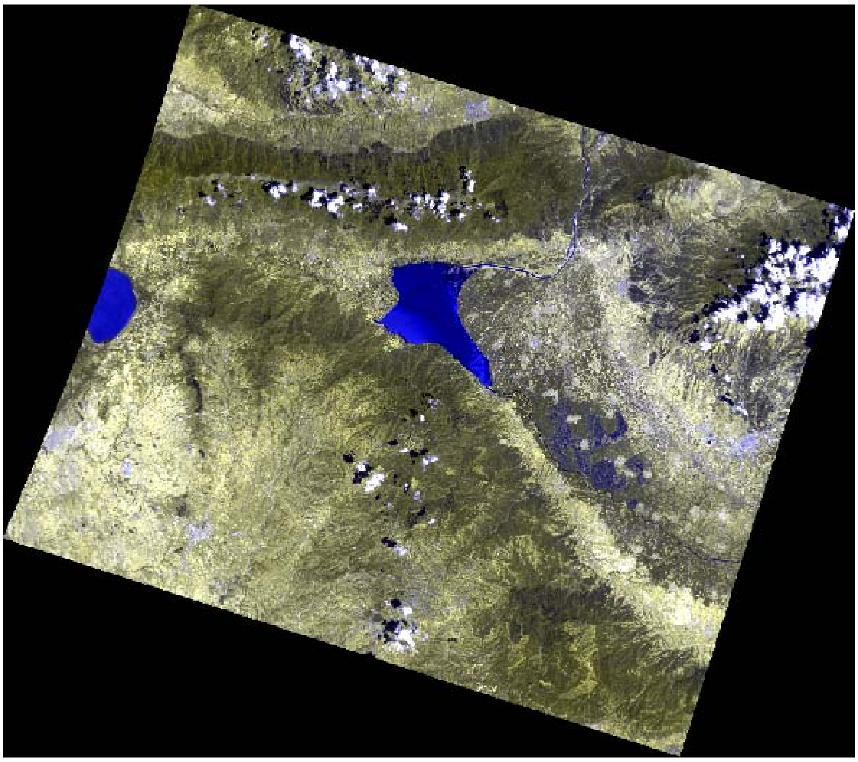

Figure 2.2.1 Scene 7 (June 22, 2005) from the NW part, georeferenced to EGSA´87.

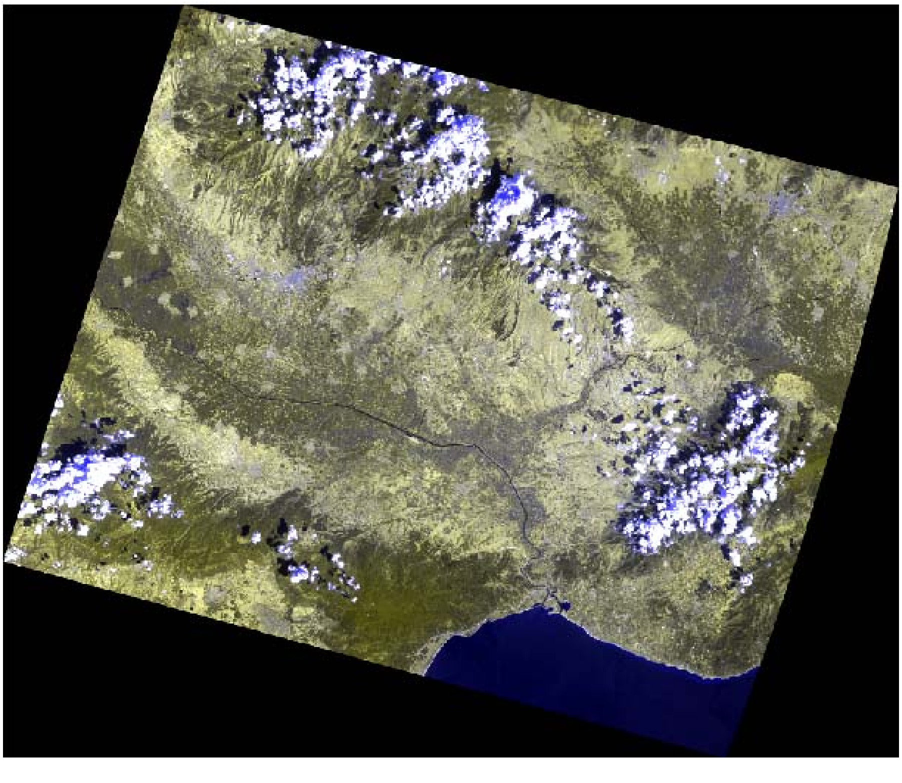

Figure 2.2.2 Scene 8 (July 9, 2005) from the SE part, georeferenced to EGSA´87.

2.3 Additional materials used

In addition to the satellite images, which were the primary source of spatial data, the following hardware used to accomplish the task:

- Computer system with Pentium/2.8 CPU, 1,5GB RAM, 300GB total disk space and windows XP operating system
- ArcGis 9.0 GIS software (both desktop and workstation)
- ArcPad V.6.0.1
- Erdas Imagine V. 8.4
- ArcView 3.2 with Image Analysis extention
- Microsoft office 2003 pro, office application.
- Trimple RECON handheld computer
- Pertec GPS system.
- 4MP digital camera (Olympus 770)
- Tape recorder

2.4 Signature collection

Two field visits were made in 1/8/2005 and 10/8/2005 for vegetation signature collection.
Using a suitable vehicle, we covered a distance of more than 350 km for each visit. A total of **164** signatures were collected from **12** different crop samples. The position of all these signatures was recorded using the GPS and ArcPad system.
A complete tracklog file from the GPS was also collected with a 10 sec time step. In this file the time and position of the GPS was recorded every 10 seconds and when the accuracy of the GPS was less than 12 m.
Additionally, detailed descriptions of the signatures were recorded.
More than 80 photographs were taken during each visit from the vegetation signatures.

Table 2.4.1 Samples per crop collected from the two field visits.

Corp	**Number of samples**
Maize	36
Tobacco	17
Cotton	32
Alfalfa	15
Rice	11
Poplar plantation	12
Sugar beets	21
Wheat	7
Tomatoes	2
Olive groves	5
Walnut groves	3
Almond groves	3

