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 1 (year 2004)

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THE GOULANDRIS NATURAL HISTORY MUSEUM
GREEK BIOTOPE / WETLAND CENTRE

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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. 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, 6 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, 3 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 x10m) of data and the significant multispectral ability to distinguish water from land resources, compared to other available space and airborne remote sensing data.

The image acquisition was programmed for the spring and summer 2004, in order to avoid cloud and ice coverage and because this is the period when we need the vegetation coverage information for the needs of the project. 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

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.

A major fallback of this year's data acquisition was that only the first of the three sets of two images had a small time gap of three days making possible the mosaicking of the two images. The other two sets had a time gap of about 20 days. During this period the physiographic characteristics of vegetation can significantly change making the mosaicking for each set useless.

From the other hand these six images from the end of April to the end of August offer valuable information about the vegetation reflectances during this period and can be effectively used for the classification of the images of the next periods.

2.2 Image preprocessing

The six SPOT images from the three sets were used to estimate the crop patterns of year 2004. They were firstly georeferenced to the Greek Geodetic Reference System EGSA΄87[1] using ERDAS IMAGINE version 8.4. "Image to map" and "image to

[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 and it measures in meters.

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 better spatial accuracy. Figures 2.2.1 to 2.2.6 show the resulted images.

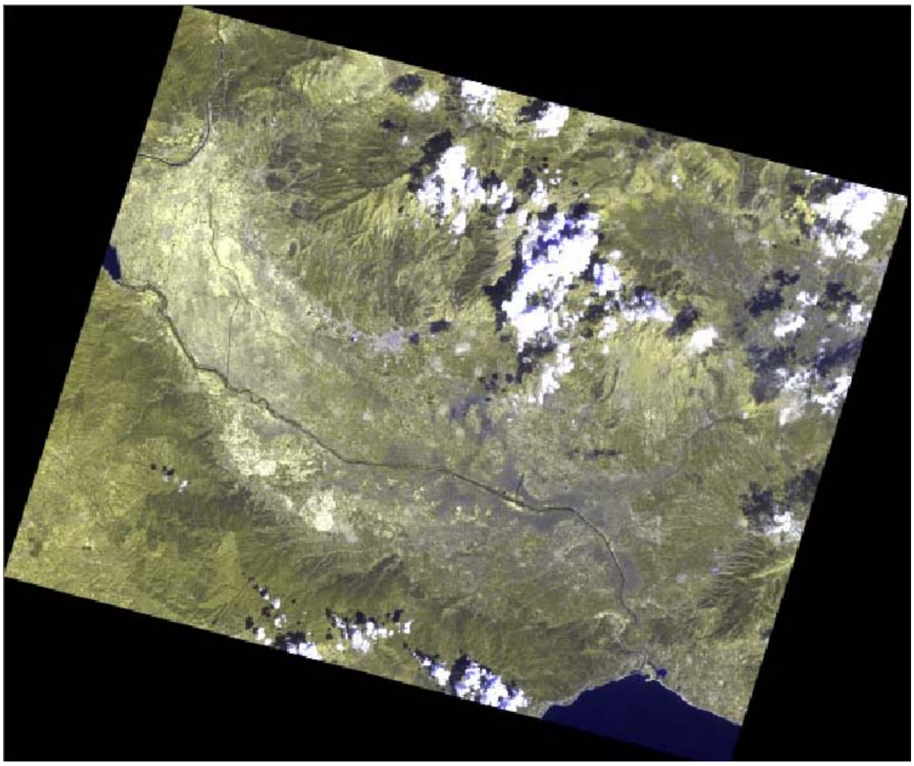

Figure 2.2.1 Scene 1 (April 23, 2004) that covers the SE part of the study area, georeferenced to EGSA´87.

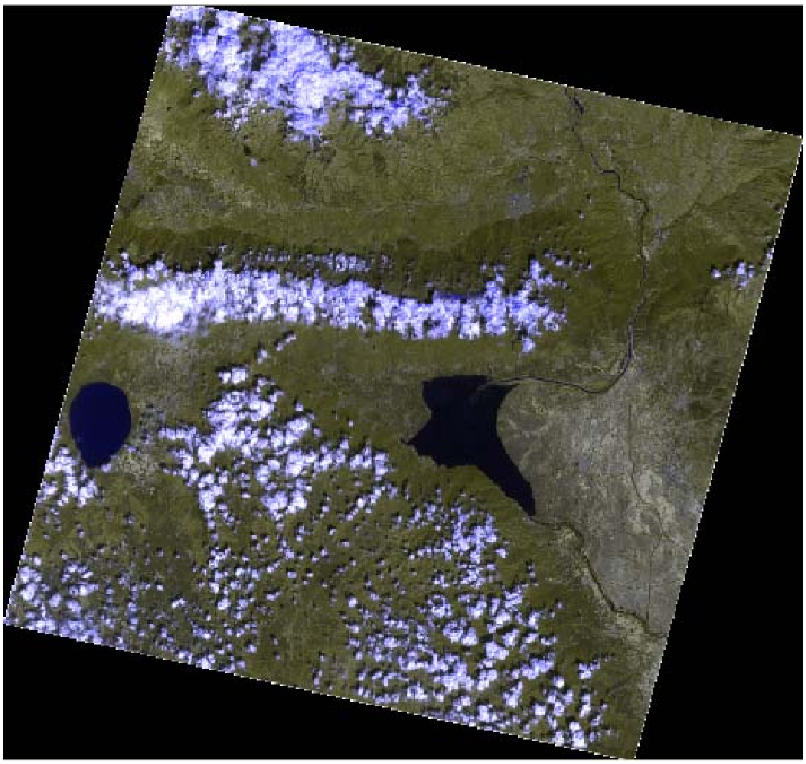

Figure 2.2.2 Scene 2 (April 29, 2004) from the NW part of the study area, georeferenced to EGSA´87.

