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 3 (year 2006)

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THE GOULANDRIS NATURAL HISTORY MUSEUM
GREEK BIOTOPE / WETLAND CENTRE

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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)

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CHAPTER 1

INTRODUCTION

The aim of this work was to estimate the vegetation patterns and areas of the total study area for the year 2006. 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, 10 multyspectral 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, the summer of 2005 and summer of 2006 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
5	9	SPOT5	HRG 2	10 m	7-July-2007	09:34:14
5	10	SPOT5	HRG 2	10 m	17-June-2006	09:18:50

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 5 that were used to identify the crop patterns of 2006 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

[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

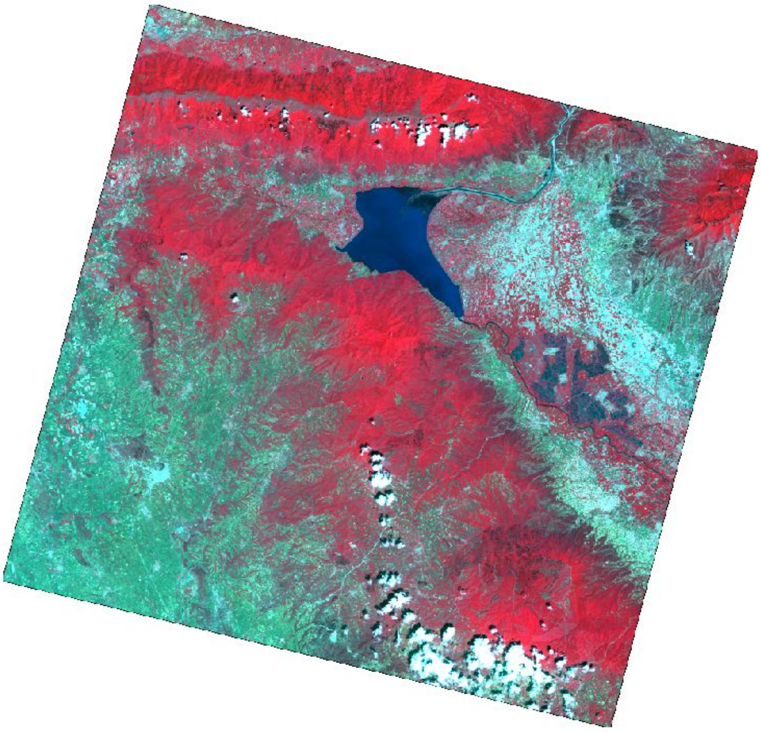

Figure 2.2.1 Scene 7 (June 22, 2005) from the NW part, georeferenced to EGSA´87.

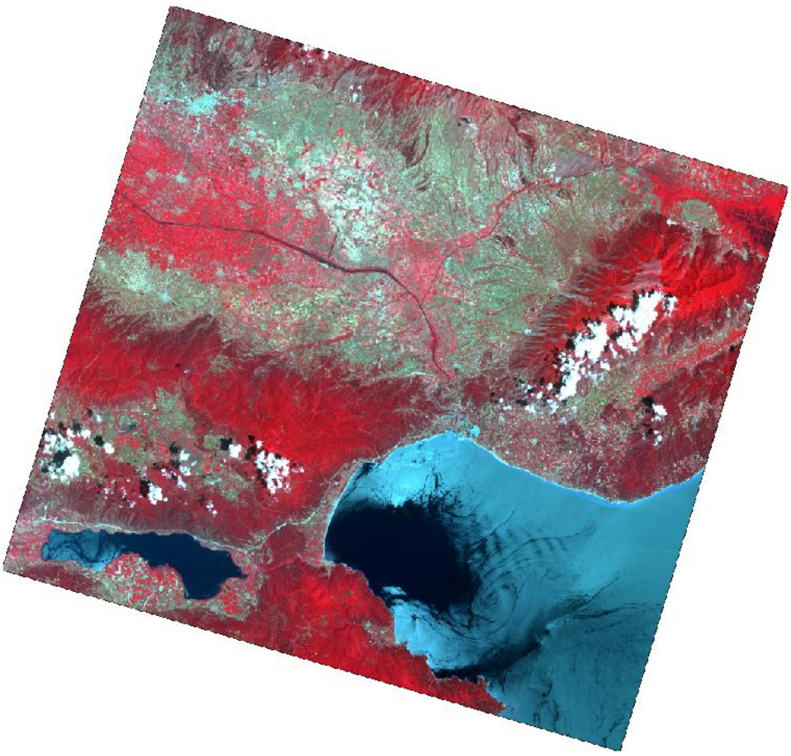

Figure 2.2.2 Scene 8 (July 9, 2005) from the SE part, georeferenced to EGSA´87.

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.)

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

Field visits during the summer and early autumn of 2006 were performed for vegetation signature collection.
A total of **134** 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 40 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	27
Tobacco	8
Cotton	31
Alfalfa	17
Rice	7
Poplar plantation	6
Sugar beets	18
Wheat	5
Tomatoes	3
Olive groves	5
Walnut groves	2
Almond groves	5