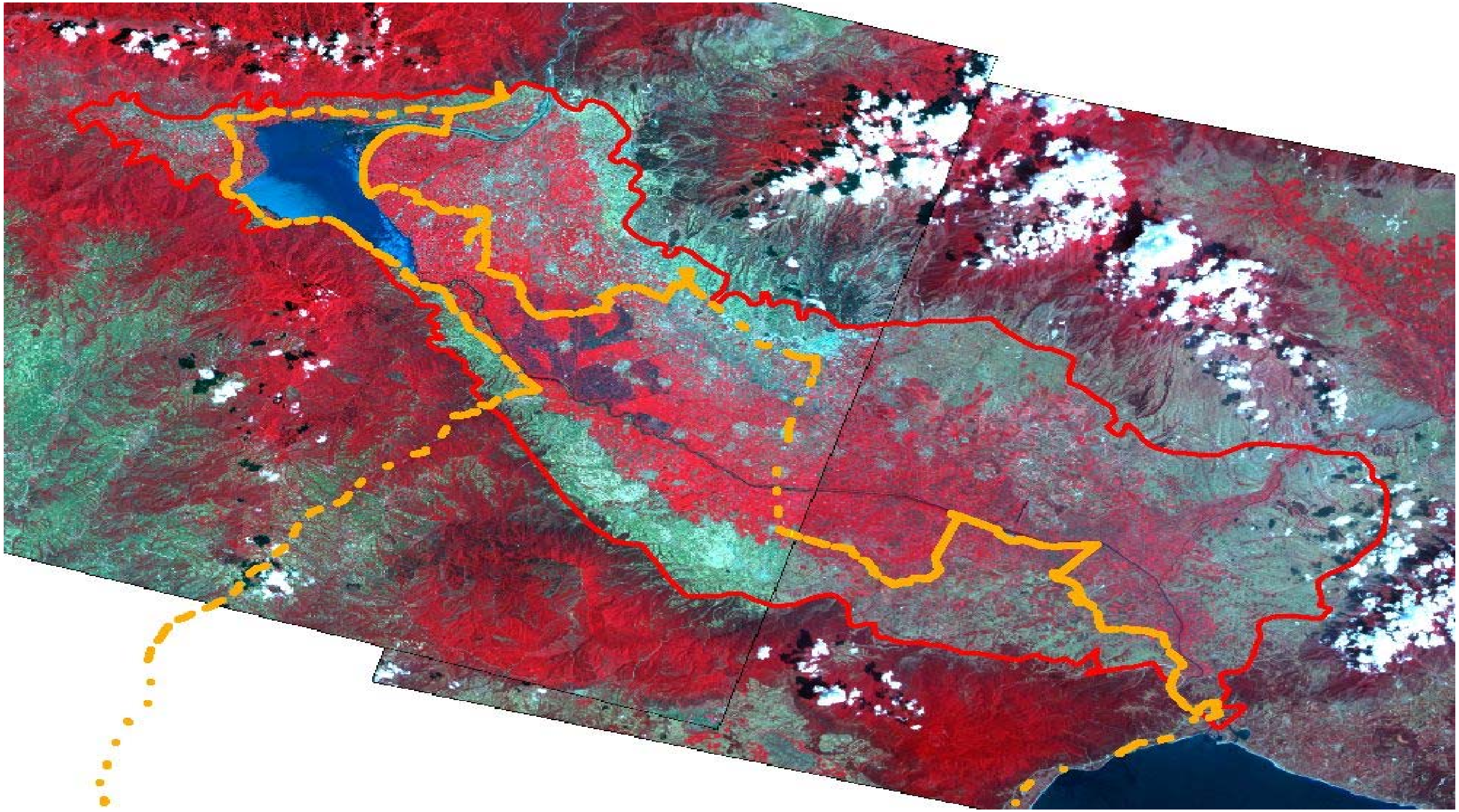

Figure 2.1.1 The route of the first field visit in 1/8/2005. The red line is the study area boundaries and the yellow dots are the GPS's tracklog points. The yellow lines were formed from dense yellow dots because of the low speed of the vehicle carrying the GPS antenna.

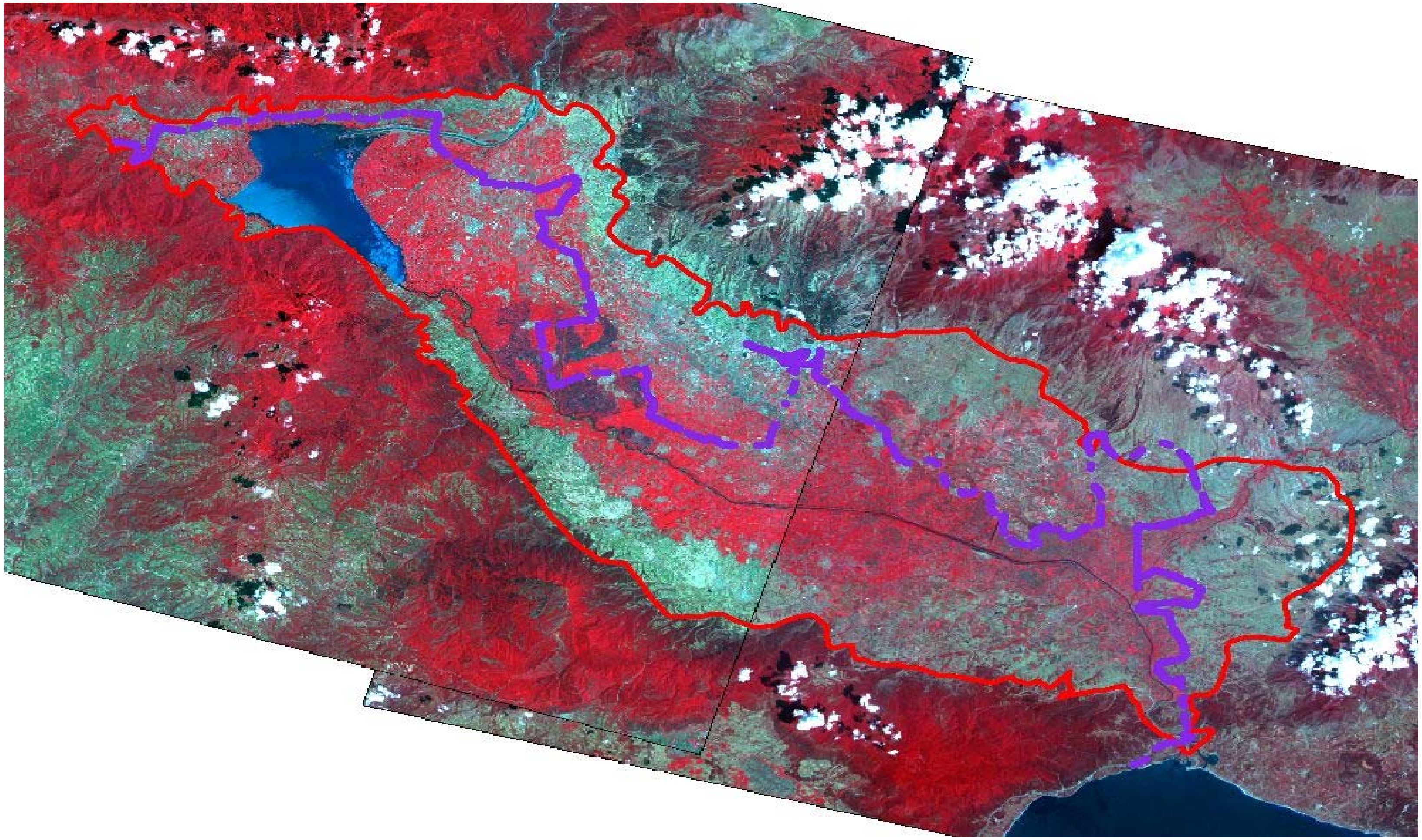

Figure 2.1.2 The route of the second excursion in 10/8/2005. The red line is the study area boundaries and the blue dots are the GPS's tracklog points. The blue lines were formed from dense blue dots because of the low speed of the vehicle carrying the GPS antenna.