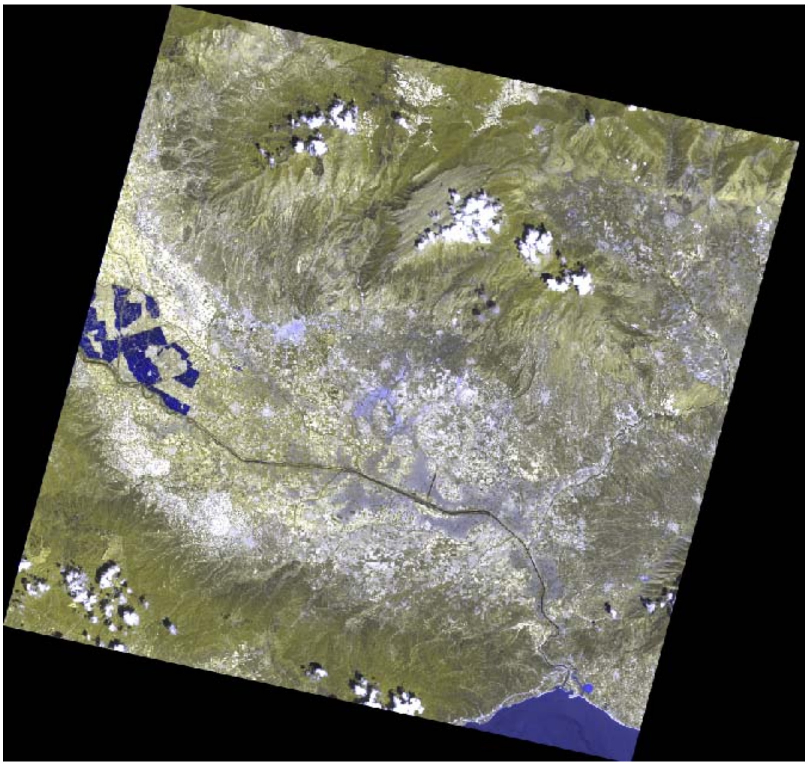

Figure 2.2.3 Scene 3 (May 25, 2004) from the SE part of the study area, georeferenced to EGSA´87.

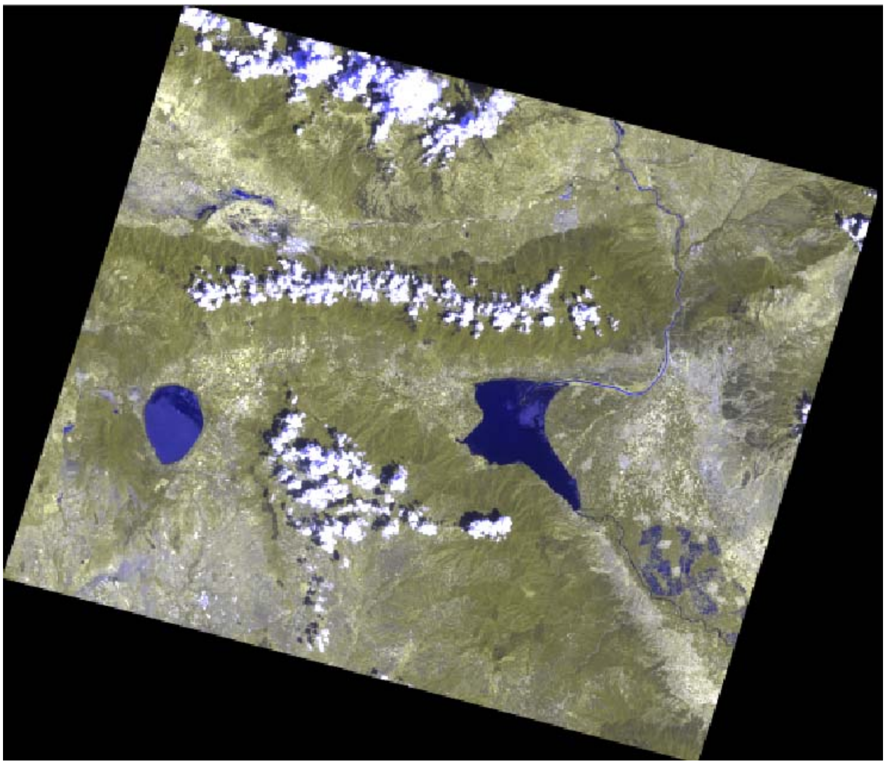

Figure 2.2.4 Scene 4 (June 14, 2004) from the NW part of the study area, georeferenced to EGSA΄87.

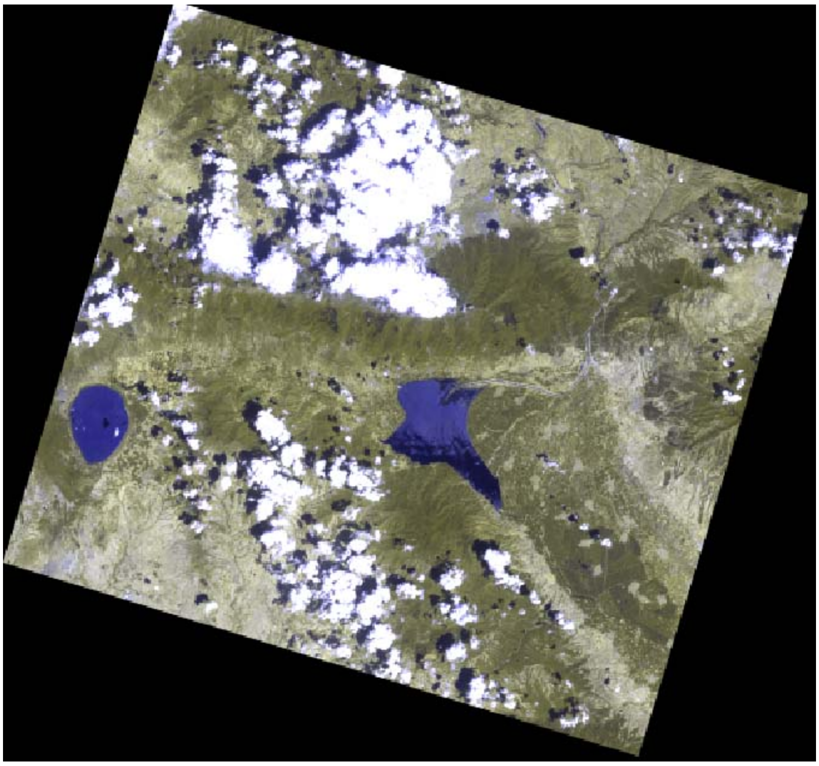

Figure 2.2.5 Scene 5 (July 14, 2004) from the NW part of the study area, georeferenced to EGSA΄87.