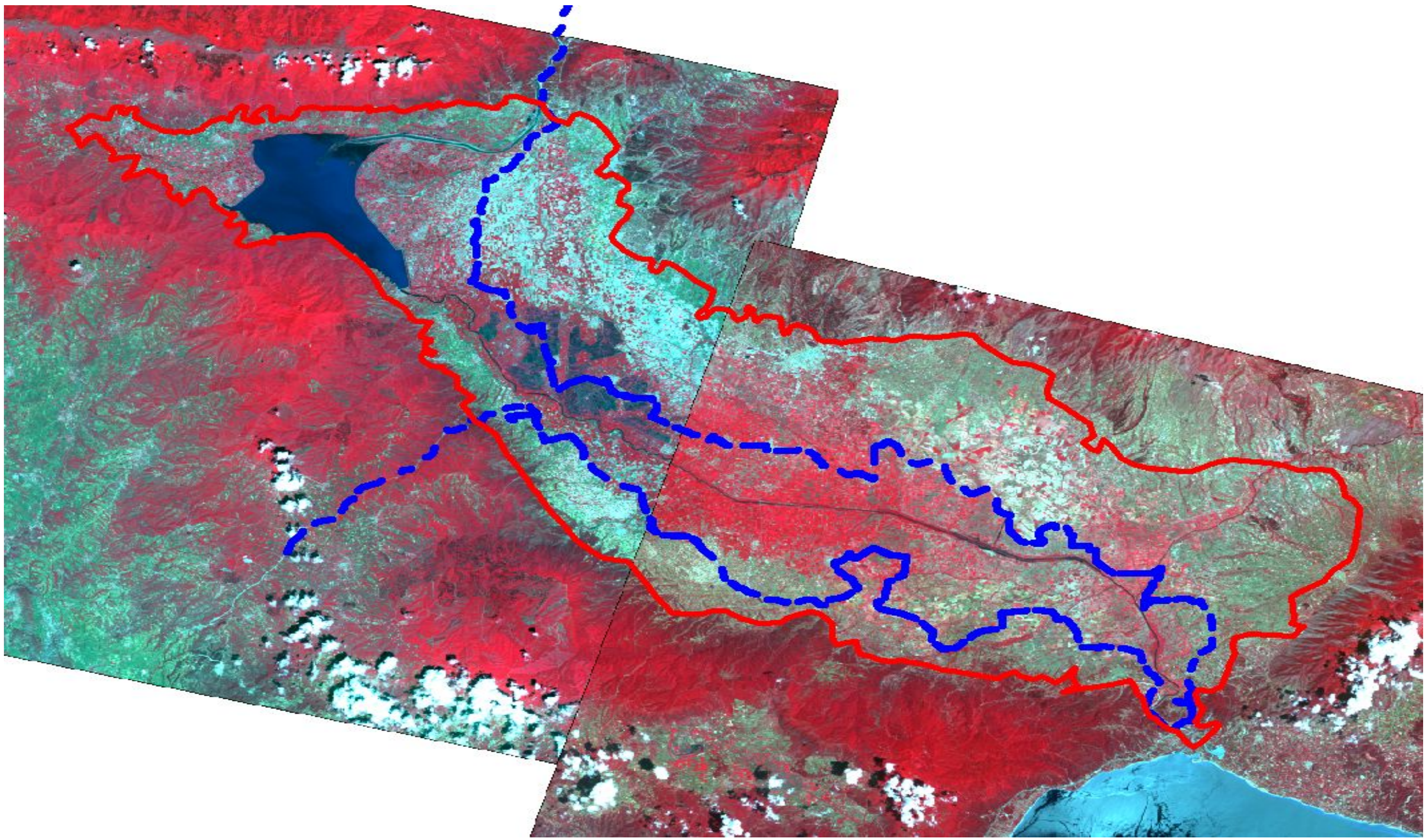

Figure 2.1.1 A sample route from a field visit in early automn. The red line is the study area boundaries and the blue dots are the GPS’s tracklog points. The blue lines were formed from dense yellow dots because of the low speed of the vehicle carrying the GPS antenna.