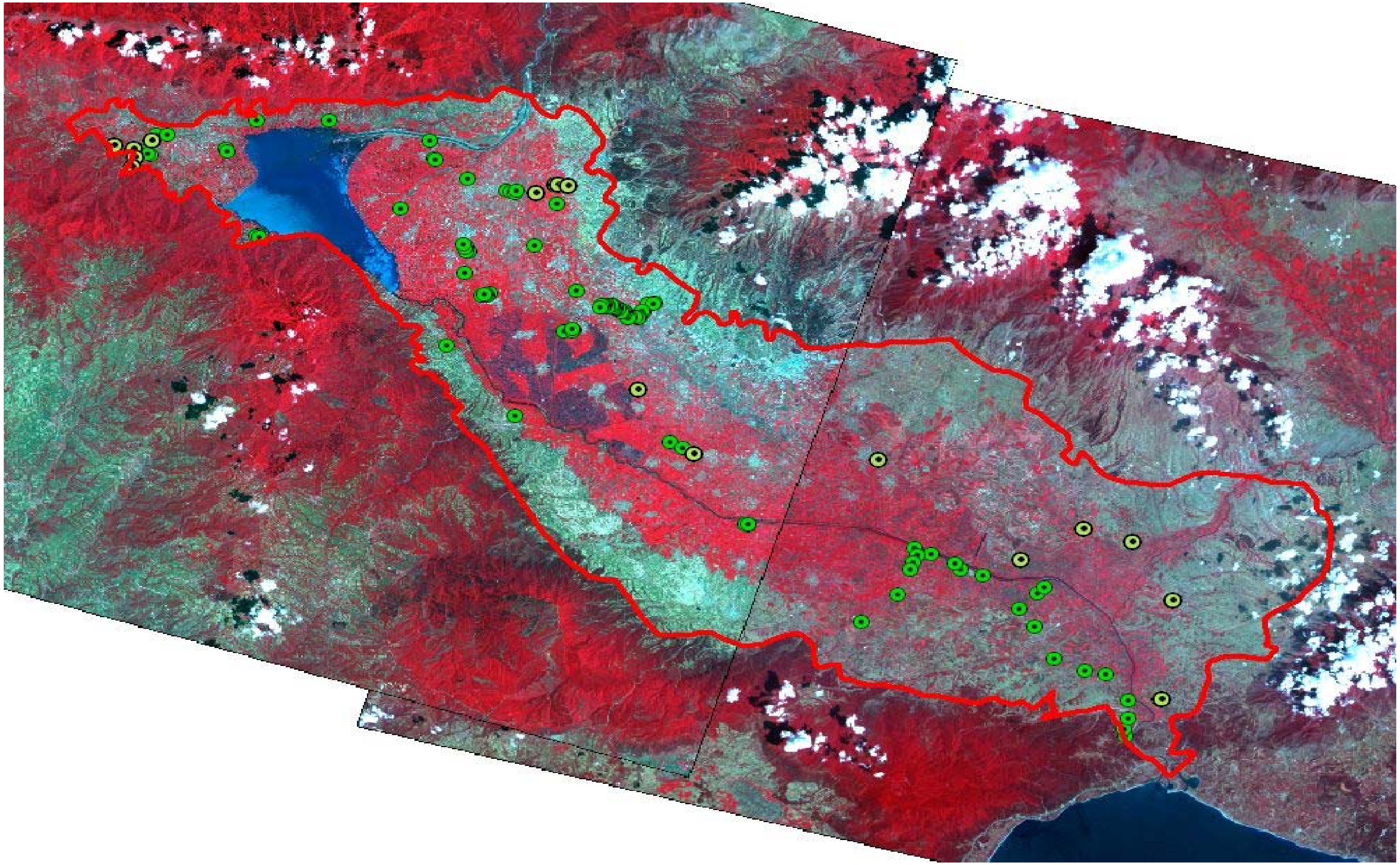

Figure 2.1.3 The signatures collected during the two field visits (green dots).

Fig 2.1.4 Collecting a signature with the GPS

Fig 2.1.5 On the road for signature collection

Fig 2.1.6 Cotton field with almond trees in the background.

Fig 2.1.7 Cotton field.

Fig 2.1.8 Rice field.

Fig 2.1.9 Poplar plantation.

Fig 2.1.10 Maize field.

Fig 2.1.11 Tobacco field.

2.5 Auxiliary data collection and preparation

Satellite images and signatures are not enough for a successful image classification. There is always a need for some auxiliary data which can be used as a general background or for some specialized tasks during the data preparation or the classification procedures. A detailed description of the auxiliary data used in this project is shown in table 3.2.1.

Table 2.5.1 Auxiliary data collection

Data	Source	Preparation	Used for..
Topographic maps in 1:50.000 scale	Hellenic Army Geographic Survey	Scanning of 16 maps at 300dpi. Georeference. Composition of a unified background of the study area	General background, field map, digitization of auxiliary data (villages, streams etc.)
Digital Elevation Model (DEM)	EKBY	Interpolation of hypsography and hydrology data	Rectification, general background
Corine Landcover	EKBY archive	-	Additional background information

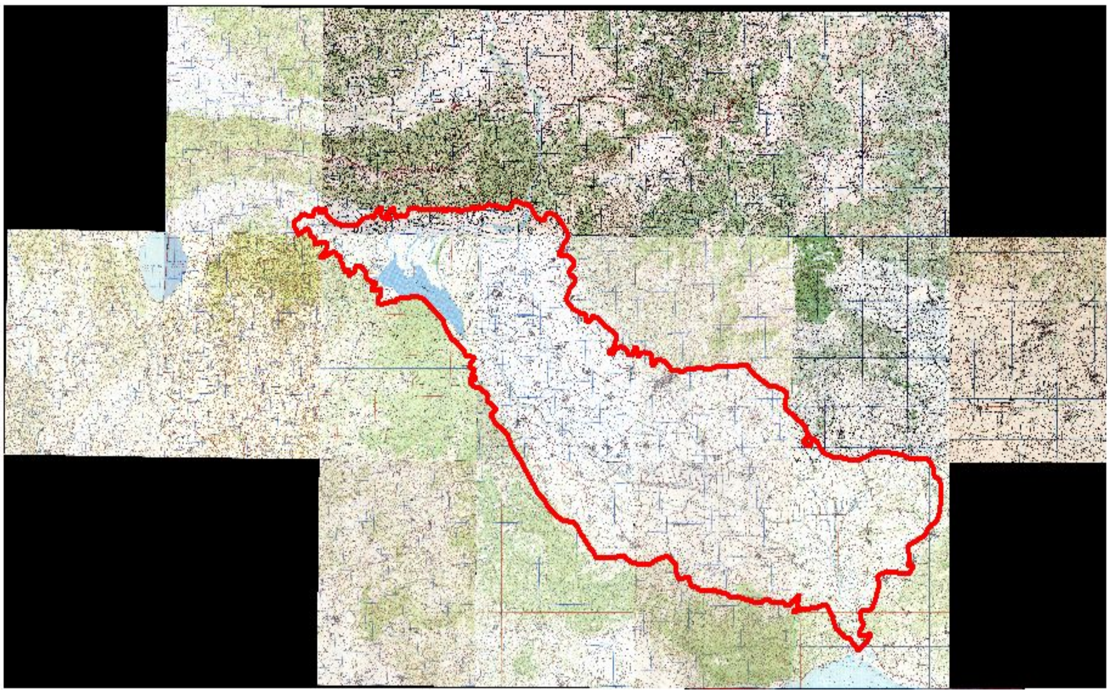

Fig 2.5.1 16 topographic maps were scanned, georeferenced and combined to compose a unique topographic background of the study area (red line)

