

**«BACCHUS»
METHODOLOGICAL APPROACH FOR VINEYARD
INVENTORY AND MANAGEMENT**

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FOR VINEYARD INVENTORY
AND MANAGEMENT



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**METHODOLOGICAL APPROACH FOR VINEYARD INVENTORY
AND MANAGEMENT (BACCHUS)
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SUMMARY

Objective: Although Europe is the most important wine producer in the world, vineyard areas managers are not available of a reliable common methodology for updating their inventories of vineyard distribution on their territory and of technical means to exploit this knowledge for supporting their decisions in matter of land management in grape producing areas.

Methodology: The Bacchus approach is to provide to vineyard management organisations with an integrated and comprehensive solution to meet their information requirements, based on the use of Very High Resolution remote sensing data, Geographical Information Systems and modern software programming languages.

Results: The most important result of project is the development of BACCHUS SW as an easy-to-use software application addressed to technicians that are not specialized on GIS according to the following criteria:

- a) Suitability of the system to the type and volume data to be handled.
- b) User-friendly application.
- c) All components based on PC's operation over WINDOWS 95/98/NT/2000/XP.
- d) Used without extensive restructuring of the organization's systems.

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EC Project Officer: Mr. Marcos Ortíz-Vandepias

BOOK OVERVIEW

This book had been divided in 6 different chapters and 3 annexes. The first chapter tackles an introduction to BACCHUS project, providing information about the state-of the art, the 3 phases of BACCHUS project and the achieved objectives in each phase.

Chapter 2, dealing with Very High Resolution Data, includes a description of the most important data characteristics of commercial satellites like QuickBird, IKONOS, SPOT and FORMOSAT.

BACCHUS Software specifications are gathered in Chapter 3, collecting the User and System Requirements from a wide number of vineyard manager's organisations. Divided in different categories, the Functional Requirements contains the translation of User's and System requirements for an ideal BACCHUS system in a total number of 27 requests.

Chapter 4 presents BACCHUS textural and structural analysis carried out for automatic detection and characterisation of vineyard plots with satellite and aerial images.

Chapter 5 contains a general view of well-known Multitemporal and Multispectral techniques for crop mapping. Besides, it also focuses on approaches that have been specifically designed to vineyard inventory, dedicating a special section to test Multitemporal and Multispectral techniques in BACCHUS vineyard test sites.

Climate, soil, morphology and management factor are use for a preliminary land potential assessment in chapter 6. The analysis of these elements tries to improve wine qualities and best oenological practices at crop level. The output products are obtained by means of VHR images, GIS and agro-meteorological models.

To complete this book, 3 annexes had been included, corresponding to: i) BACCHUS fly campaigns with a multispectral camera over France, Italy, Spain and Portugal test sites; ii) BACCHUS Metadata description, elaborated to

organised BACCHUS dataset according ISO (International Standard Organization) instructions, and finally iii) Colour Images annex.

1. INTRODUCTION

Montesinos S. & Fernández L.

1.1. BACKGROUND AND RATIONALE

Although European vineyards account with 45% of wine areas in the world and produce the 60% of world wine, European Union has a strong competition from third countries like Argentina, Australia, Canada, Chile, New Zealand, South Africa, USA or Uruguay, so-called «New World» producers.

The European wine-making industry is mainly SMEs and presents a market very segmented (most of all consisting in family business), whereas «New World» producers presents a strong and innovative wine-market with a few leaders by country and with a high volume of production, being a strong competitor to Europe (see figure 1.1).

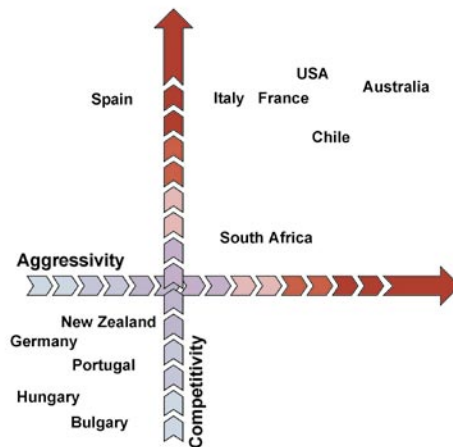


FIGURE 1.1. WINE-MARKET SCENARIO. (DIVINO PROJECT SOURCE).

In order to gain competitiveness and trying to stay as leader of the market, Europe must improve their technologies, increasing their production of quality wines thanks to new techniques like Remote Sensing and GIS.

Also European vineyard areas managers are not available of a reliable common methodology for updating their inventories of vineyard distribution on their territory and of technical means to exploit this knowledge for supporting their decisions in matter of land management in grape producing areas.

Very High Resolution remote sensing data and Geographical Information Systems allows the generation of integrated and comprehensive solutions to create and maintain an updated register of vine cultivation as well as the extraction of information crossing vine inventories with other important data like pre-existing vine producers' database, slope maps, meteorological data, etc.

1.2. OBJECTIVES

BACCHUS project aimed to develop a methodological approach to define and test:

- A semi-automatic method for vineyard detection using very high-resolution remotely-sensed digital data. These data include very high-resolution satellite images from the IKONOS and QuickBird satellites, digital multispectral aerial photography and conventional ortophotography.
- A vineyard database structure for the efficient organisation of the information related to vineyard plots.
- Spatial analysis procedures for supporting decision-making processes by integrating the vineyard maps with other relevant data such as slope maps, bio-types, geomorphological features, administrative boundaries, production records, etc.

Providing to the final users – Public Administration, Wine Quality Regulating bodies and Vine-growing Co-operatives – with information at three different levels:

1. Up-dated database of wine producing areas. All the information related to wine production (name of the vine grower, location of the estate, average production, etc.) can be linked to the perimeters of areas cultivated with vine (Simplified Cadastre). In this way, the organisations in charge of vineyard management are be able to:

- Easily update the administrative data related to each wine producer, in case of change of land property or land use.
- Generate statistical data at different administrative levels (vine state, municipality, province, etc.).

- Elaborate documentation to present administrative applications (e.g. request for subsidies, bank credit request, etc.).
- Support the routine management of wine production during the different cultivation phases (e.g. planning of fertilisation, phyto-sanitary treatment) and integration with other management tools (e.g. meteorological parameters) for the promotion of eco-compatible practices.
- Simplify the reporting of local wine producers data and their integration in the local/regional information systems (e.g. Reg. CEE 2078/92).