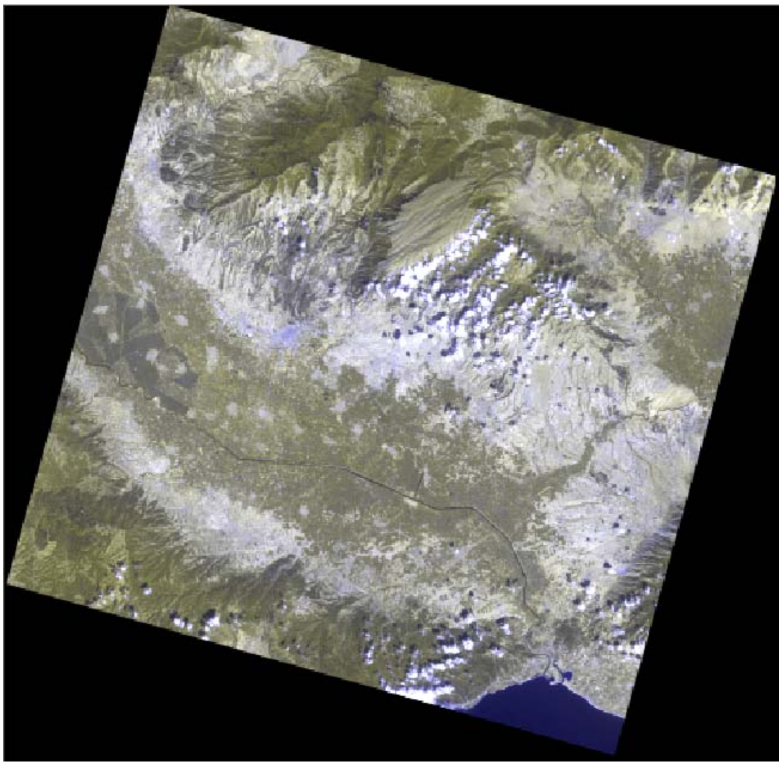

Figure 2.2.6 Scene 6 (August 25, 2004) from the SE part of the study area, georeferenced to EGSA´87.

2.3 Equipment used

The following equipment 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)
- Erdas Imagine V. 8.4
- ArcView 3.2 with Image Analysis extention
- Microsoft office 2003 pro, office application.
- Magellan Promark XP GPS system.

2.4 Signature collection

Two main field visits were accomplished in August 2004 for vegetation signature collection.

Using a suitable vehicle, we covered a distance of more than 200 km for each visit. A total of **36** signatures were collected from **12** different vegetation samples. The position of all these signatures recorded using the GPS system.

It was not possible to collect enough signatures for all the vegetation types especially the most rare of them.

During this field work, we used scale 1:50000 topographic maps to design our routes and to estimate our position. We also used a unsupervised classification map of the second set of satellite images to establish possible relationships between vegetation and vegetation classes.

Table 2.4.1 Samples per cultivation collected

Corp	**Number of samples**
Maize	7
Tobacco	3
Cotton	6
Alfalfa	1
Rice	2
Poplar plantation	2
Sugar beets	4
Wheat	4
Tomatoes	1
Olive groves	2
Walnut groves	1
Almond groves	3
Olive trees	2
Walnut trees	1
Almond trees	3