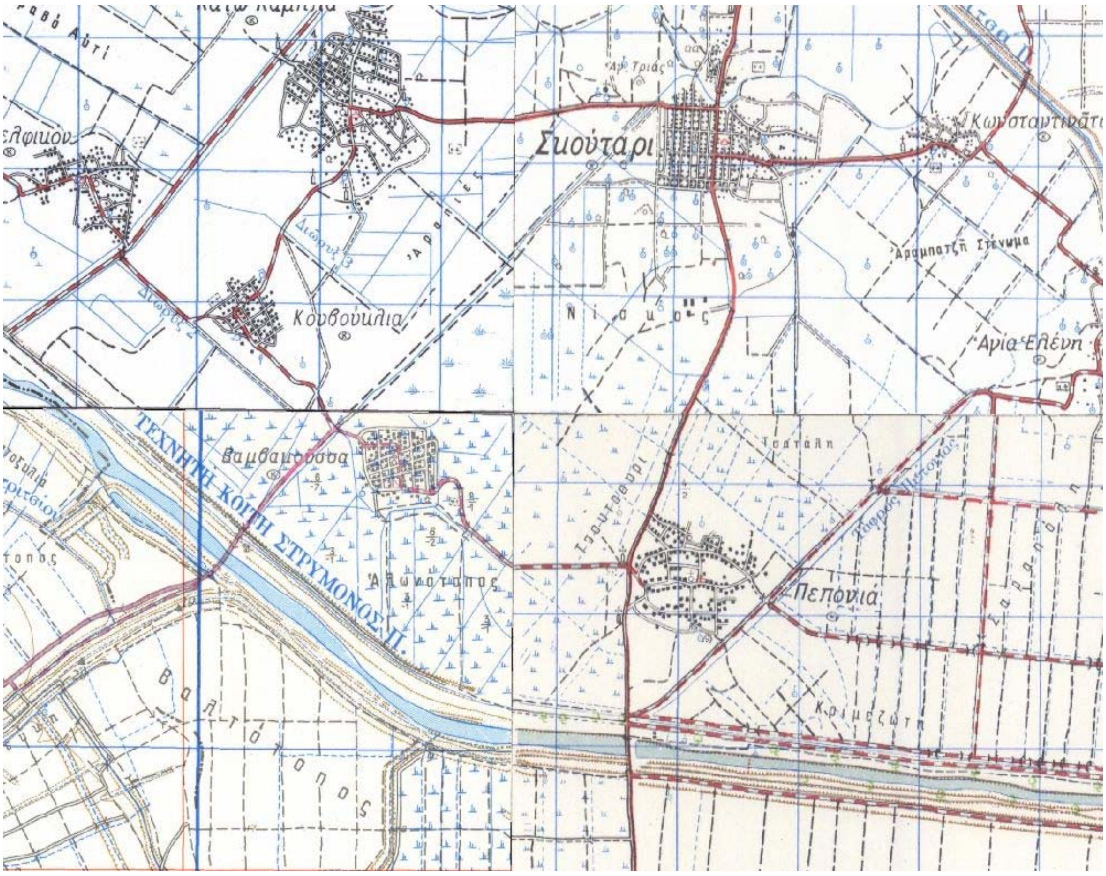

Fig 2.5.2 Detail of the topographic background (junction of 4 maps)

2.6 The classification procedure

2.6.1 Preparation of satellite images

Using the topographic background the two satellite images were georeferenced in EGSA87 projection system.

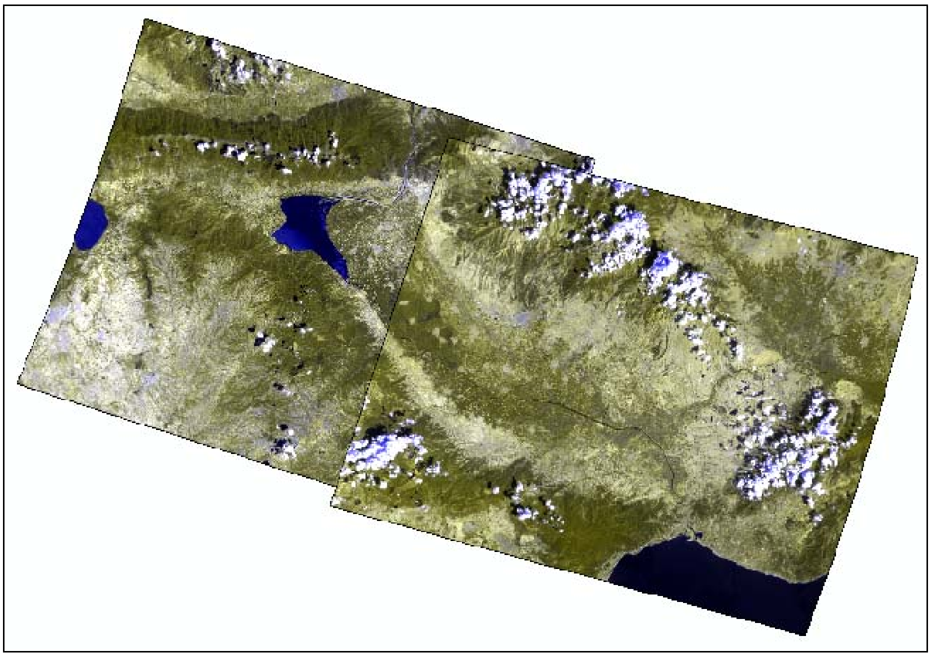

Figure 2.6.1 Fourth set of SPOT images. Scene 7 at the left (June 22, 2005) and scene 8 at the right (July 9, 2005) displayed in RGB combination, using the 4th and 2nd spectral bands.

2.6.2 Digitization of more detailed boundaries of the study area

After a close examination of the original boundaries of the study area, we found that in many cases some forested and mountainous areas were included. As these areas were out of the interest of this study and additionally could have a negative effect in the classification procedure, we decided to re-digitize the boundary polygon in more detail to exclude these areas. The new boundaries also included some agricultural areas not included in the original boundaries

The area of the new polygon is **173,727 ha** while the old boundaries covered an area of 192,689 ha.