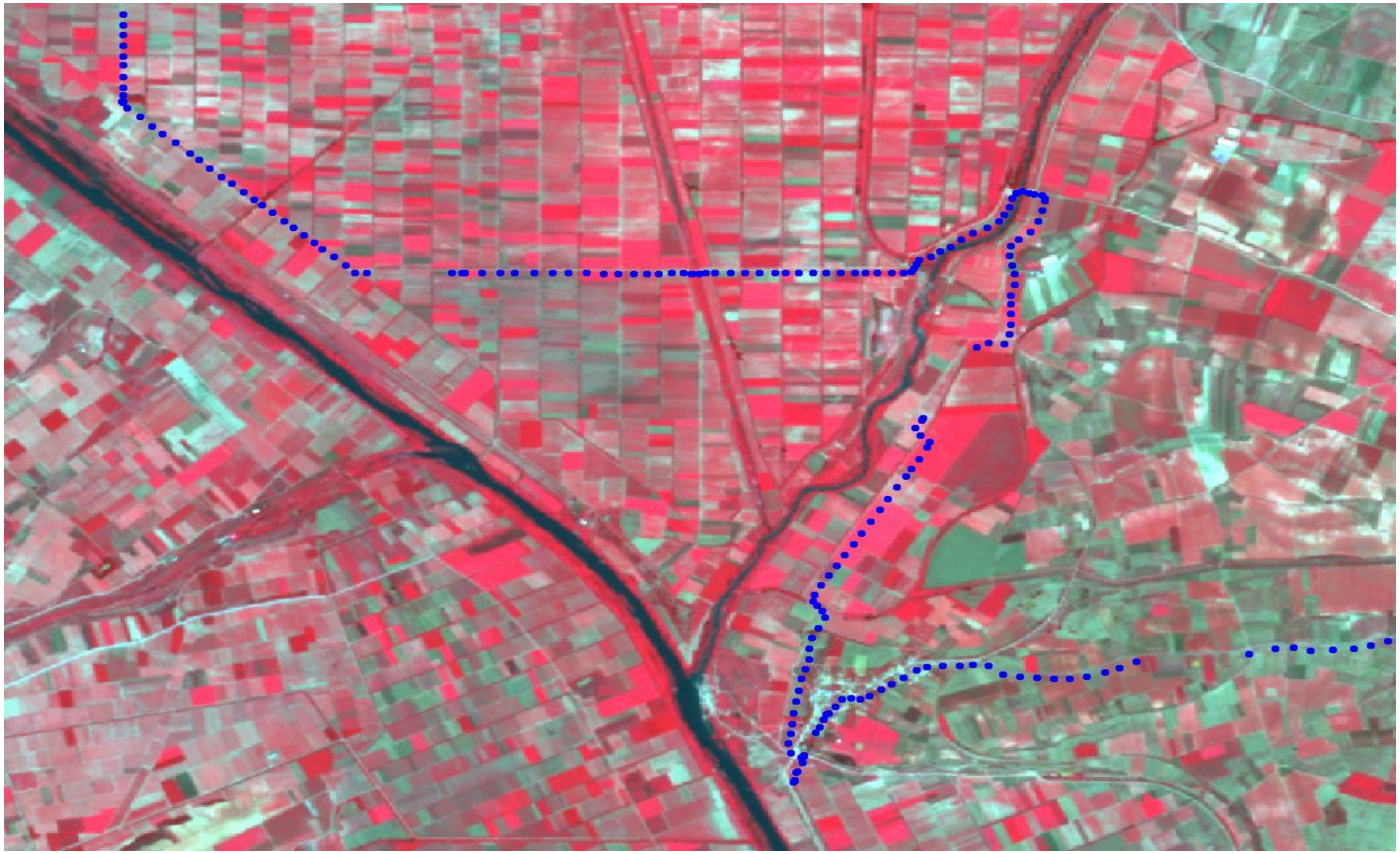

Figure 2.1.2 Detail from Figure 2.1.1 showing the points of tracklog collected.

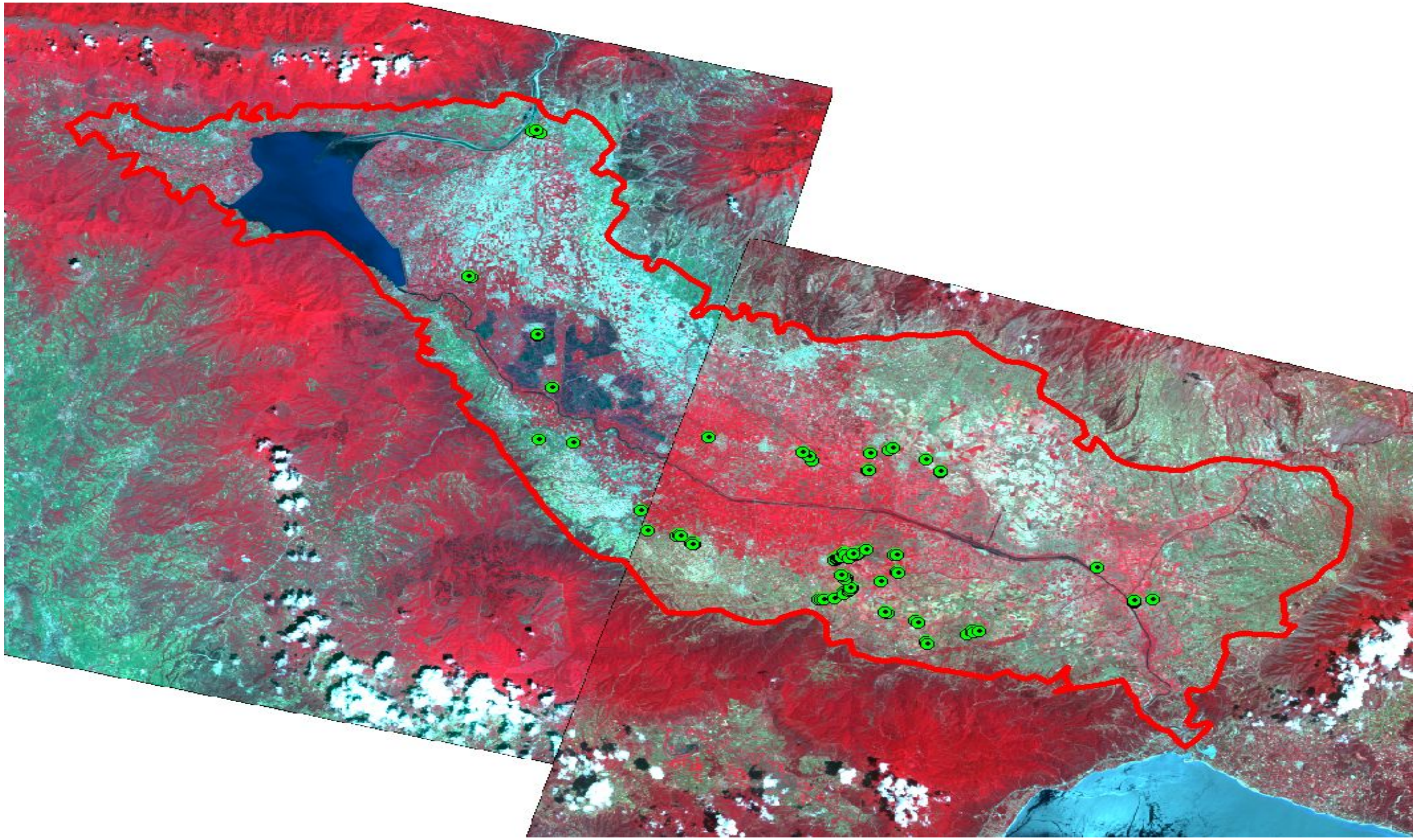

Figure 2.1.3 Signatures collected from a field visit (green dots).

Fig 2.1.4 Collecting a signature with the GPS

Fig 2.1.5 On the road for signature collection

Fig 2.1.6 Sugar beets.

Fig 2.1.7 Cotton field.

Fig 2.1.8 Rice field.

Fig 2.1.9 Cotton field near a ditch.

Fig 2.1.10 Maize field.

Fig 2.1.11 Maize and cotton fields.