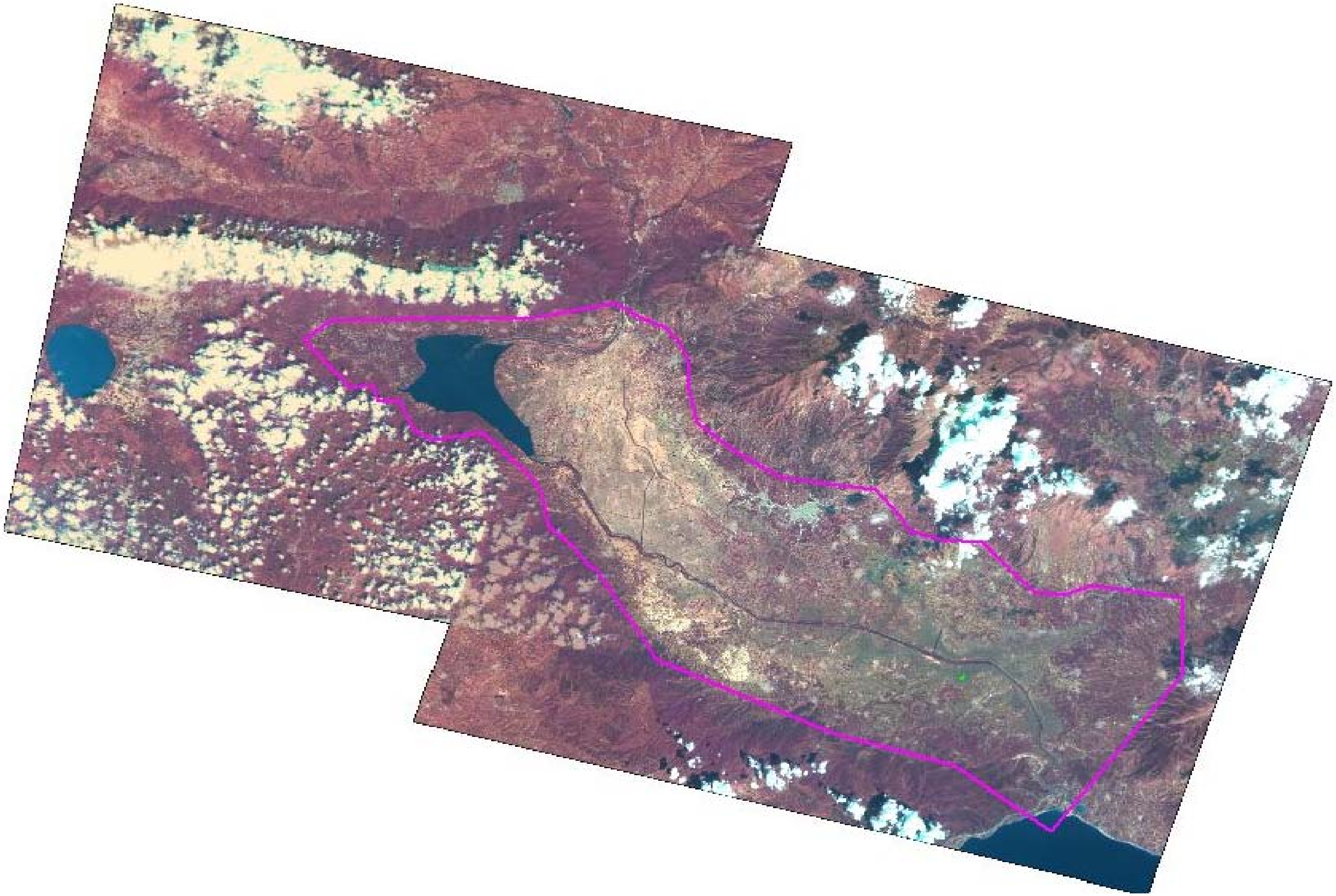

Figure 2.4.1 Mosaic of the images of the first set and our study area (magenta line)

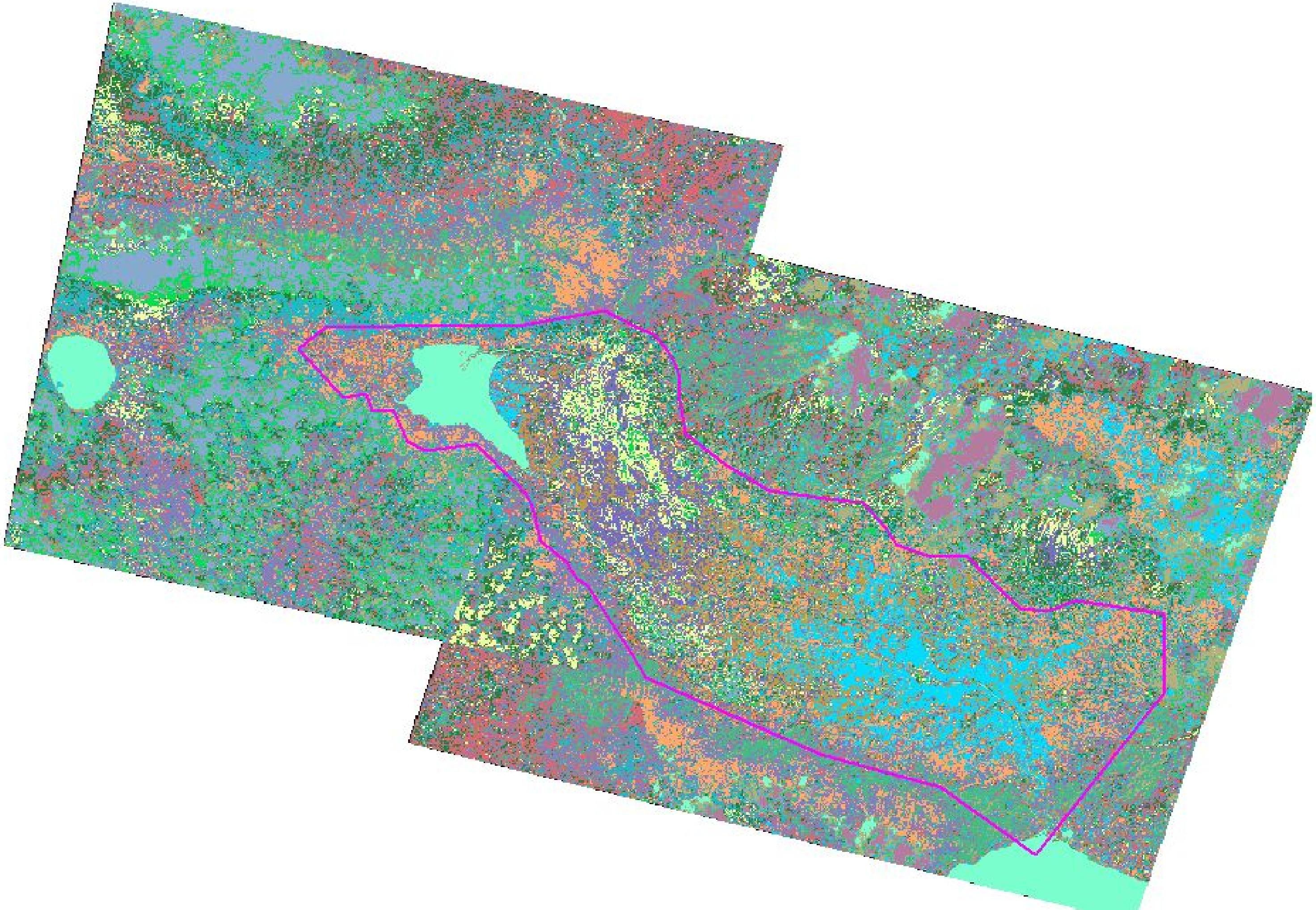

Fig 2.4.2 Unsupervised classification in 16 classes of the mosaic of the first set (map used on the field).