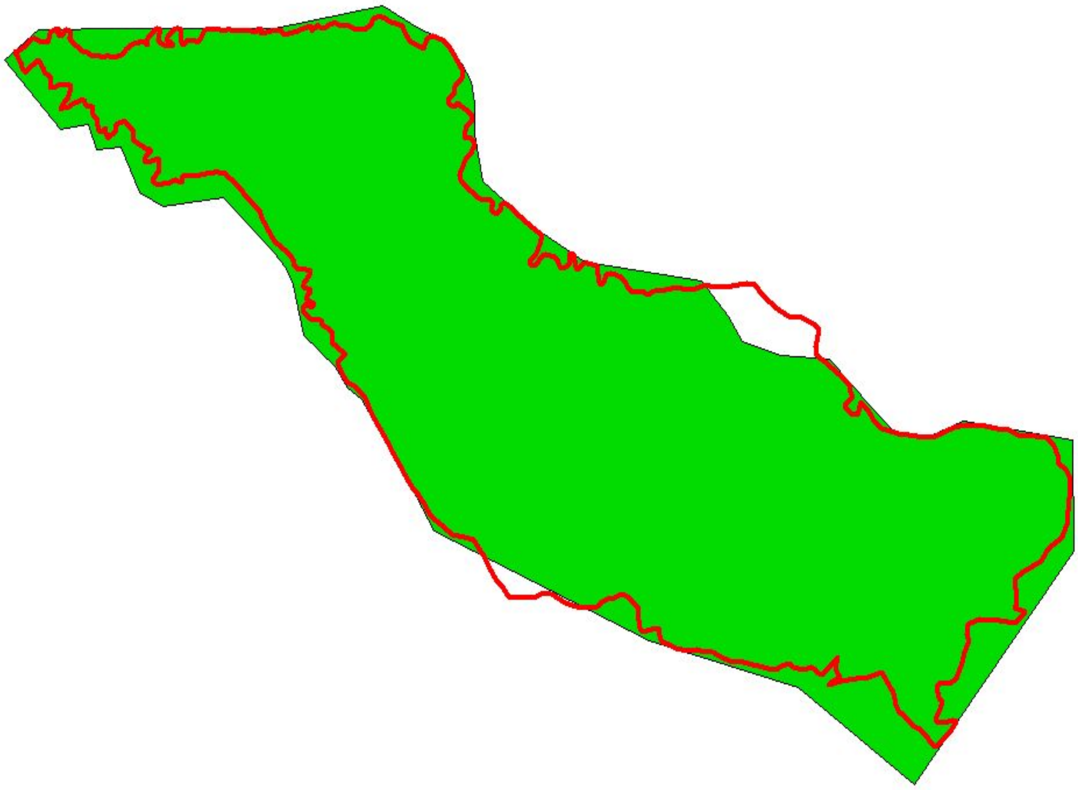

Figure 2.6.2 The original study area (green polygon) and the area after the detailed digitization (red line).

2.6.3 Extraction of inhabited areas

In this step we took out from our study area all the cities and villages. The boundaries of these areas were delivered from the CORINE landcover layer and corrected using the satellite images. These areas are easily recognized in the satellite images so the correction of the CORINE layer was a rather easy procedure.

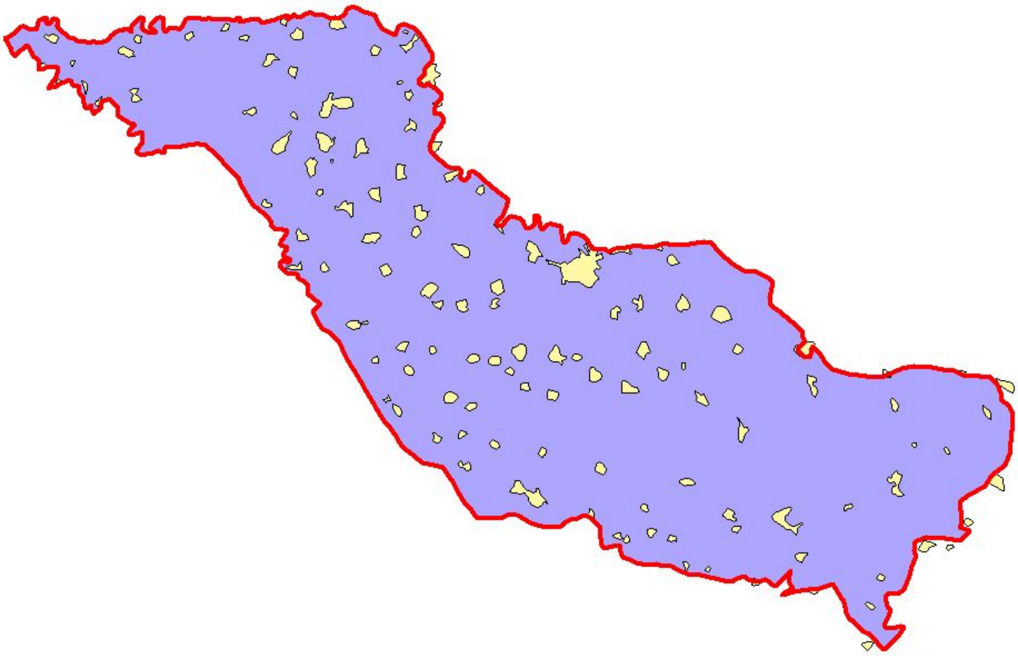

Figure 2.6.3 Inhabited areas (yellow polygons) which were taken out of the study area.

2.6.4 Water body and clouds extraction

The study area contains some rather large water bodies like Kerkini lake, Strymon and Agitis rivers and Belitsa stream. These bodies cover a significance percentage of our study area and could have some negative effects in the accuracy of the classification.

In the same category fall the areas covered by clouds and their shadows. Fortunately cloud – covered areas are only on the south-east of the study area and cover less than 2% of the total area.

So our next step was to take out from the satellite images all the areas covered by water bodies, clouds and cloud – shadows.

The water bodies were easily delineated using unsupervised classification. After few test – classifications we easily found the pixels of water bodies in the satellite images and we took them out. With a similar procedure we also found the areas covered by clouds and their shadows and deleted them from the satellite images.

2.6.5 Rice beds extraction

As the satellite images were taken in the end of June and in the beginning of July, the rice fields of the area were full of water. These areas were easily delineated after some test unsupervised classifications.

A total area of **4958.3 ha** was as rice fields.

After the delineation these areas were taken out from the images. Thus we continued the classification with fewer classes and less pixels to process.