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

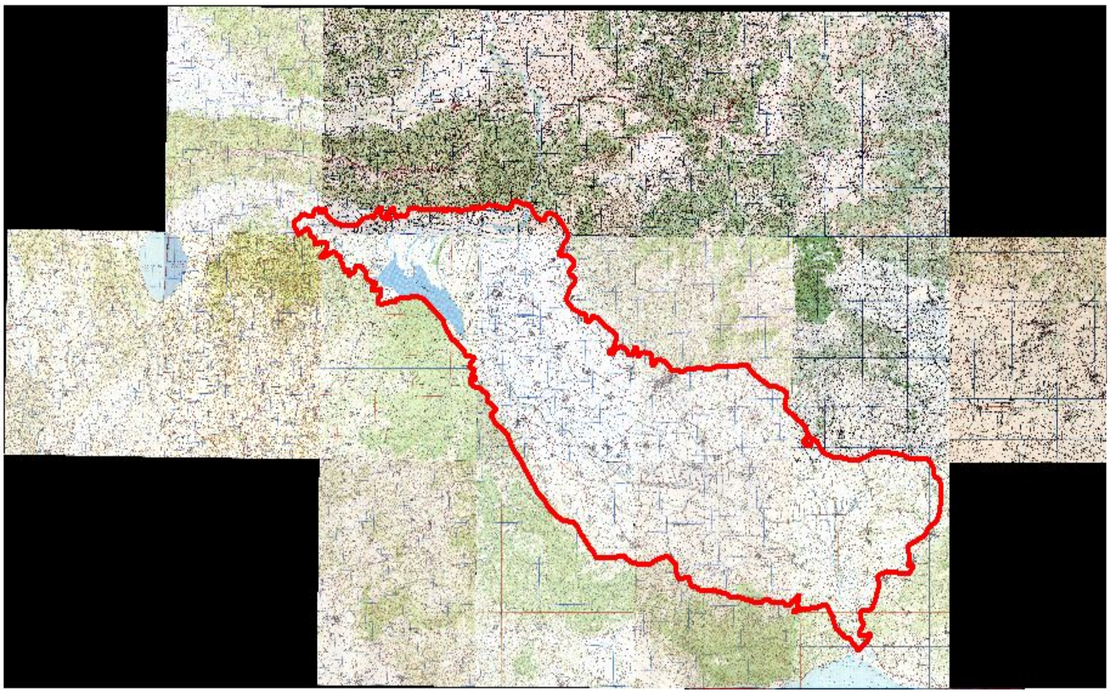

Fig 2.5.1 16 topographic maps were scanned, georeferenced and combined to compose a unique topographic background of the study area (red line)

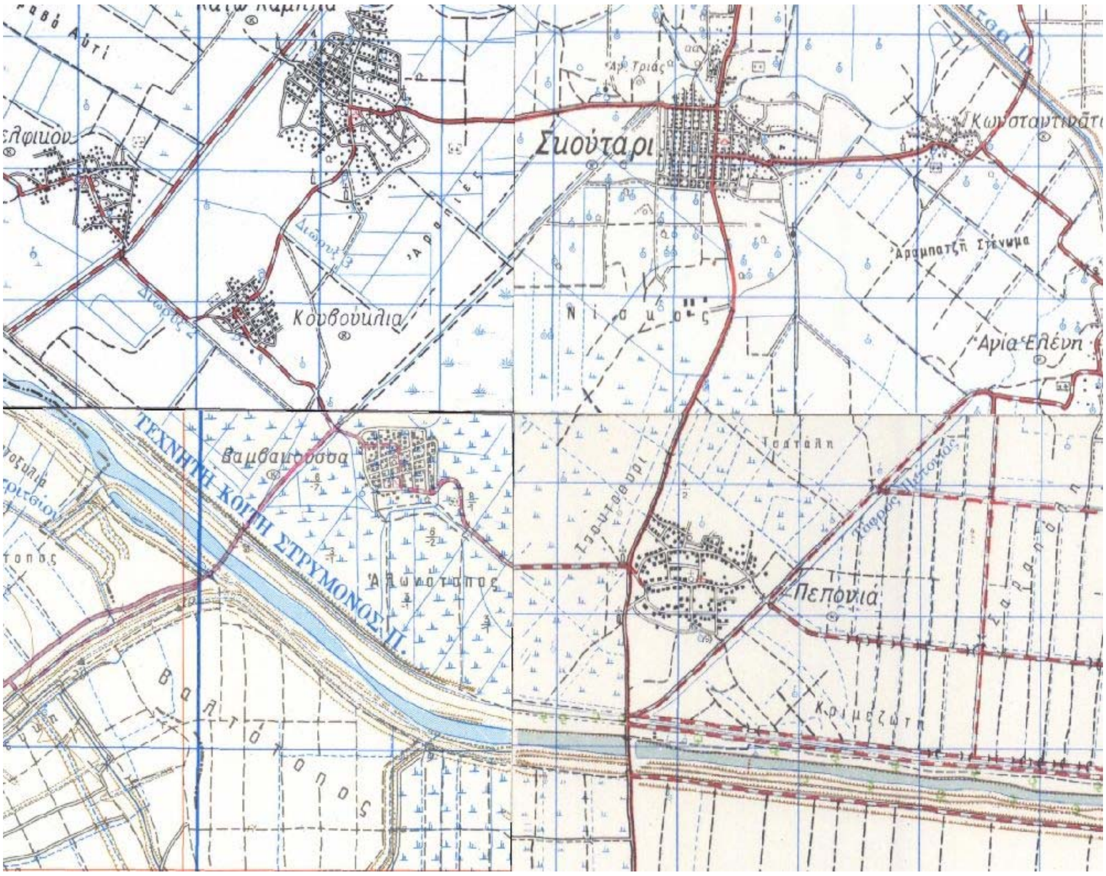

Fig 2.5.2 Detail of the topographic background (junction of 4 maps)

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.