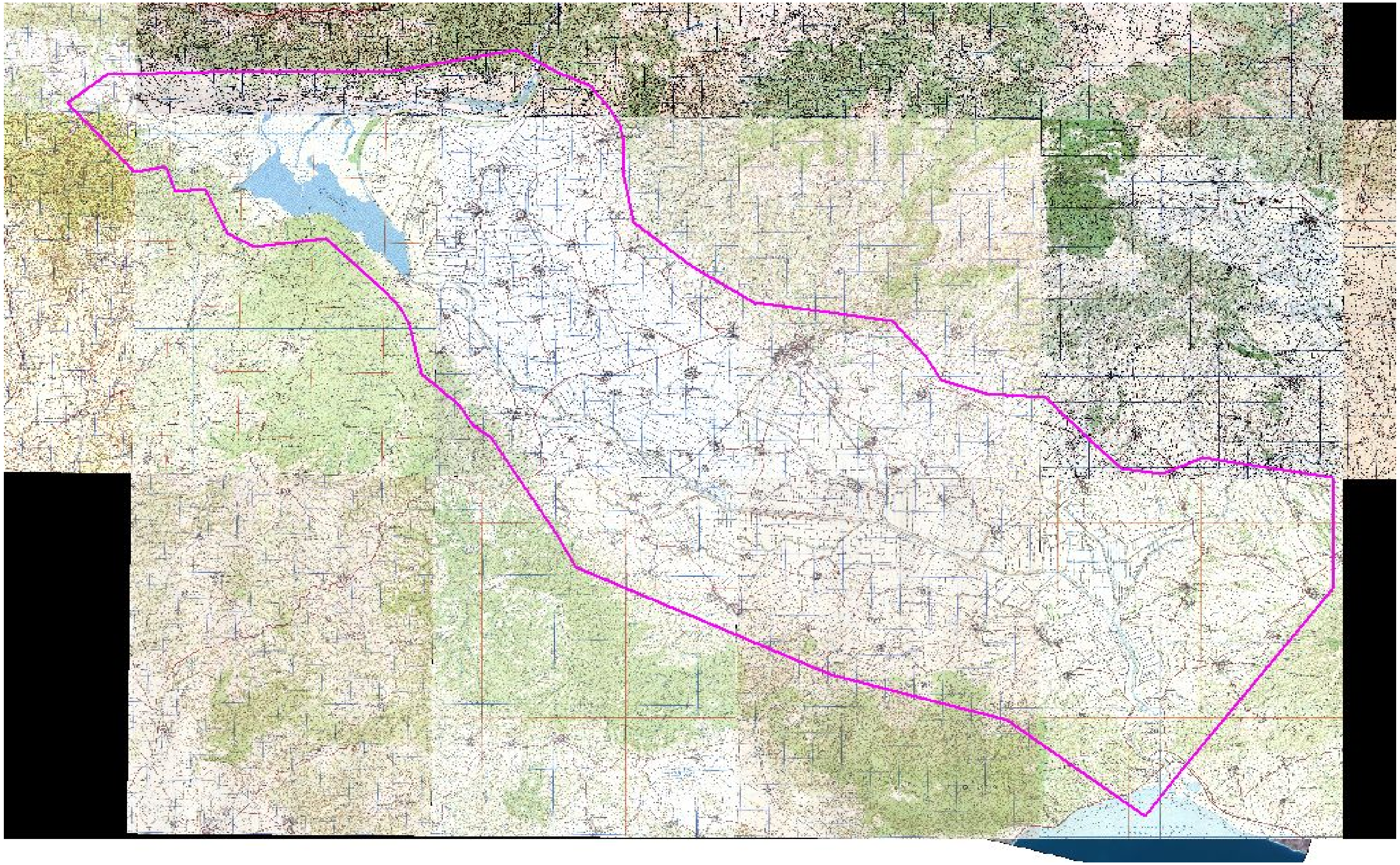

Fig 2.4.3 Topographic map used on the field (original scale 1:50000)

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 in the following table:

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

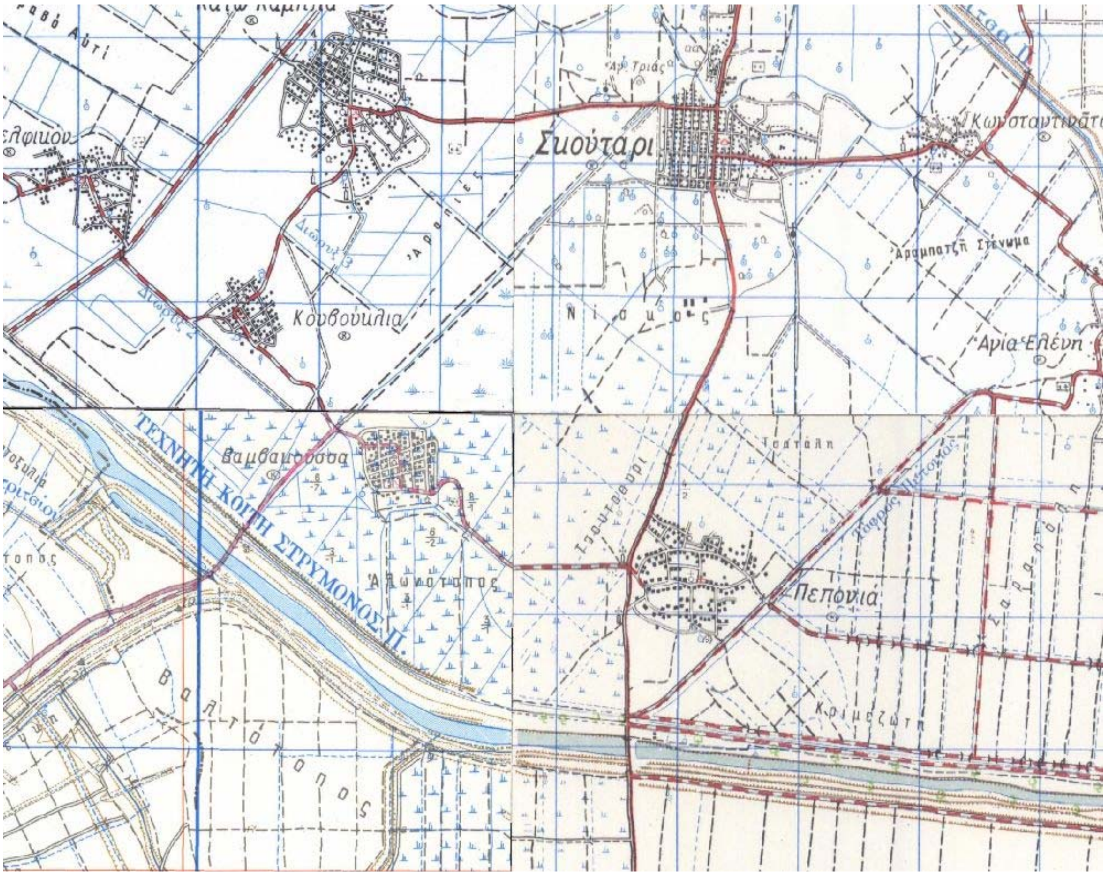

Fig 2.5.1 Detail of the topographic background (junction of 4 maps)

2.6 The classification procedure

2.6.1 Preparation of satellite images

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

As mentioned before only the first set was mosaicked as it has a reasonable time gap of only 3 days.