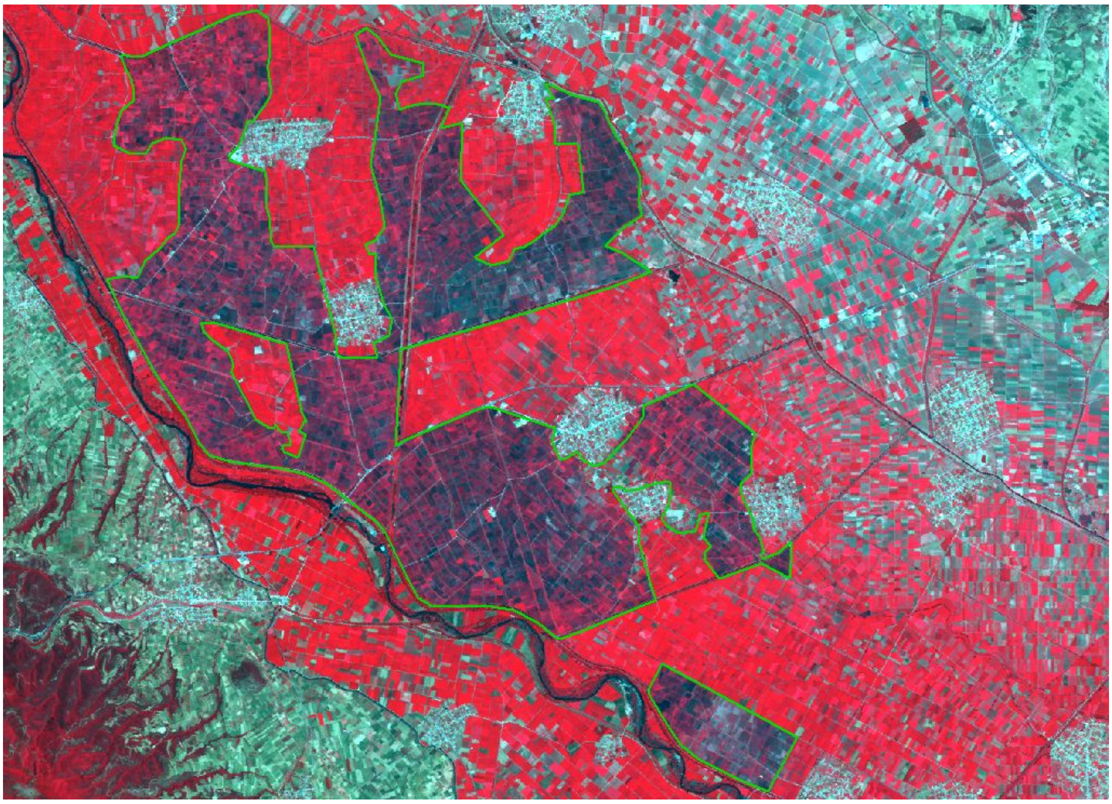

Figure 2.6.5 Delineation of rice beds (green line)

2.7 Supervised classification

After extracting all the above areas (mountainous, inhabited, water bodies, clouds, cloud shadows, rice fields) the remaining pixels were classified using supervised classification based on the signatures that we collected.

The classification process was repeated several times using different signatures. An accuracy assessment was performed after each classification to estimate the effectiveness of the procedure. We also performed some fine – tuning and corrections in the position of the signatures based on the results of the classification and accuracy assessment.

As the study area contains a lot of non – agricultural land uses (roads, streams, ditches, factories etc.), it was necessary to follow a step by step classification (one step for every class) so that the remaining area to correspond to the no – agricultural uses. This method could be described in the following steps:

1. Based on the available signatures and some draft-classification tests we choose the class we are going to extract
2. Perform the supervised classification based on the class's signatures
3. Perform accuracy assessment
4. Make corrections and fine tuning of the signatures and their position
5. Repeat from step 2 until we get the best accuracy assessment
6. Save the layer representing the class in raster format, convert to vector and estimate the area of the class
7. Remove from the satellite image the pixels corresponding to the class we estimated
8. Repeat previous steps 1 – 7 in the remaining image's pixels and for the rest of the classes.
9. After the completion of the above procedure the remaining pixels, represent no agricultural uses.

The results and conclusion of the application of the above procedure are presented in the next chapter.

CHAPTER 3
RESULTS AND DISCUSSION

3.1 Results

The results of the classification are presented in table 3.1.1

Table 3.1.1 Total area and accuracy assessment for each cultivation as occurred from the classification procedure.

	Cultivation	Area (ha)	Classification Accuracy assessment (%)
1	Maize	29192	97
2	Tobacco	8877	74
3	Cotton	34130	78
4	Alfalfa	6840	82
5	Rice	4958	100
6	Poplar plantation	6090	95
7	Sugar beets	1511	77
8	Tomatoes	2567	42
9	Olive groves	2642	62
10	Walnut groves	557	38
11	Almond groves	10067	58