2. *Land management criteria.* Knowing the spatial distribution of vineyard and the agro-climatic characteristics of the territory, land managers have a valuable support for their decision making:

- In case of reduction of wine production, which areas are eligible for vine grubbing-up taking into consideration the quality of plants and the role they can play in the prevention of soil erosion.
- In case of encouragement of vine planting, which areas are particularly suitable for high-quality vine plantation.
- When considering the improvement of land productivity, identify those areas that, for slope exposure, soil and steepness characteristics, would give better results if vineyard is substituted by other kinds of crops.

3. *Controlled Origin Denomination management.* Organisations regulating the production areas of certified quality vine (*Denominazione d'Origine Controllata, Appellation d'Origine, Denominación de Origen, etc.*) can:

- Keep a record of high quality wine areas, which are exempt from regulation measures of the European Commission.
- Detect which areas have geomorphologic and climatic conditions to be proposed as Controlled Origin Denomination areas. Within these areas, detect which sub-regions have special biological, pedological and geomorphological characteristics and vocation for special "territories".
- Support the commercialisation of the derived products providing specific information (e.g. geo-localisation, specific land characterisation) to be used for publications and product promotion.

1.3. PHASES

BACCHUS project was carried out over 30 months from February 2002 until July 2005. The schedule divided the project into three main phases: 1. Definition, 2. Development, and 3. Implementation.

Along first phase, user's requirements were defined as well as the revision of state of the art. Next, system design in terms of architecture and specifications

translate the gathered user's requirement into system's requirements. The second phase, from tenth to twentieth months, entailed a complex phase due the development of BACCHUS methodologies for the vine detection and management, the implementation of BACCHUS software as well the execution of airborne campaigns over the different test sites or the acquisition and processing of VHR satellite images. Finally, the third phase of the project, with duration of 10 months, produced the configuration of the System along numerous versions that was tested by consortium, especially BACCHUS users, improving their functions until a solid tool was implemented.

Along the project life's cycle, Bacchus consortium was provided their experiences and knowledge depending on the phase in progress. In the first phase, users took a high power in order to define their competences and activities as well as their weak points in their organism. These users had been represented by four different countries (Spain, Portugal, France and Italy) and also covering different aspects of vine cultivation:

In *Spain* and *Portugal*, the involved users are **governmental organisations**, which have to monitor the vine activity to apply the EC policy and indications. Their role is to combine this implementation with the achievement of public welfare, nature protection and sustainable development. The Portuguese *Instituto da Vinha e do Vinho* has a national scope, while the Spanish *Junta de Comunidades de Castilla - La Mancha* is in charge of the administration of Castilla-La Mancha, a region having the biggest concentration of vine in the world. In *France*, one user, *ONIVINS* (*Office National Interprofessionnel des Vins*), which executes the national and European interventions of the viticultural and wine sector, is a public organisation, but with an important professional participation.

In *France* and *Italy*, the BACCHUS users belong to the **wine-production sector** and their interest is focused on optimising the production and considering the economic aspects linked to wine production. Their tasks and responsibilities are related with production monitoring and supporting farmers and producers during the normal production cycle; planning the future management of the Controlled Origin Denomination areas; establishing of a zonation plans; identifying areas for new plantation, etc. The French *GéoDASEA* offers technical support to grape producers at a regional level, while the Italian users are Consortia of Controlled Origin Denomination areas (*Consorzio Tutela Vino Prosecco*, *Consorzio Tutela Denominazione Frascati*). The last user is a French private cooperative organisation, FRCA (*Fédération Régionale de la Coopération Agricole*), which federates 2.200 wine cooperatives.

The technical partners responsible to compile all users feedback was *GEOSYS*, a private company, acted as project coordinator and project manager. In charge

of the User Requirements Analysis and the System Design Definition since, GEOSYS is skilled to gather and analyse the user's requirements and translate them in a system design.

Along the second phase, the technological private companies as well the research institutes takes the control of the BACCHUS progress to develop the methodologies for vine detection and management, to implement the BACCHUS software and to acquired and processes the VHR images. These members were:

GEOSYS was in charge of the Pilot System Implementation due to its expertise in the development in-house software and in the generation of user friendly applications. The Company carried out an EC-funded project for «Earth Observation Product Development and Marketing». **GEOSYS** collaborated with CEMAGREF and IDR in the vine detection methodology, taking advantage of the expertise gained by its staff in the implementation of *Registro Oleícola Español* (Spanish Olive tree Register) using aerial photography.

As Research Institutes, with an international name in the field of remote sensing, cartography and agriculture applications: **CEMAGREF** (France), **IGP** (Portugal), **CNR** (Italy), **IDR-UCLM** (Spain) and **INTA** (Spain).

CEMAGREF led the research activities related to the Vineyard Detection Methodology due to its deep know-how in this field, in particular for the structural and textural analysis. **CEMAGREF** also lead the review of the state of the art activity during the first phase of the project.

IGP was responsible for the Land Segmentation and the Data Acquisition and Processing. Its experience in remote sensing and co-ordination of the national net for geo-information allows its technicians to have a good knowledge of how to manage and cross-different kinds of information, and different GIS software and tools.

The expertise of **CNR** had focused in spatial and environmental analysis techniques for leading in the Vine Management Criteria. Since the Italian users represent the point of view of vine producers in DOC areas, **CNR** was in charge of defining the spatial analysis operations related to the management of DOC areas and the selection of new high quality vine-growing areas.

IDR-UCLM worked in the development of the vine detection methodology, in the latter as responsible of the multispectral and multitemporal analysis of remotely-sensed data. Moreover, it was responsible for Dissemination and Exploitation of results, due to its dissemination capabilities related to the publication facilities provided by the Universidad de Castilla-La Mancha.

The Remote Sensing Laboratory (LABTEL) of **INTA** is specialised in planning, designing and carrying out flight campaigns to get high spatial resolution airborne remote sensed data. The Laboratory has the facilities and «know-how» to process

the data acquired and to extract useful information from them. *INTA* operated a new-generation airborne multispectral digital camera to collect very high resolution data in the test sites of Spain, France, Portugal and Italy.

To finish, the third phase of the project, users again played an important role, testing and improving with suggestions and comment the different versionS of BACCHUS software. As well as *GEOSYS* as responsible of BACCHUS tool development, and *IGP* as responsible of the Evaluation and Validation activities.

BACCHUS was benefit of the external support of *ESA-ESRIN*, which acted as project promoter.

Table 1.1 shows the BACCHUS dataset employed along the different phases of the project.