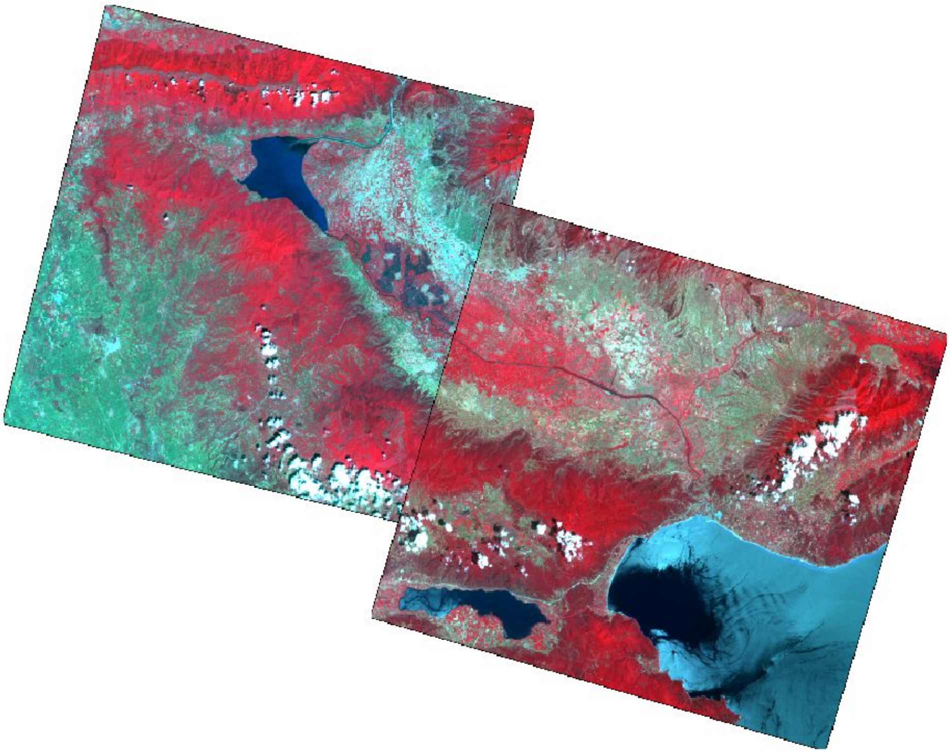

Figure 2.6.1 Fifth set of SPOT images georeferenced in EGSA87 projection system.

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.

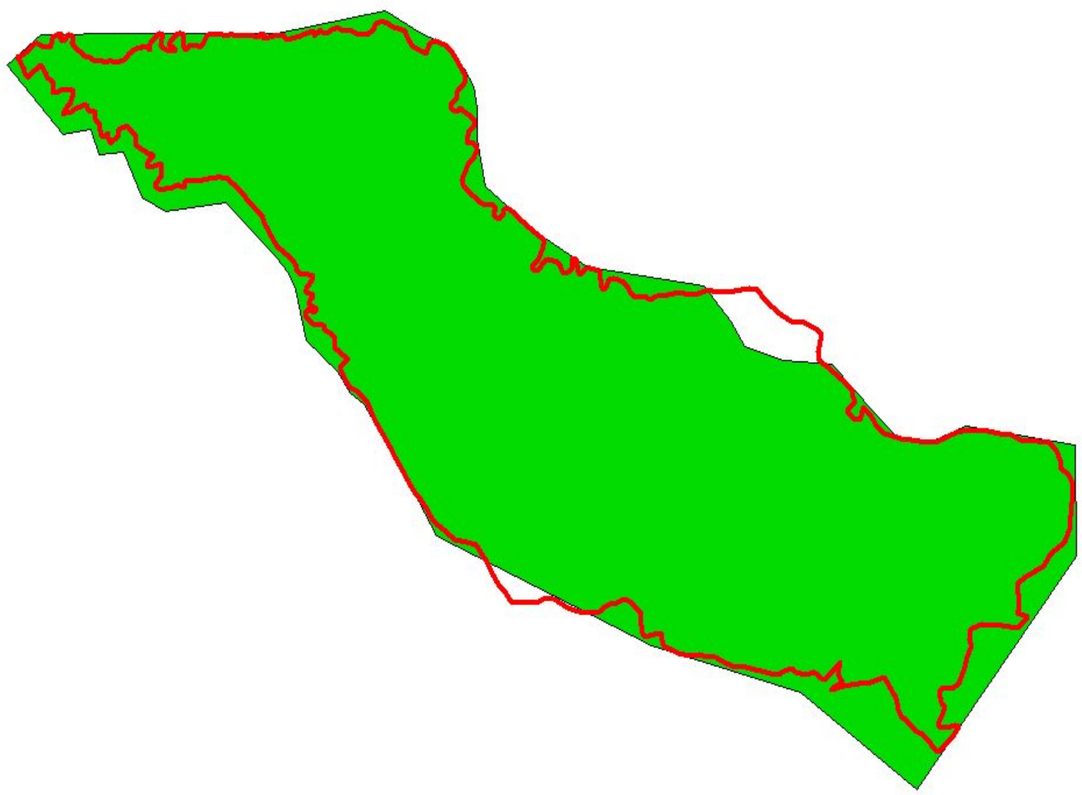

Figure 2.6.2 The original study area (green polygon) and the area after the detailed digitization (red line).

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.