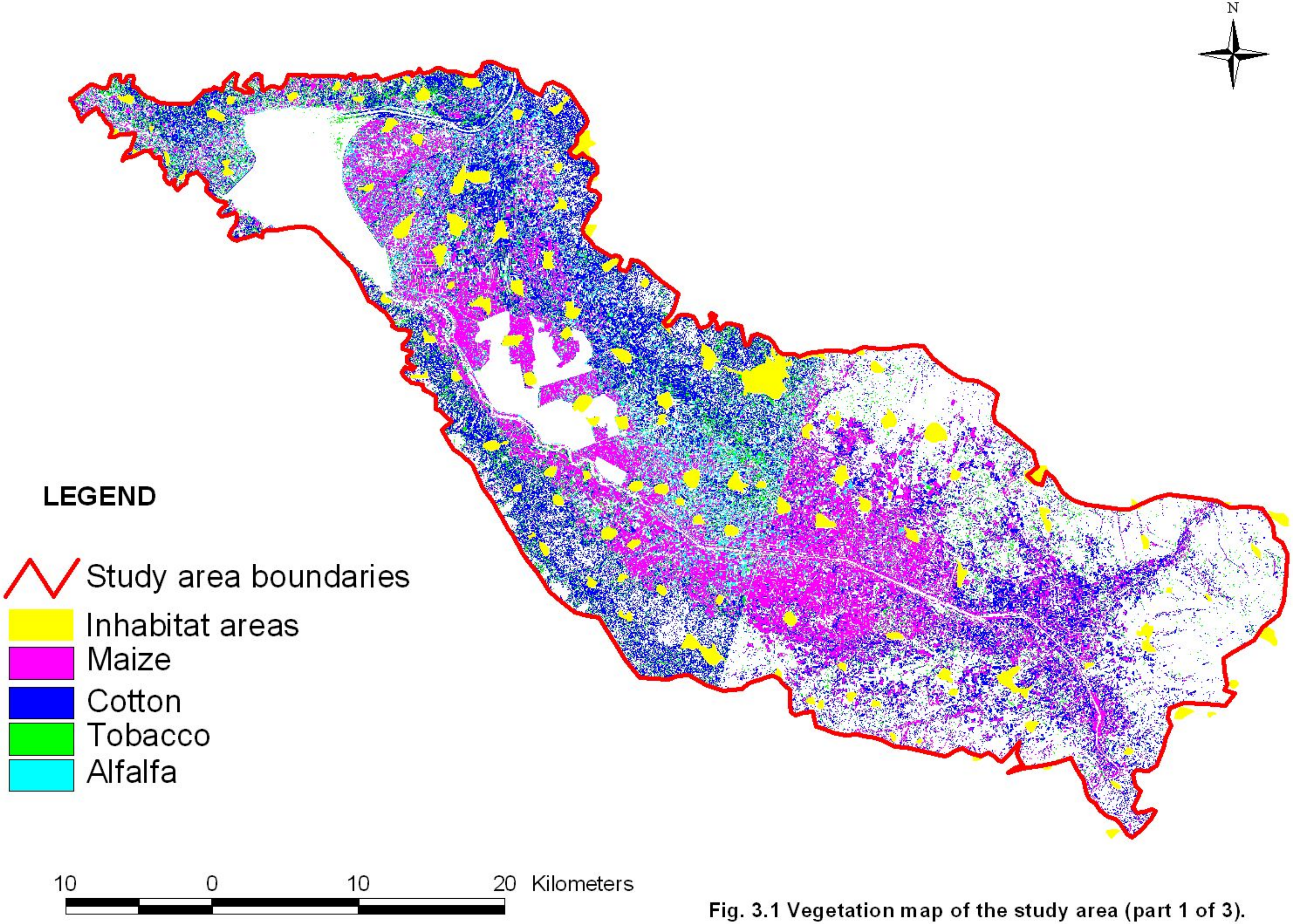

Fig. 3.1 Vegetation map of the study area (part 1 of 3).

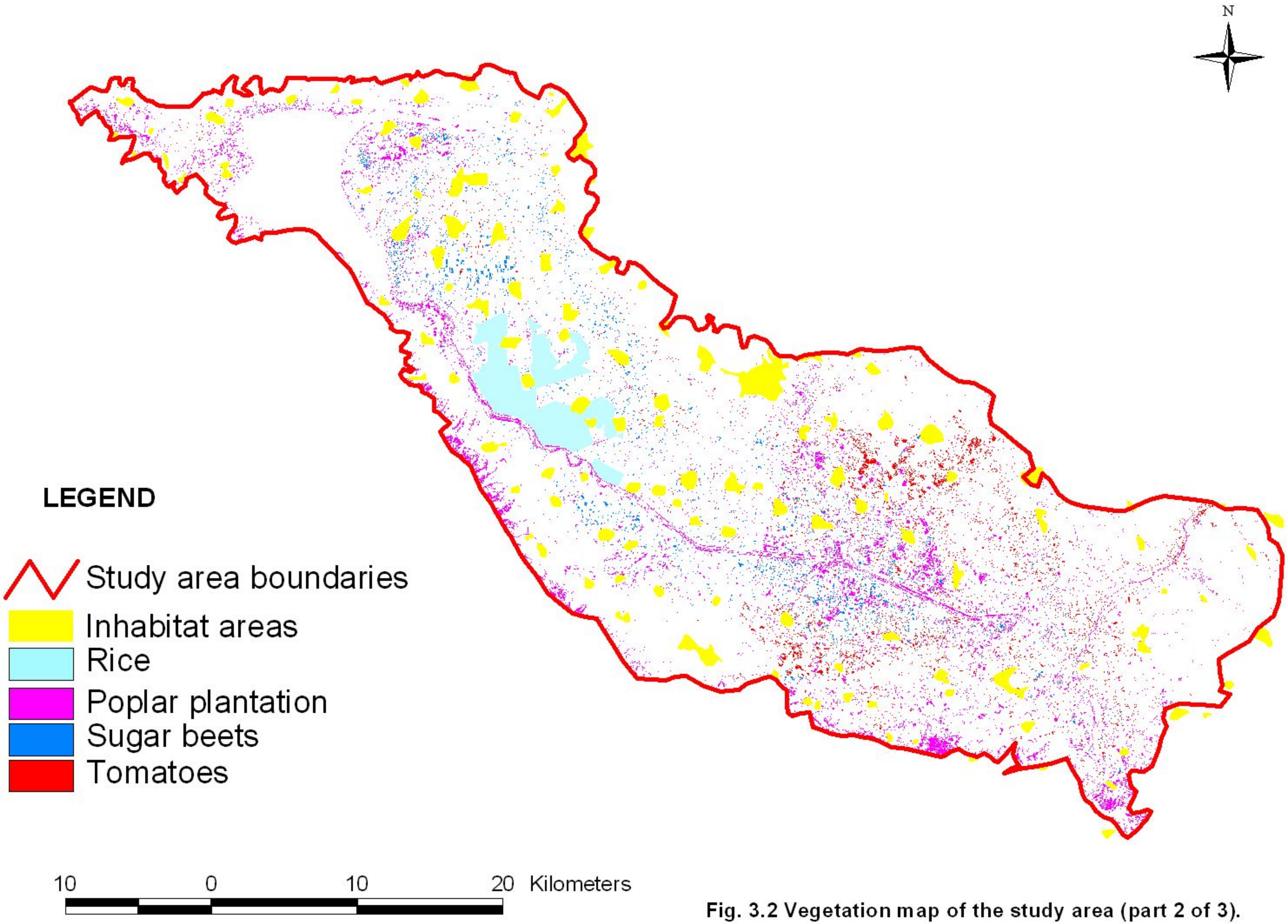

Fig. 3.2 Vegetation map of the study area (part 2 of 3).