Table 1.1. Main data sources used

Task	Space data	Non-space data
Structural Analysis	Landsat satellite images, 30 meters resolution. QuickBird satellite images, 0,6 meters resolution. Ortophotography, 0,5 meters resolution.	
Textural Analysis	QuickBird satellite images, 0,6 meters resolution. Ortophotography, 0,5 meters resolution.	
Multispectral Analysis	Landsat satellite images, 30 meters resolution. QuickBird satellite images, 0,6 meters resolution.	Field data.
Multitemporal Analysis	Landsat satellite images, 30 meters resolution. QuickBird satellite images, 0,6 meters resolution.	Field data.
Land and Vine Management Spatial Analysis	Landsat satellite images, 30 meters resolution.	Meteorological data, DEM, Cadastral data, Soil map, Solar radiation map.
Land Segmentation		Climatic characteristics, Production Rates, DOC delimitation.

The project contained several milestones according the schedule of the three phases which can be summarising in:

Milestone 1. Kick-Off Meeting. Phase 1. Definition.

Milestone 2. Agreement on User Requirements. Phase 1. Definition.

Milestone 3. Complete State of the Art. Phase 1. Definition.

Milestone 4. Agreement on System Design. Phase 1. Definition.

Milestone 5. Complete Vine Detection Methodology. Phase 2. Development.

Milestone 6. Complete Vine Management Operations. Phase 2. Development.

Milestone 7. Pilot System Implementation. Phase 3. Implementation.

Milestone 8. Pilot System Acceptance. Phase 3. Implementation.

The consortium members have produced different technical deliverables according the carried out Work-packages:

National Users Requirements Document, Responsible: GEOSYS, CO¹.

User Requirement Document, Responsible: GEOSYS, RE².

End Users Database, Responsible: GEOSYS, RE.

State of the Art report, Responsible: CEMAGREF, RE.

System Design Document, Responsible: GEOSYS, RE.

System Evaluation Plan Document, Responsible: GEOSYS, CO.

Land Segmentation Document, Responsible: IGP, RE.

Test Sites Selection Document, Responsible: IGP, RE.

Vine Detection Methodology, Responsible: CEMAGREF, RE.

Technical note on Vine Detection Methodology, Responsible: CEMAGREF, CO.

Spatial Analysis Operations for Land & Vine Management, Responsible: CNR, RE.

Technical note on Spatial Analysis Operations for Land and Vine Management, Responsible: CNR, CO.

Test Site Dataset, Responsible: IGP, CO.

Data Gathering and Processing, Responsible: IGP, CO.

BACCHUS Pilot System, Responsible: GEOSYS, P³.

BACCHUS System Manual, Responsible: GEOSYS, P.

Evaluation Report, Responsible: IGP, RE.

KEY: ¹ CO: Confidential, only for consortium members; ² RE: Restricted to a group specified by the consortium & ³ P: Public.

The Public deliverables can be consulted at: www.bacchus_project.com or www.geosys.es. And the Restricted documents can be request to Dr. Salomón Montesinos, BACCHUS coordinator.

2. VHR DATA SOURCE

Montesinos S. & Fernández L.

In the actual Society, the «taking-decision» must be based on solid and truthful information, obtained from reliable dataset. The Geographic Information Systems allows us the tools and algorithms necessary to convert «data» on «information».

Since year 1972, when it was launched the first natural resources satellite, the remote sensing had converted on a «data source», providing dynamic dataset to be combined, within the framework of a Geographic Information System, with other data sources like digital ortophotography, thematic cartography, alphanumerical database, and GPS data, getting «information» (elaborate data).

2.1. CHARACTERISTICS OF SATELLITE DATA

The main characteristics which guarantee the remote sensing technique in these kinds of studies are:

- *Objectivity*. The supplied data are digital images (representing an object by a bidimensional numerical matrix) obtained by international spatial agencies (ESA, NASA, etc) which are commercially accessible for any person.
- *Continuity of data*. The supplied data from satellites are not extrapolate or interpolate data from punctual observations, like happens with statistical techniques, but these data are a discretization of an observed continuity of space, by units called *pixel* (from English contraction *picture element*) generating a digital image.
- *Recurrence of observations*. Due the satellite orbital models, these fly over the same area each a short period of time, allows us to obtain periodical observations of an area. The potentiality of this technique can

be translate as the actual satellite in orbit, the LANDSAT series, which supply an observation of the same area each 16 days which means that it's possible to find 22 observations of a same area by year or 660 in the last 30 years. The SPOT satellites series over fly each 26 days or 14 by year or 280 times in the last 20 years. Perhaps this characteristics is more obvious if we compare with the available ortophotography for the Spanish territory, where in the last 20 years, as general way, it's available the ortophotography of year 1987 (inter-ministerial fly), 1997 (SIG Oleícola) and 2001-2002 (SIGPAC).

- *Multispectrality of the observation.* The sensors on board capture the data not only in the visible region (which is the region received by the human eye or the digital ortophotography) but also infrared spectral region, which allow to «observe» invisible things for the human eye.
- *Multiscale of the observation.* Whith the actual satellite range, it's possible to carry out studies at 1:150.000 scale (from 30 metres spatial resolution images, for and maximum allowed error of 0,2 mm) or at 1:3.500 scale (from QuickBird images with 70 centimetres of spatial resolution).
- *Low acquisition cost of data.* The acquisition cost vary depending on the mission (Landsat, SPOT, QuickBird...), or even depending on if it's an actual image or ancillary data, anyhow prices can fluctuate from 23 /Km² of a QuickBird, to the 2,00 /Km² of a SPOT of 2,5 metres of spatial resolution , or to 0,05 /Km² of an actual Landsat image, with 7 spectral bands and 30 metres of spatial resolution.

Independently of the employed methodology (photointerpretation or digital analysis) for information extraction of the satellite data, the remote sensing is a powerful, dynamic and objective source of data.

2.2. CLASSIFICATIONS OF SATELLITE DATA

The remote sensing data are subject to different classifications depending to *i) the orbital characteristics of the satellite, ii) the energy source used by sensors and, iii) the supplied spatial resolution.*

According to orbital characteristics, the satellites are classified in 3 main groups (figure 2.1):

- 1) *Geostationary Satellites.*
- 2) *Polar Orbit Satellites.*
- 3) *General Orbit Satellites.*

The *Geostationary satellites*, also called *Geosynchronous*, appear immobile over a fixed point of the terrestrial surface. Its happen because the satellite is

located in a orbital height where their orbital period (time employed to give one round to a planet by their orbit) is equal to the Earth rotation speed. This orbital height is around 35.800 Km or 5,6 times the terrestrial radio (approximately 6.370 Km). By this reason, the Geosynchronous orbits are equatorials or almost equatorial. Some examples of these satellites are the meteorological USA satellites, ATS (*Applications Technology Satellites*) or GOES (*Geostationary Operational Environmental Satellites*), the European METEOSAT satellite. These are characterising by a low spatial resolution and a high periodicity of recurrence period (several times by day).