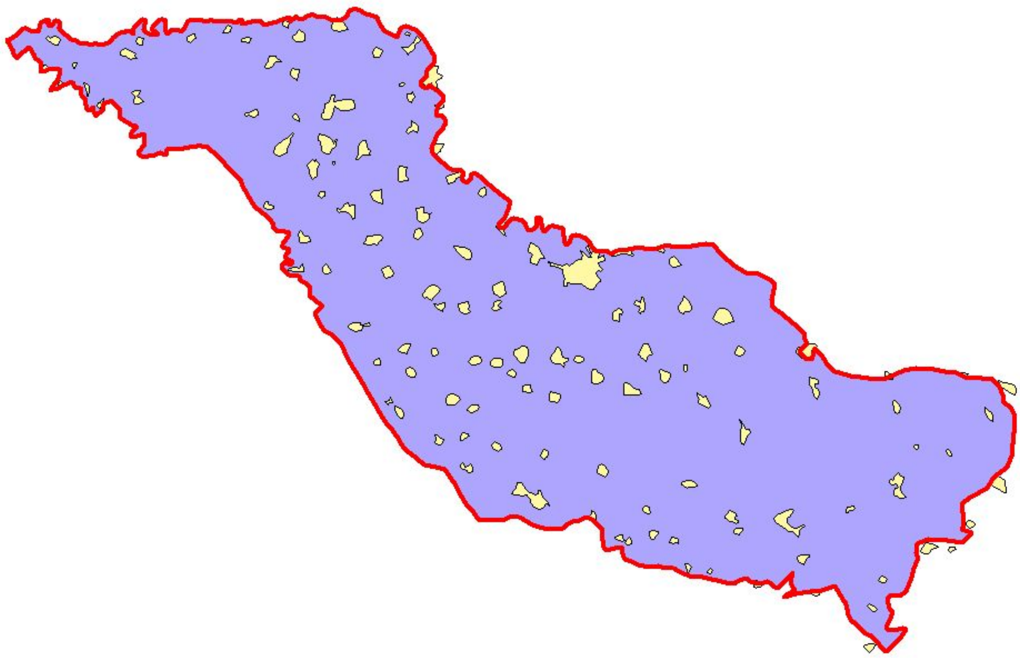

Figure 2.6.3 Inhabited areas (yellow polygons) which were taken out of the study area.

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 **4228.3 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.

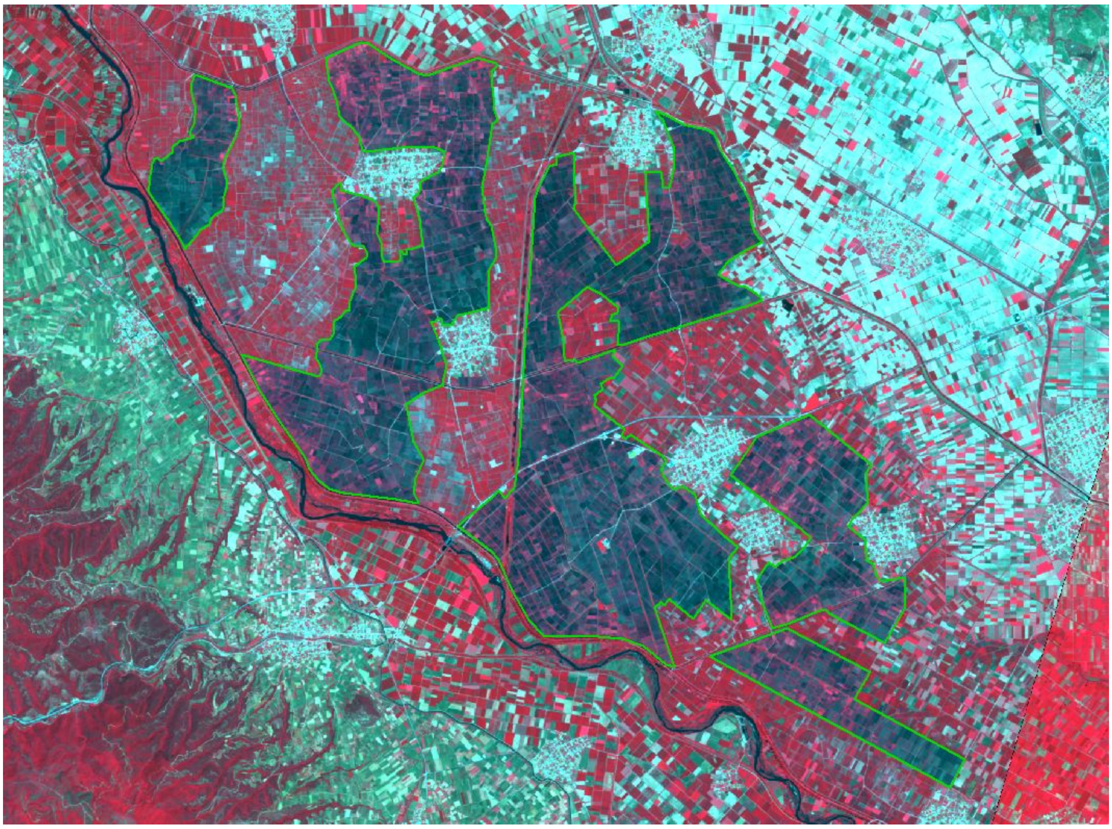

Figure 2.6.5 Delineation of rice beds (green line)

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	31796	93
2	Tobacco	8581	70
3	Cotton	35439	68
4	Alfalfa	7702	77
5	Rice	4228	100
6	Poplar plantation	6575	96
7	Sugar beets	1427	76
8	Tomatoes	2488	55
9	Olive groves	2853	65
10	Almond groves	10366	60