2.6.2 Extraction of inhabited areas

In this step we extracted 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.

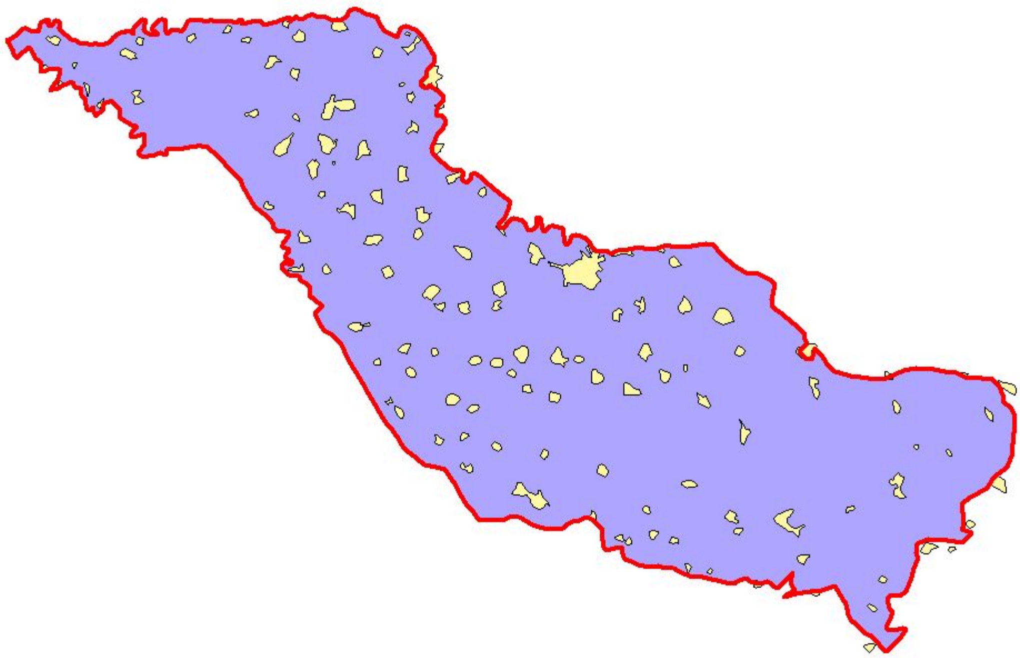

Figure 2.6.2 Inhabited areas (yellow polygons) which were taken out of the study area.

2.6.3 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 midle of the study area (north boundary) and cover less than 1% of the total area for the first set of images.

The cloud coverage for the second set of images was 0.3 % while for the third was 3.2 %.

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.

2.6.4 Rice fields 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 **4750.4 ha** was calculated for rice beds

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 2.6.4 Delineation of rice beds (red line)

2.7 Supervised classification

After extracting all the above areas (outside of area of interest, water bodies, clouds, cloud shadows, rice beds) 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.
Unfortunately, for some classes the accuracy assessment was not possible because of the limited number of collected signatures.
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. Check the reflectance of the class for each available image and time period.
3. Perform the supervised classification based on the class's signatures
4. Perform accuracy assessment
5. Make corrections and fine tuning of the signatures and their position
6. Repeat from step 2 until we get the best accuracy assessment
7. Save the layer representing the class in raster format, convert to vector and estimate the area of the class
8. Remove from the satellite images the pixels corresponding to the class we estimated
9. Repeat previous steps 1 – 7 in the remaining image's pixels and for the rest of the classes.
10. 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 presenting on table 3.1.1

Table 3.1.1 Results of classification

	Cultivation	Area (ha)	Classification Accuracy assessment (%)
1	Maize	21762	82
2	Tobacco	6601	68
3	Cotton	28504	70
4	Alfalfa	9218	65
5	Rice	4750	100
6	Poplar plantation	6112	94
7	Sugar beets	2469	69
8	Tomatoes	2780	-
9	Olive groves	2855	-
10	Wheat	11220	-
11	Almond groves	10566	-

The lack of accuracy assessment for classes 8, 9, 10, 11 and 12 is because of the limited samples collected for these classes