The *Polar satellites* are also called heliosynchronous, due that the angular relation between .Sun and the orbital plane of the satellite are constant (Widger, 1966) (Petrie, 1970). Its means that satellite always over flies the same point of the terrestrial surface at the same solar time.

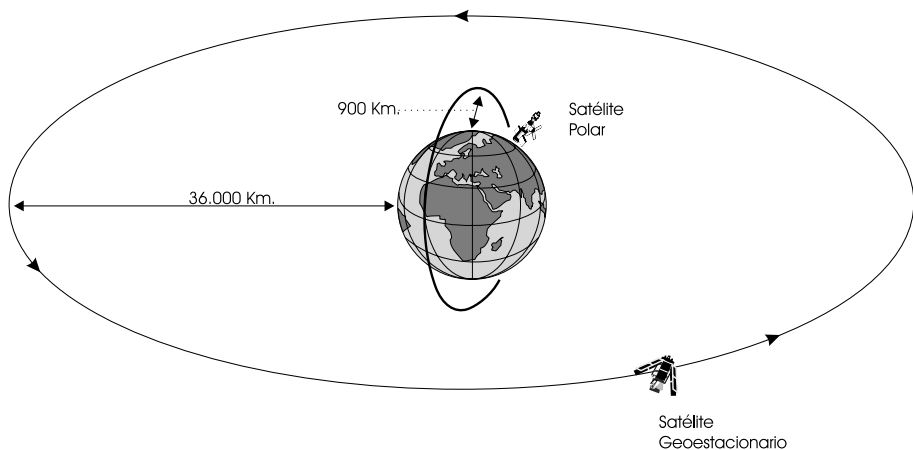


FIGURE 2.1. POLAR ORBIT AND GEOSTATIONARY SATELLITES (MONTESINOS, 1990).

On the contrary of Geostationary satellites, the Polar Orbit satellites don't stay over the same point of the terrestrial surface, but they describe circular or lightly eccentric orbits, on a N-S direction, while Earth is spinning on W-E direction. The orbit inclination limits the observed terrestrial zone. This way a satellite with an inclination upper of 50° only can over fly an area located between 50° de North latitude and 50° Sud latitude. The Landsat 5, with an orbital inclination of 98° , can over fly an area between 82° N and 82° S. Only a satellite with an orbital inclination of 90° could over fly the whole planet surface (Verger, 1982).

Polar Orbit satellites are located in a high lower of 1.000 Km of the terrestrial surface with a very short orbital period (less than 2 hours). Examples of these

kind of satellites are the USA Landsat satellite series, created for natural resources observation, the HCMM (*Heat Capacity Mapping Mission*) for thermal research at high resolution and the French satellite of natural resources, SPOT.

Finally, the General Orbit satellites don't present geosynchronous or heliosynchronous orbits. An example is Seasat 1, launched by USA in June 1978 to study the ocean bottom. This satellite presents an almost circular orbit with 108° of inclination angle and located on a high of 800 Km.

By the employed energy source of satellites, it's obtained other classification for the remote sensing data, depending if these data came from active sensors or passive sensors.

The active sensors illuminate the object with a radiation, picking up the reflected energy by him. On the contrary, the passive sensors pick up the reflected or emitted electromagnetic energy by an object, when it's illuminate by an external source like Sun.

Under the active sensors, the most used is the RADAR ones (*Radio Detection and Ranging*). When the platform of observation is an airborne, it's called SLAR (*Side Looking Airborne Radar*). It consists on an emitted electric energy pulse along the microwave frequency, picking up their reflection on the land by a beam located on the airborne.

These images are characterising by presenting along their axis a white band corresponding to the airborne vertical. It's due that the incident angles (incident shaft and perpendicular to the terrain) cannot be smaller because the receptor cannot solve the echo of arriving times.

The problem of this system lies in the relation between the opening diameter and the spatial resolution, hindering their use on spatial platforms, due to get an acceptable resolution its necessary very big beams.

To solve this problem, it had been developed other radar called, *Synthetic Aperture Radar*. It's called like this way because the own observation vehicle synthesizes with their movement, containing an aerial of high dimension than real ones producing better spatial resolutions for the same aperture (fig. 2.7).

Actually, all operative radars have *Synthetic Aperture*, providing lower spatial resolution than 20 metres.

The radar images present a sunny soil aspect, since the radar acts as Sun. The image texture will depends on the geometric characteristic of the soil.

When the roughness is lower than the used wavelength, the echo is poor, by this reason the water bodies and the roads appear in black colour. On the contrary, the buildings produce very intense reflections.

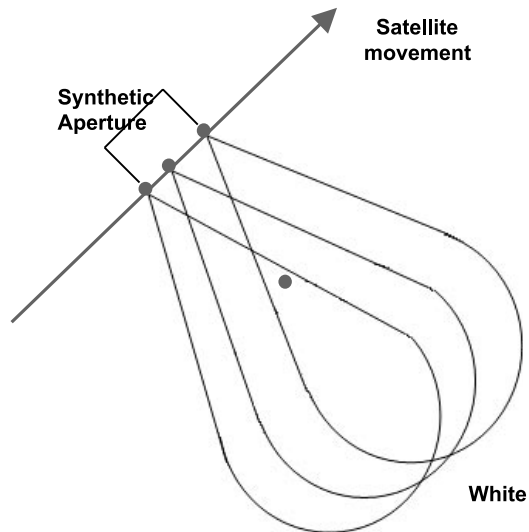


FIGURE 2.7. SAR CONCEPT. THE MOVEMENT OF THE PLATFORM IS USED TO SYNTHESIZE A BEAN OF HIGH DIMENSIONS. LIKE THIS, A SAME POINT OF THE SOIL IS ILLUMINATE BY ALL THE *SYNTHETIC APERTURE*. (ADAPT OF RICHARDS, 1986).

For detailed information about this system, consult Tomiyasu (1978); Cumming et al. (1979); Elachi (1981); Elachi et al. (1982); Ulaby et al: (1982).