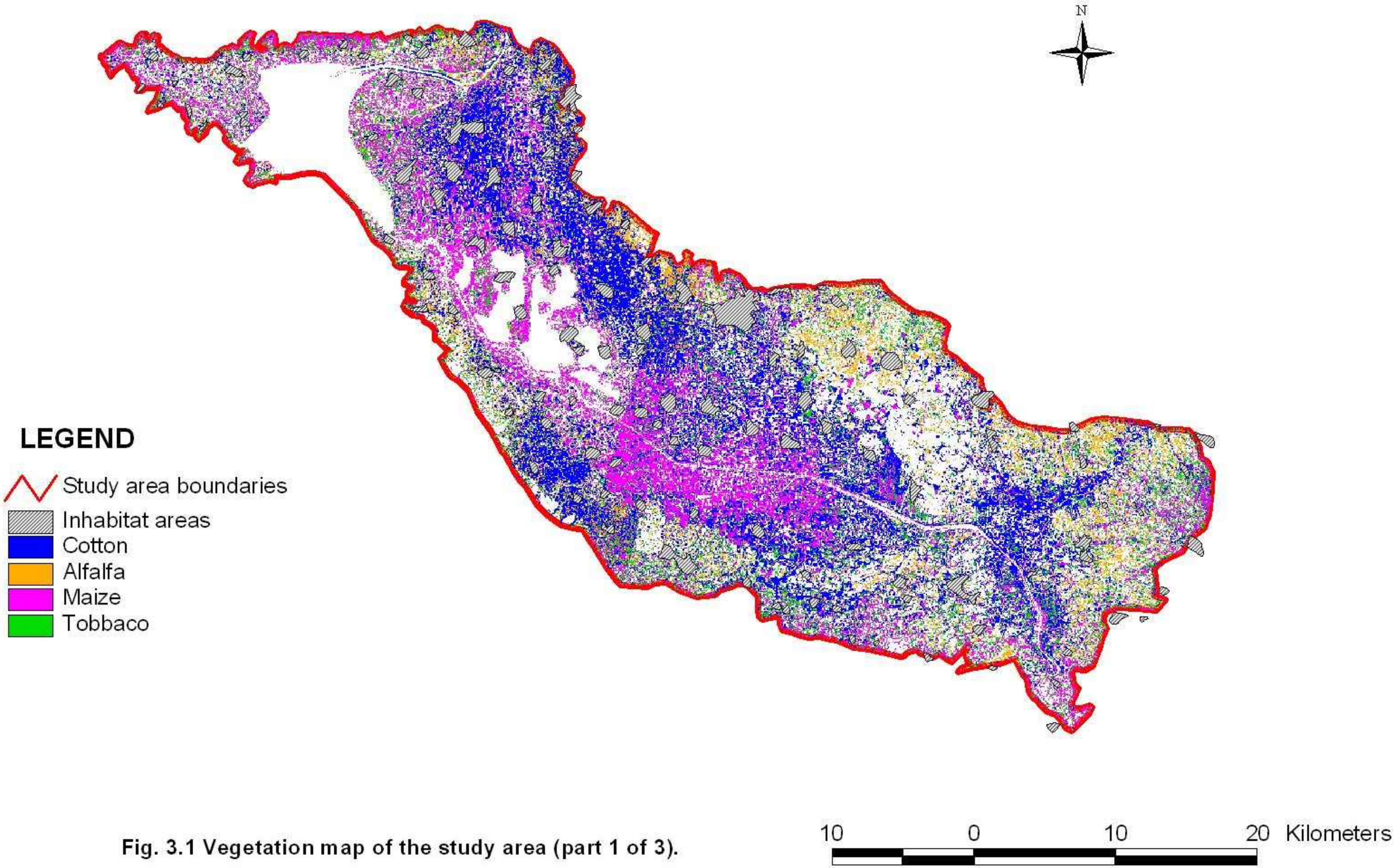

Fig. 3.1 Vegetation map of the study area (part 1 of 3).