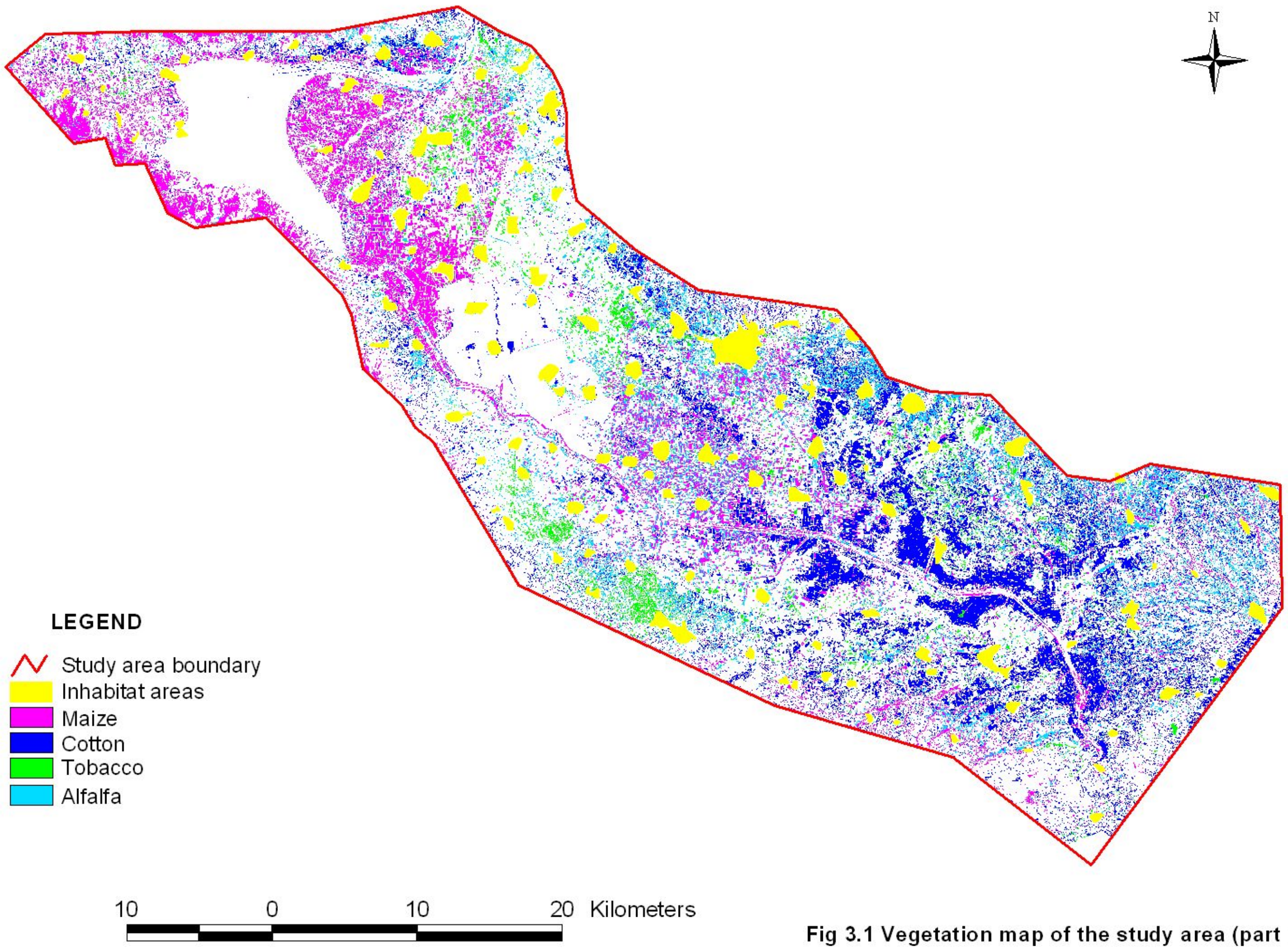

Fig 3.1 Vegetation map of the study area (part 1 of 3)

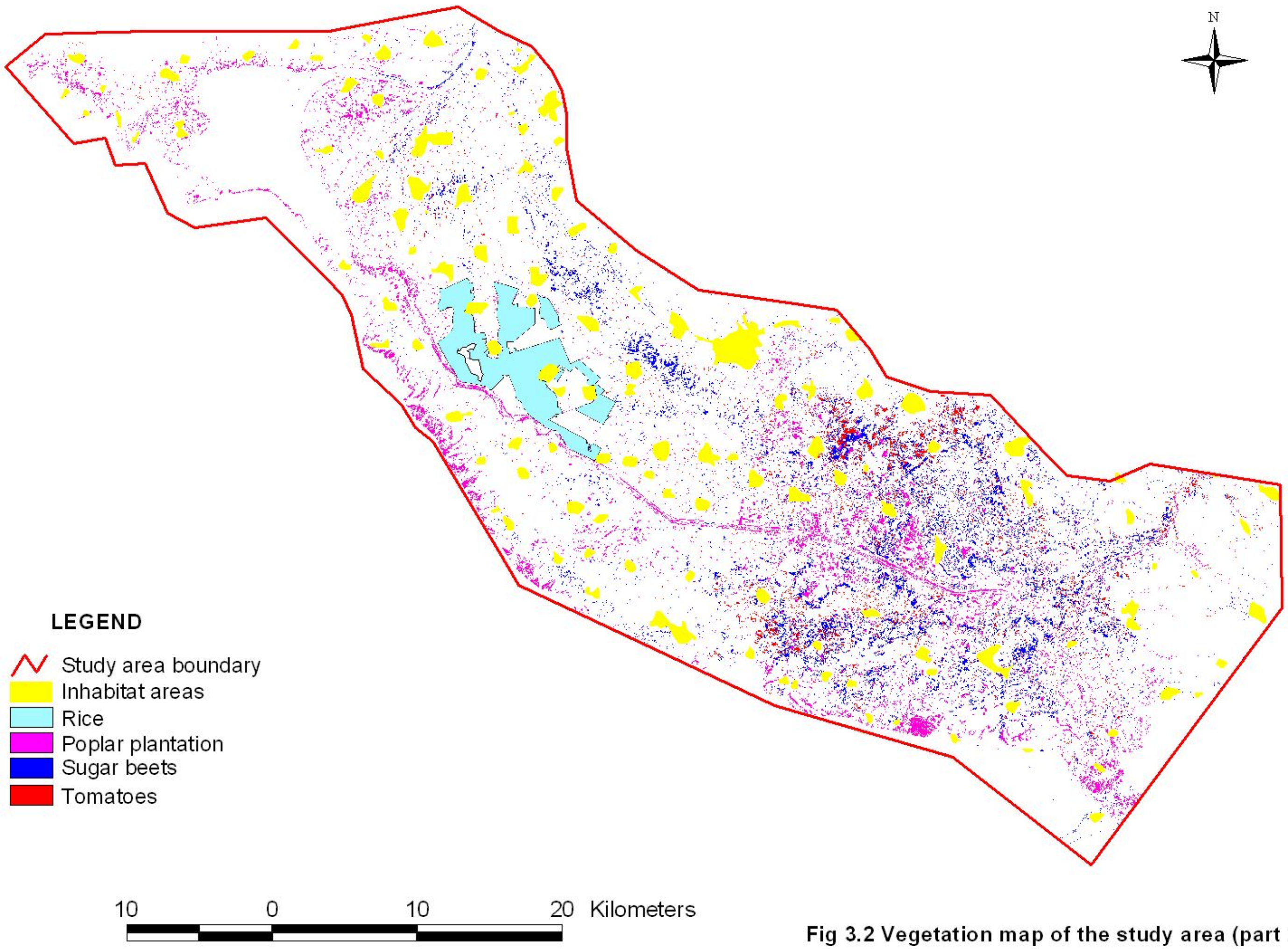

Fig 3.2 Vegetation map of the study area (part 2 of 3)