The *Passive Sensors* work gathering the reflected or emitted energy by the objects.

Within this kind of sensors, it's possible to distinguish 3 different groups:

- a) *Mechanical Scanning device sensor (MSS, TM)*.
- b) *Electronical Scanning device sensor (HRV)*.
- c) *Microwave sensor*.

The *MSS (MultiSpectral Scanner)* and *TM (Thematic Mapper)* scanners represent the typical mechanical scanning device sensor. They are based on a revolving mirror, which oscillate perpendicularly to the fly trajectory picking up the electromagnetically radiation and driving this radiation to different spectral bands.

The spatial resolution of this scanner depends on the geometrical parameters like the *Instantaneous Field Of View (IFOV)* or the total scanning angle.

The *IFOV (Instantaneous Field Of View)* is the angle thought detector are sensible to radiation (fig. 2.8). As much smaller be this parameter, better spatial resolution could be obtain; by on the contrary, higher data number and noise/signal relation will be too obtain.

The *FOV* (*Field of View*) is the angular movement of the mirror along the terrain is scanned (fig. 2.8). It's limited by the tolerable panoramic distortion.

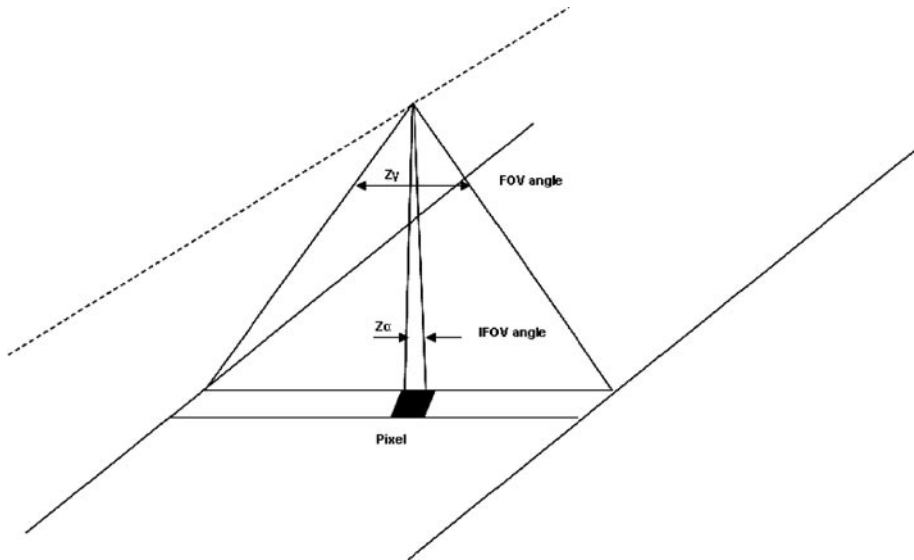


FIGURE 2.8. IFOV AND FOV CONCEPT. (ADAPTED OF RICHARDS, 1986)

The HRV (*High Resolution Visible*) sensor, on SPOT satellite board, is a typical Electronical Scanning device sensor. The detectors are CCD (*Charge Coupled Device*). Some thousand of sensible elements are integrated over monoblock bars, allowing the total reception of a perpendicular view of line to the satellite trajectory without the need of a mechanical scanning device.

This particular way to pick up the information, allow an improvement on the spatial resolution. However, this CCD technology cannot apply in the medium infrared band.

Finally, a third kind of passive sensors are the microwave sensors. They act in a frequency range of 20 and 60 Ghz. Their main problem consists in to obtain the needed signal, it's necessary to have an instantaneous and big field of vision, producing a poor spatial resolution.

By their spatial resolution, a third kind of classification can be obtained:

- Low Resolution Data (LR, since 5 Km of Meteosat, 1.1 Km of NOAA or 250 metres of MODIS).
- High Resolution Data (HR, since 80 metres of MSS sensor of Landsat, going to 30 m of TM, to 20 m of XS of SPOT satellite , 15 m PAN of ETM or 10 metres of SPOT PAN).

- Very High Resolution Data (VHR, since 5 metres of SPOT to 60 cm of QuickBird satellite or 1 metre of IKONOS)

These classifications determine the work scope and scale, like this the LR satellites supply data to carry out works at worldwide or continental level, at national or regional level with HR satellites and, at local level with VHR satellites. If we take into account the tolerable maximum error of geometrical precision of 0.2 mm, the VHR data allows tackling works at 1:3,000 scales, enough to develop useful products and services for territorial managers until parcel level.

At this vineyard parcel level BACCHUS had been developed, starting from VHR data, as data source and implementing tools and algorithms to convert these data on useful information for vineyard managers.

Below, we'll see the most important data characteristics of the following commercial satellites suppliers of VHR data (QuickBird, IKONOS, SPOT and FORMOSAT).

2.3. QUICKBIRD DATA

QuickBird from DigitalGlobe™ is the highest-resolution commercial remote sensing satellite now operating, offering imagery from 60 cm resolution.

Launched October 18, 2001, QuickBird collects multi-spectral and panchromatic imagery concurrently, and Pansharpened products in natural or infrared colours are offered. Strips up to 250 km long can be collected in a single pass.

QuickBird provides the widest swath, largest on-board storage, and highest resolution of any current commercial satellite. QuickBird is designed to efficiently and accurately image large areas with industry-leading geolocational accuracy.

QuickBird's on-board tape recorder gives worldwide coverage, being Eurimage the exclusive reseller for world-wide QuickBird products: panchromatic, multi-spectral and pansharpened images.

2.3.1. QuickBird Products

Imagery products are offered at three levels:

- Basic Imagery.
- Standard Imagery.
- Orthorectified Imagery.

Basic Imagery products are the least processed of the QuickBird Imagery products and are designed for customers having advanced image processing capabilities. Basic Imagery products are radiometrically corrected and sensor

corrected, but not geometrically corrected nor mapped to a cartographic projection and ellipsoid.

Image resolution varies between 60 centimetres (at nadir) to 72 centimetres (25° off-nadir look angle) for panchromatic products, and 2.44 meters (at nadir) to 2.88 meters (25° off-nadir look angle) for multispectral imagery. Basic Imagery products are not available with pan-sharpening.

Standard Imagery products are suitable for users requiring modest absolute accuracy and/or small area coverage.

Standard Imagery products are radiometrically corrected, sensor corrected, geometrically corrected, and mapped to a cartographic projection.