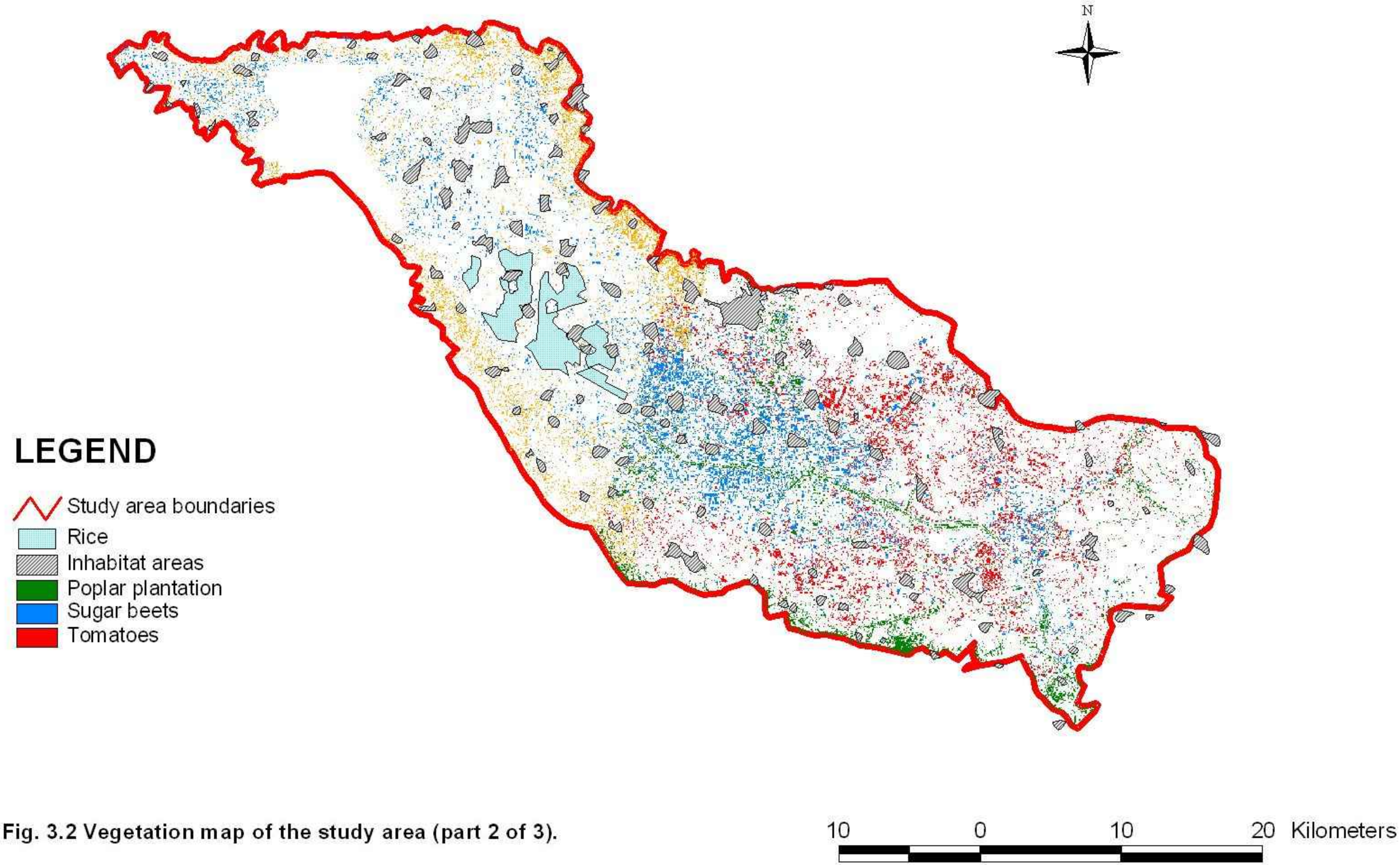

Fig. 3.2 Vegetation map of the study area (part 2 of 3).

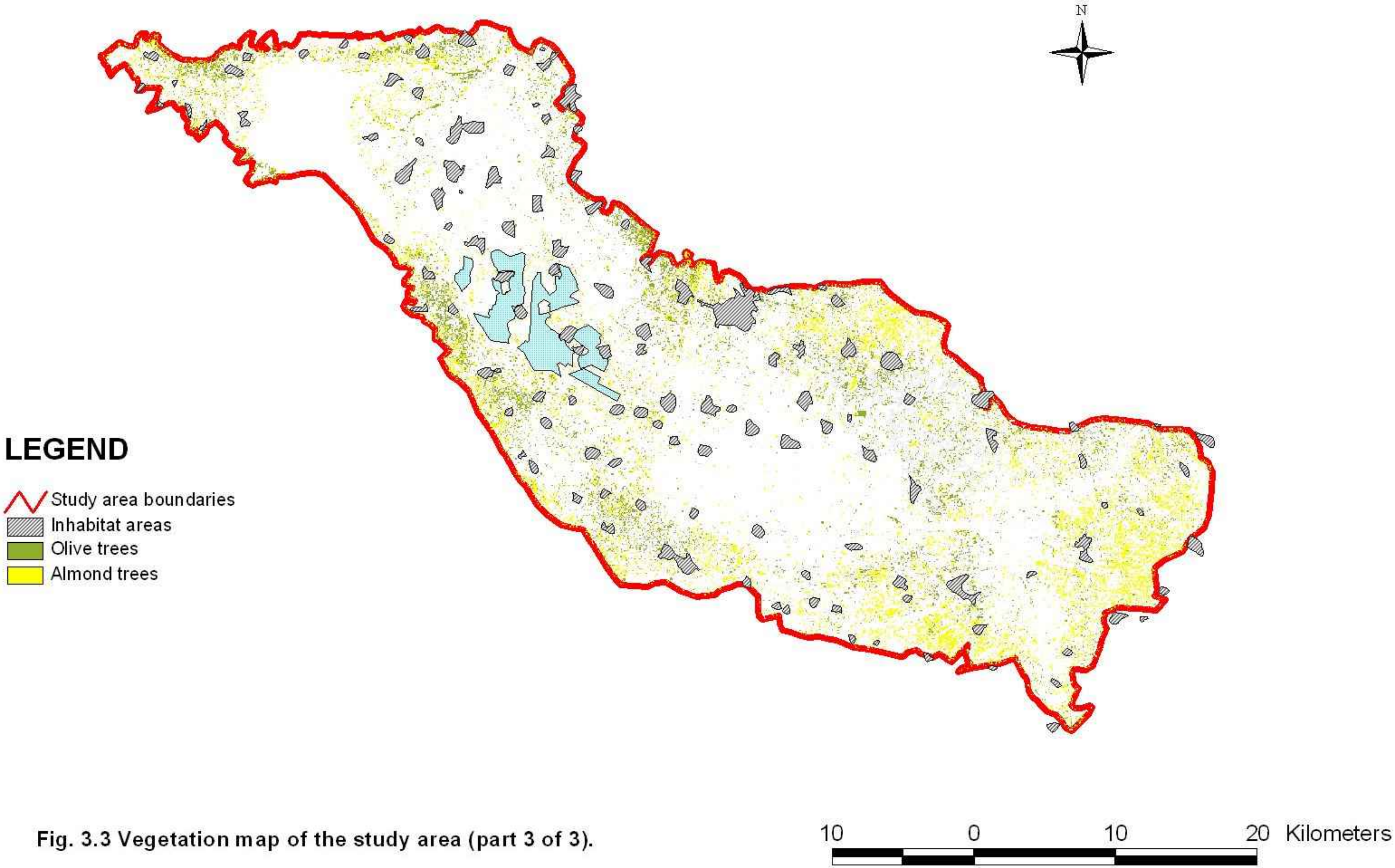

Fig. 3.3 Vegetation map of the study area (part 3 of 3).

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 21 days (17/6 – 7/7 2006) 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 21 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 using the same equipment with year's 2005. This combination of hardware, software and technique proved very effective and productive for signature collection.

This combination, basically consisted by the GPS's track log file with the oral descriptions recorded in a tape recorder during the field visits, was also very useful in the signature evaluation procedure and in the completion of more signatures on the screen.

The only problem here is that, like in 2005, 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.

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. So to face this problem, this year a second set of images was ordered. Unfortunately because of high percentage of cloud cover and difficulties in satellite programming, collection of this extra set was not possible during the summer. It is worth mentioning here that these two layers of images, when they are available, also provide higher accuracy assessment to all classes even the ones with good separetability.

3.2.4 Classes used and classification area

As mentioned in years 2005 report, there are some questions which were raised during the classification process which we need to face as they 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)

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