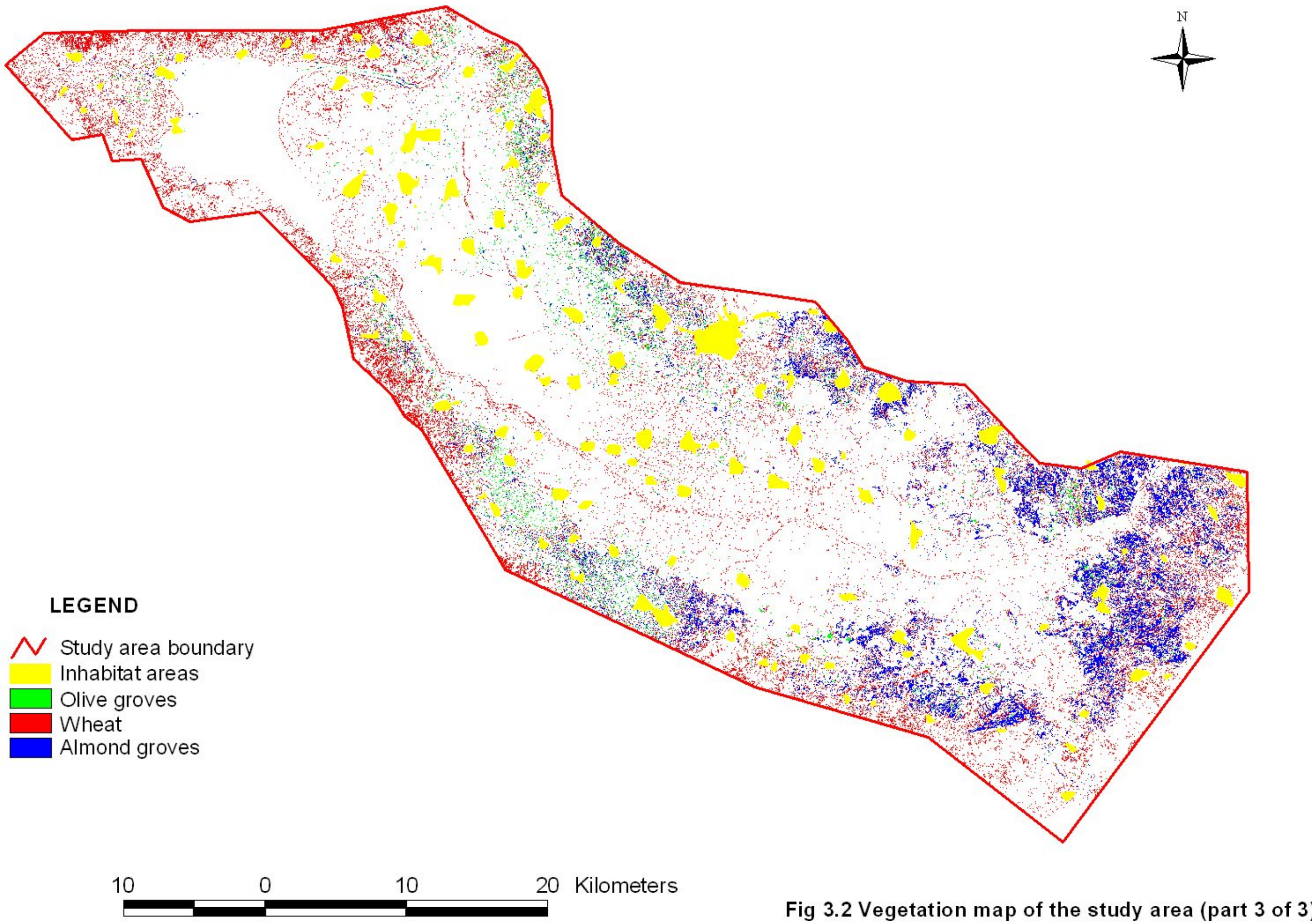

Fig 3.2 Vegetation map of the study area (part 3 of 3)

3.2 Discussion

Based on the above description of the classification procedure and the experience we got testing the signatures and estimating the accuracy of the results, we can easily 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 of the three image sets in one. The main reason for this was that the two images were taken, in both cases, with a time gap of 20 days and in a period of great plant growth. So these images had quite different pixel values for the same classes and practically it was impossible to archive a good mosaic of these 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.
These time gaps occurred as a combination of continuous cloud coverage during this period of the area of interest and some satellite programming problems.
The best 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.

3.2.2 Signature collection

The need for a more productive equipment for signature collection was obvious from the first signatures collected. H hand held computer with GPS and suitable software is highly recommended both for signature collection and tracklog accumulation.
The main problem with the equipment used was that we need about 30 to 40 minutes to collect a single signature and put it on a paper map. One major fallback of the method was also the lack of signatures for some 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 Seperatability of classes

Some seperatability problems were encountered in specific classes in the same image. This happened to the classes between tobacco, cotton and sugar beets. This was a rather difficult problem and we have to use some advanced techniques to reduce it. It was also necessary to perform some preprocessing to archive better results.

The accuracy assessment achieved for the above classes is still lower than it was accepted.

A good solution for this problem is to apply change detection for the same classes in different images and check the how reflectances change. Then apply this information for a supervised classification.

3.2.4 Orthorectification and change detection.

As mentioned before, to successfully separate some classes, we need to apply change detection procedures between two or more time periods.

To effectively apply change detection you need to use *orthorectification* to the satellite images. So you need to use an accurate and high resolution DEM (Digital Elevation Model) of the area. In our case a DEM with a resolution of at least 20 meters is recommended. We can create a DEM using hypsography and hydrology data from 1:50000 scale maps or build it directly from satellite images using suitable software.

This issue is very important in our case because the majority of parcels in our study area are very small (less than 1ha) and the accurate overlapping between all layers of satellite images is rather a necessity than just a good source of spatial data.

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