Standard Imagery products are available as panchromatic with a 60 or 70 centimetres resolution, multi-spectral with a 2.4 or 2.8 meters resolution, or pan-sharpened (4-bands or 3 bands with natural or infrared false colour) with a 60 or 70 centimetres resolution.

Orthorectification of imagery removes topographic distortion and therefore provides greater positioning accuracy.

Orthorectified Imagery products are radiometrically corrected, sensor corrected, orthorectified, and mapped to a cartographic projection and datum. Orthorectified Imagery products are available as multi-spectral with 2.4 or 2.8 metres resolution, or panchromatic or pansharpened with a 60 or 70 centimetres resolution. Final accuracy depends on the quality of DEMs and GCPs.

2.3.2. QuickBird Products Options

a) Panchromatic Products

QuickBird panchromatic (black and white) products are based on 60 centimeter resolution (at nadir) and 11-bit collected information depth. The panchromatic sensor collects information at the visible and nearinfrared wavelengths and has a bandwidth of 450-900 nm.

The output resolution of the panchromatic product varies with product level. Basic Imagery is delivered at the Ground Sample Distance in which the data were collected (ranging from 60 cm at nadir to 72 cm at 25° off-nadir), while Standard and Ortho Imagery products are resampled to a 60 or 70 cm resolution.

b) Multi-spectral Products

QuickBird multi-spectral products provide four discrete non-overlapping spectral bands and 11-bit collected information depth. The multi-spectral products

cover the visible and near-infrared wavelengths in four bands. All four bands are delivered in one file.

The output resolution of the multi-spectral product varies with product level. Basic Imagery products are delivered at the resolution in which the data were collected (ranging from 2.44 m to 2.88 m), while Standard and Ortho Imagery products are resampled to a 2.4 or 2.8 m pixel spacing.

c) Panchromatic and Multi-spectral Bundle

The QuickBird satellite collects both multi-spectral and panchromatic imagery concurrently; therefore customers have the option to order both panchromatic and multi-spectral products for the same area. When a customer selects this option, the products will be processed to the same product level, the same product parameters, and delivered as two distinct products (one containing panchromatic imagery and one containing all four multi-spectral bands) with two sets of associated Image Support Data (ISD) files.

d) Pan-Sharpended Colour Products

60 or 70 centimetres pan-sharpened products, combine the visual information of the 2.4/2.8 meters multispectral bands with the spatial information of the panchromatic band.

The options are:


4 bands (b, g, r, nir).

Natural colour composite (blue, green, red).

Colour infrared composite (green, red, infrared).

Pan-sharpened Colour products are delivered as a single file. They are available only as Standard or Ortho (not Basic) Imagery products.

2.3.3. QuickBird Specifications

	Description	QuickBird is the commercial satellite with high spatial resolution and also with a strong capability to get data.	
	Launch date	18 october, 2001	
	Altitude	450 Km	
	Orbit time/Revisit time	93.5 minutos / 1 – 3.5 días	
	Resolution	0.61 – 2.44 m	
General Characteristics	QuickBird has 4 multispectral bands and 1 panchromatic in the visible spectrum and in the near infrared. In the panchromatic band (B & W), QB has a maximum spatial resolution of 60cm..		
Sensor Characteristics			
Sensor	Wavelength interval (µm)	Pixel size (m)	
Multispectral			
Band 1 (blue)	0.45-0.52	2.44-2.88	
Band 2 (green)	0.52-0.60	2.44-2.88	
Band 3 (red)	0.63-0.69	2.44-2.88	
Band 4 (near IR)	0.76-0.90	2.44-2.88	
Panchromatic			
Band PAN	0.45-0.90	0.61-0.72	
Applications	The use of QB images allow the observation of small dimension objects like infrastructures, streets, buildings, also vehicles, improvement the elaboration or digital cartography at 1:3,000 scale.		
Reference	http://www.digitalglobe.com/		

2.4. IKONOS DATA

When Space Imaging successfully launched the IKONOS[®] satellite in 1999, it made history with the world's first one-meter commercial remote sensing satellite.

Moving over the ground at approximately seven kilometers per second, IKONOS collects black-and-white and multispectral data at a rate of over 2,000 square kilometers per minute.

IKONOS satellite imagery provides access to any location on the earth's surface. Through the nearly fifteen, 98 minute journeys it makes around the globe each day, IKONOS collects statistics about the Earth's ever-changing features—from fluctuations in land and water resources to the build-out of new urban areas.

2.4.1. IKONOS Products

There are six levels of IKONOS imagery products, determined by the level of positional accuracy:

Geo, Standard Ortho, Reference, Pro, Precision and, PrecisionPlus.

Space Imaging's line of 1 m and 4 m *Geo products* are ideal for visual and interpretive applications such as intelligence or visualization that do not require high positional accuracy.

All Geo products are map projected—rectified to a datum and map projection system. To produce a Geo product, Space Imaging uses a correction process that removes image distortions introduced by the collection geometry and then resamples the imagery to a uniform ground sample distance (GSD) and a specified map projection. Because Geo images are not orthorectified, their accuracy is limited by terrain displacement.

Typically, Geo products are developed from IKONOS images captured at an elevation angle between 60 and 90 degrees from the Earth's horizon. Because multiple Geo images in a single order are not mosaicked, tonal variations may be evident among images.

Standard Ortho is an entry-level orthorectified product. It is designed for basic mapping projects at 1:100,000.

Standard Ortho products are orthorectified and have an accuracy of 50 meter in most locations but may be up to 75 meters in undeveloped areas with high terrain relief.

Reference products designed at 1m and 4m to be suitable for regional mapping, in addition to projects requiring an orthorectified image product with accuracy suitable for 1:50,000 mapping applications.

IKONOS collects Reference imagery at an elevation angle between 60 and 90 degrees. Space Imaging orthorectifies and mosaicks all Reference-level imagery to a minimum accuracy of 25 meters.

Pro-level products are perfect for projects requiring high-resolution imagery and medium-scale accuracy when ground control may be costly, difficult or impossible to acquire.

The 1 m and 4 m Pro products are the most accurate, orthorectified imagery derived from IKONOS that do not require ground control. Consistent within the 10 meters, accessing to 1:12,000 imagery. IKONOS Pro imagery is collected at a slightly higher elevation angle—between 66 and 90 degrees—to ensure positional accuracy.

Precision products, with a 1:4,800 map accuracy level, support most regional and large-scale urban planning projects. IKONOS collects these imagery for the 1 m and 4 m at elevation angles between 72 and 90 degrees.