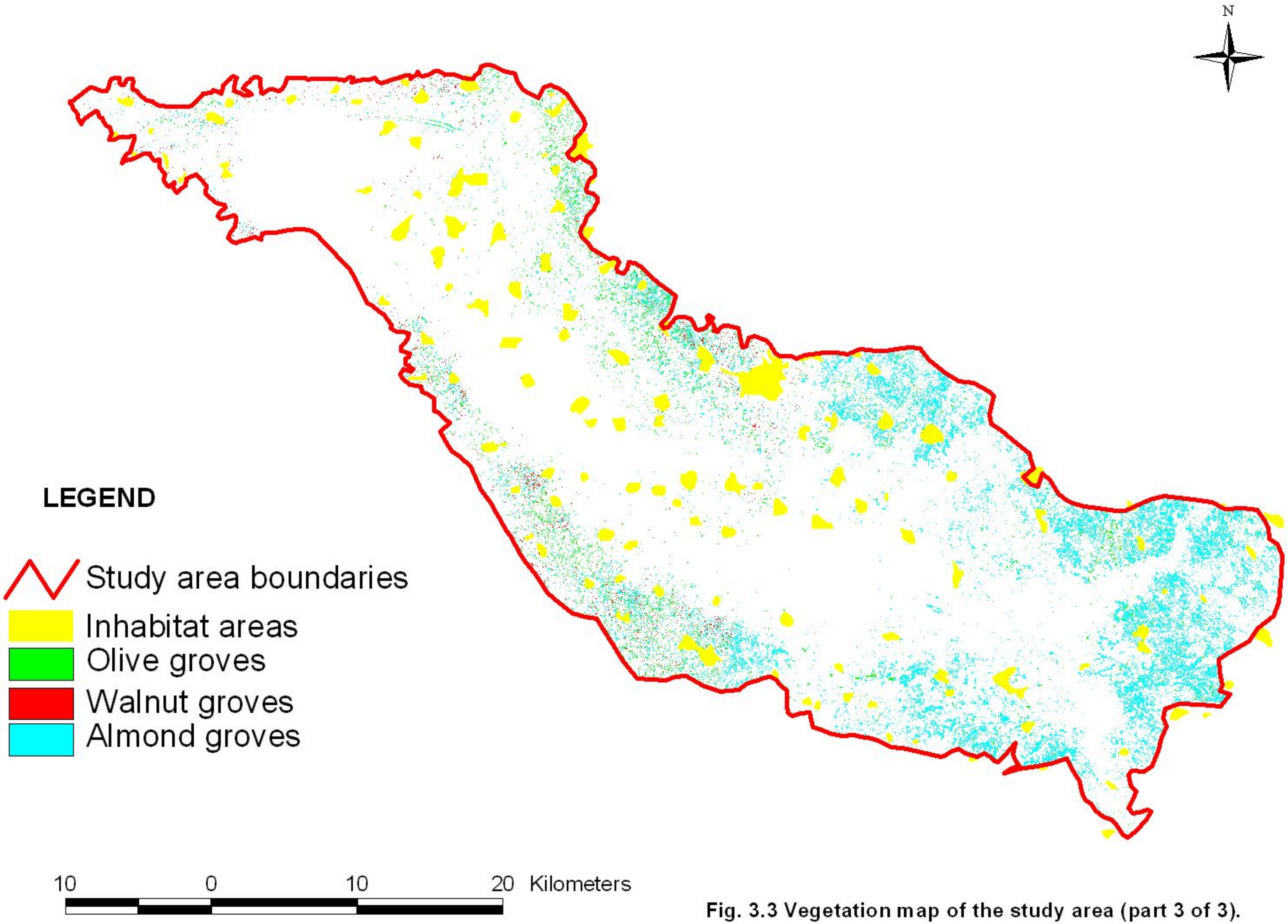

Fig. 3.3 Vegetation map of the study area (part 3 of 3).

3.2 Discussion

Based on the above description of the classification procedure and the experience gained in testing the signatures and estimating the accuracy of the results, we can come to some conclusions. There are also some issues raised during this procedure, affecting the project's targets and some suggestions.

All the above are discussed below:

3.2.1 Mosaicing

A major fallback and time consuming issue was the fact that it was not possible to mosaic the two images in one. The main reason for this was that the two images were taken with a time gap of 17 days (22/6 – 9/7 2005) in a period of fast plant growth.

So the two images had quite different pixel values for the same classes and practically it was impossible to archive a good mosaic of the two images.

This resulted in performing two separate classification for each image for every class. This was a rather time consuming procedure which also increased the risk level for errors.

This 17 days time gap was a result of continuous cloud coverage during this period in the study area.

A solution for this problem is to order the images with a maximum time gap of 3 days This is not always possible and can be affected by the available programmable options of the satellite, the cloud coverage, and the satellite image provider. (Leica Geosystems, 2002. Erdas Spectral Analysis)

3.2.2 Signature collection

This year's signature collection was performed with much more advanced equipment in comparison with year's 2004. The combination of the GPS's track log file with the oral descriptions recorded in a tape recorder was very useful in the signature evaluation and in the completion of more signatures on the screen.

The only problem here is that for some classes it was not possible to collect enough signatures for an effective classification and accuracy assessment. This happened in hard to find classes in the study area like large areas with walnut trees, olive trees, potatoes, cabbages etc. A solution for this problem could be a more intense search for these hard to find signatures or to completely exclude them from the classification process. More about this topic is discussed in paragraph 3.2.4

3.2.3 Separetability of classes

Some separetability problems were encountered in specific classes. i.e. between tobacco, cotton and sugar beets. This was a rather difficult problem and we have to use some advanced techniques to face it. It was also necessary to perform some preprocessing to achive better results.

The accuracy assessment achieved for the above classes has still low values.

A good solution for this problem could be to have a second layer of satellite images with time gap of 30 to 40 days so that to apply a change detection procedure and to have additional layers of information to achieve better separetability and to perform a successful classification.

A second set of images was ordered to the provider but it was not possible to be collected because of the high percentage of cloud coverage of the area. So a very important issue here is to program the image acquisition at least 3 to 4 months before the end of June to have higher possibilities to receive two layers of images.

It is worth mentioning here that these two layers of images also provide higher accuracy assessment to all classes even the ones with good separetability.

3.2.4 Classes used and classification area

There are some questions which were raised during the classification process which we need to face as the affect directly the achievement of the project's targets:

- Do we need to know the spatial distribution of all these classes in our study area to achieve the project's targets?
- Do we need all these classes or less?
- Which of these classes are the more important?
- Can we separate the study area in some zones where we need high values of classification accuracy assessment?

A good approach to answer the first three questions is to have a draft estimation of the main water consuming classes for each cultivation period. As some of them are rather standard for each year (rice, maize, cotton, sugar beets) the decision has to be taken for some of them (tomatoes, potatoes, etc.). A similar decision has to be taken for parcels covered by trees: Do we really need the areas covered by walnut trees?
The last of the above questions affects the available irrigation networks. It is obvious that we need high values of accuracy assessment in areas covered by the existing irrigation networks as the consumption and need for water there is very important for an effective water management.

3.2.5 Alfalfa, wheat, and uncultivated areas

Alfalfa is a very special case of crop because it does not have the same (or similar) pixel values in the same area, the same time. This happens because some fields may have just been harvested (so the look like bare land), some may have little growth (because of a previous harvest) or some may have a complete growth.
There is also a separetability problem between harvested wheat fields and uncultivated areas and just-harvested alfalfa. This happens because these three classes look the same.
A good (and possibly the only) practical solution to this problem is to use two or more layers of satellite images, to detect the changes and combine these layers for the classification process. So we have one more good reason (in addition to the one we described in 3.2.3) to obtain and use two sets of images for the classification process. (Leica Geosystems, 2002. Erdas Imagine Tour Gide, Leica Geosystems, 2002. Erdas Imagine Field Gide)

REFERENCES

Leica Geosystems, 2002. Erdas Imagine Tour Gide. GIS and mapping division. Atlanda Georgia USA. 706p.

Leica Geosystems, 2002. Erdas Imagine Field Gide. GIS and mapping division. Atlanda Georgia USA. 686p.

Leica Geosystems, 2002. Erdas Spectral Analysis. GIS and mapping division. Atlanda Georgia USA. 234p

Chalkidis, I., D. Papadimos, Ch. Mertzianis. 2004. Water Quality and Hydrological Regime monitoring network. Greek Biotope/Wetland Centre (EKBY). Thermi, Greece. 21 p.

Hatziiordanou, Eleni, D. Papadimos. 2004. SHYLOC Implementation in Strymonas Basin - Volume 1. Greek Biotope/Wetland Centre (EKBY). Thermi, Greece. 52 p.