PrecisionPlus, the most positionally accurate product, provides the spatial accuracy necessary for most urban planning applications, as well as cadastral and infrastructure mapping requirements.

With a two-meter accuracy, it's only available in one-meter black-and-white and one-meter color. To obtain these accuracy levels, it's necessary to use high-precision ground control and precise terrain models.

2.4.2. IKONOS Products Options

a) Black and White Products

One-meter IKONOS panchromatic imagery delivered as a single band.

b) Multispectral Products

Four-meter IKONOS imagery delivered as one file with three bands in true color (red, green, blue) or false color (near infrared, red, green); or four files of one band each (near infrared, red, green, blue).

c) Colour Products


IKONOS imagery created using a pan-sharpening process that combines one-meter spatial resolution of the panchromatic image with the spectral resolution of the multispectral bands to create a one-meter color product.

This option is delivers one-meter color imagery as either one file with three bands in true color (red, green, blue) or false color (near infrared, red, green); or four files of one band each (near infrared, red, green, blue).

d) Bundle Products

When the bundle order option is selected, customers receive both one-meter black-and-white and four-meter multispectral IKONOS imagery. Space Imaging delivers one-meter black-and-white imagery as a single band file. Multispectral imagery is delivered as either one file with three bands in true color (red, green, blue) or false color (near infrared, red, green); or four files of one band each (near infrared, red, green, blue).

2.4.3. IKONOS Specifications

	Description	IKONOS is one of the highest spatial resolutions at civil framework with QuickBird. Their last version was launched in 1999, being the first commercial satellite of Very High Resolution.	
	Launch date	24 september, 1999	
	Altitude	681 Km	
	Orbit time/Revisit time	98 minutes / 2.9 – 1.5 days	
	Resolution	1 – 4 m	
General Characteristics	IKONOS has sensor in panchromatic and multispectral bands providing images with a spatial resolution of 1 metre.		
Sensor Characteristics			
Sensor	Wavelength Interval (µm)		Pixel size (m)
Multispectral			
Band 1 (blue)	0.45-0.52		4
Band 2 (green)	0.52-0.60		4
Band 3 (red)	0.63-0.69		4
Band 4 (near IR)	0.76-0.90		4
Panchromatic			
Band PAN	0.45-0.90		1
Applications	Thanks to this high resolution, the IKONOS images allow to make cartography of infrastructures, constructions or other terrestrial elements at 1:5,000 or 1:20,000 scale.		
Reference	http://www.spaceimaging.com/		

2.5. SPOT DATA

SPOT from Spot Image ® was launched in 1986, since when a further 4 satellites have been successfully launched.

Spot 5, the latest satellite in this family, was launched on 3 May, 2002, and offers a higher resolution plus a new stereo instrument.

All the Spot missions have repetitive, circular, near-polar orbits that provide full earth coverage. The 2 sensors are steerable and can be moved independently to acquire the same area or simultaneously for a bigger swath.

2.5.1. SPOT 5 Products

Imagery products are offered at different levels:

Level 1A, Level 1B, Level 2A, Level 2B and, Level 3.

Level 1A was primarily designed for mapping applications and used for geometric processing—to orthorectify images and generate digital elevation models (DEMs)—and for precise radiometric processing. Corrected to compensate for radiometric variations. No geometric corrections.

Location accuracy better than 50 metres thanks to tracker on SPOT 5 which provides more accurate satellite altitude data.

Level 1B is suited to geometric measurements (distances, angles and areas), photo-interpretation and thematic studies. Its present the same radiometric corrections as level 1A. Their geometric corrections compensate for systematic effects, including panoramic distortion, the Earth's rotation and curvature, and variations in the satellite's orbital altitude. The location accuracy is equivalent to level 1A.

Level 2A is for users who want to combine different kinds of geographic information, from different sources, and apply their own colour processing in order to extract specific information.

While allowing for location error, level 2A images register directly with other layers of geographic information—vector data, raster maps or other satellite images—in the same map projection.

Its present the same radiometric corrections as level 1A and 1B. The geometric corrections is to match a standard map projection (UTM on WGS 84), without using ground control points. For SPOT 5, is available a global DEM with a post spacing of one kilometre is used.

Level 2B products are designed for use as digital maps, providing up-to-date geographic information and global coverage. Can be used whenever relief distortions are not a major concern (for example, when imaging flat terrain).

It's a georeferenced product: the scenes are framed in a given map projection and tied to ground control points (GCPs, obtained from a map or topographic surveys) for even better location accuracy. At the rectification elevation or on flat terrain, the location error is generally lower than 30 metres. The mean location accuracy depends on the quality of GCPs or DEMs obtained for the area of interest.

Level 3 Ortho are ideal for mapping relief. Such a sophisticated level of preprocessing is designed to offer maximum accuracy for producing and updating maps.

Ortho are pre-processed using a digital elevation model (DEM) to correct residual parallax errors due to relief, reducing the location error to less than 15 metres per pixel.

2.5.2. SPOT 5 Products Options

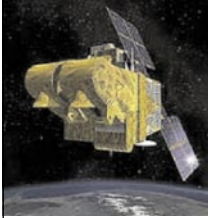
a) **2,5 M Color:** Spot 5; combination of Panchromatic and Multispectral bands to produce a colour high resolution image.

b) **2,5 M B&W:** Spot 5; Panchromatic and Multispectral bands.

c) **5 M Color:** Spot 5; combination of Panchromatic and Multispectral bands to produce a colour high resolution image.

d) **5 M B&W:** Spot 5; Panchromatic and Multispectral bands.

2.5.3. SPOT Specifications

	Description	SPOT is one of the most famous distributor of satellite images, with a system composed of 5 different platforms..	
	Launch date	SPOT 1: 1986. SPOT 5: 4 May, 2002	
	Altitude	832 Km	
	Orbit time/Revisit time	101 minutes/ 26 days	
	Resolution	2.5 – 20 m	
General Characteristics	The SPOT satellites has sensors of VHR in visible and near IR range, allowing Multispectral images (XS) as well as Panchromatic images (PAN).		
Sensor Characteristics			
	Sensor	Wavelength Interval (µm)	Pixel size (m)
SPOT 5	Multispectral		
	Banda 1	0.50-0.59	10
	Band 2	0.61-0.68	10
	Band 3	0.78-0.89	10
	Band 4	1.58-1.75	20
	Panchomatic		
	Band PAN	0.48-0.71	2.5 o 5
Aplicaciones	The SPOT images allow carrying out analysis at different scales focusing to several scopes like agriculture, cartography, public works, land management or natural disaster research.		
Referencia	http://www.spot.com/		

2.6. FORMOSAT DATA

The Taiwanese FORMOSAT-2 satellite developed for the **NSPO** (National Space Organization) was successfully launched on 21 May 2004.

NSPO has chosen Spot Image ® to be the exclusive worldwide distributor of FORMOSAT-2 products and services, except for Taiwan and the continental China.

FORMOSAT-2 has a geosynchronous orbit: FORMOSAT-2 covers a whole number of revolutions per day (14 to be precise), which means it passes over the same regions at least once a day. This characteristic of its orbit, coupled with the satellite's lateral off pointing capability, enables it to acquire a daily image of any given site from the same viewing angle.

The FORMOSAT-2 orbit is also sun synchronous with each region of the globe being observed at the same local solar time. This means that images of a given region acquired on several, successive days have more or less the same illumination conditions which makes it easier to compare them.

The characteristics of FORMOSAT-2 images combined with its unique revisit capabilities make it a valuable tool for agriculture, defence and risk management but also for cartography, town and country planning, forest management, etc.

2.6.1. FORMOSAT Products

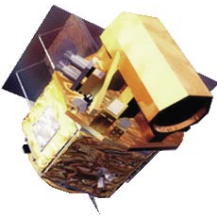
Imagery products are offered at different packages:

a) Multitemporal series: through a subscription you can acquire a series of images for one or more sites of interest according to a set frequency and for a fixed period of your choice.

b) Resource booking: by booking acquisition time, this guarantees you priority programming for sites of interest.

c) Direct access to the satellite resource: this involves buying a receiving station and subscribing to the telemetry.

2.6.2. FORMOSAT Specifications

	Description	It's a new satellite of VHR resolution images with a high orbit time (14 times by day), supplying information at 2m spatial resolution.	
	Launch date	21 May, 2004	
	Altitude	891 Km	
	Orbit time/ Revisit time	97 minutes/ 1 day	
	Resolution	2 - 8 m	
General Characteristics	The FORMOSAT satellites has sensors of VHR in visible and near IR range, allowing Multispectral images (XS) as well as Panchromatic images(PAN).		
Sensor Characteristics			
	Sensor	Wavelength Interval (µm)	Pixel size (m)
SPOT 5	Multispectral		
	Banda 1 (blue)	0,45 – 0,52	8
	Band 2 (green)	0,52 – 0,60	8
	Band 3 (red)	0,60 – 0,69	8
	Band 4 (near infrared)	0,76 – 0,90	8
	Panchomatic		
Band PAN	0,45 – 0,90	2	
Aplicaciones	FORMOSAT is a valuable tool for agriculture, defence and risk management but also for cartography, town and country planning, forest management, etc		
Referencia	www.spotimage.fr/home		

2.6.3. FORMOSAT Products Options

- a) **Black and White** images with 2-m resolution,
- b) **Colour** images with 8-m resolution (4 spectral bands: near infrared, red, green and blue).

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3. USER AND SYSTEM REQUIREMENTS

Bea M., Montesinos S. & Fernández L.

The design elaborated for the BACCHUS system has been the result of the works carried out within one specific Work Package in the project, being the list of System Requirements coming from the User Requirements Analysis and to the results extracted from the State of the Art review the preliminary and basic inputs used for its creation.

This process has been performed in several steps. The User Requirements have been translated into System Requirements, being the feasibility for their possible implementation assessed with the results obtained in the review of the current State of Art in vineyard detection and management using EO data. Then, the system architecture and structure has been designed, also providing the needed technical specifications for the implementation phase.

This analysis has allowed the design of a desktop and user friendly tool, addressed to cover the main needs, capabilities and constraints of a wide number of vineyard manager's organisations operating at different scales in relation to the use of EO data and Spatial Analysis techniques for the generation of a Methodological Approach for the Vineyard Inventory and Management.

This chapter compiles the results derived from all this process that constituted the work basis for the implementation of the BACCHUS system.

3.1. NATIONAL USER REQUIREMENTS EXTRACTION

The aim of this procedure was to introduce the results of the analysis of the Users Requirements for the generation of a Vineyard Inventory and Management system in each of the countries participating in the project, (Spain, Portugal, France and Italy), which constitute the main vine producing regions in Europe.

The major objective of this activity was to perform an exhaustive analysis of the tasks and information needs of all the potential end users of the BACHUS system, basing the rationale behind the procedure in the answers to the Users Requirements Questionnaire provided by several organisations in all of the countries participating in BACCHUS. The filled questionnaires have been used for describing the organisations and their competence area, giving an overview of their responsibilities in relation to the vineyard management and analysing their main needs and requirements according to the scope of the project.

The approach used to derive the User Requirements of the organisations representing the vine and wine sector in each of the four countries participating in BACCHUS project has focused on a methodology for the Users Requirement Definition basing in the use of specific questionnaires.

The User Requirements Questionnaire template address on the description of the main aspects of the organisations activities. The use of a predefined and structured questionnaire has been chosen in order to collect information according to a standard layout (ISO, 2002). This aspect allows simplifying the analysis of the results. This questionnaire counts with 110 questions divided in five *different blocks*:

- General Information of your organisation and Geographic Area under responsibility,
- General functions of your organisation,
- Organisation available means to deal with EO data and Spatial Analysis techniques,
- Organisation needs related to EO data and Spatial Analysis techniques development,
- Dissemination and Exploitation.

The group of users this questionnaire has been addressed to is very heterogeneous, as a wide range of organisations or persons whose work is directly related to the vineyard management (and consequently with the scope of this project) can be found. The definition of the questionnaire has been done taking into account the very significant variety of functions and operational contexts existing among BACCHUS system potential users. The following classes of BACCHUS users have been considered regarding the project scope:

- National and regional bodies controlling the wine business (planning and market regulation, land management, implementation of legislation...).
- Regional and local bodies controlling the vineyard areas (vineyard areas management, DOC areas monitoring and controlling...).
- Associations giving representation to co-operatives or individual farmers.
- Co-operatives, land owners.

- Users with interest in the commercial or intellectual exploitation of the developed technology.

The questionnaires fully answered by the user's organisations participating in BACCHUS were completed with the assistance of the technical partners. In addition to this, a shortened and focused version of the questionnaire has been sent, or sometimes discussed during a visit to selected potential end users organisations, collecting their requirements and incorporating the results to the analysis in order to get a further representation of the vineyard managers interests for the project.

Once concluded the fulfilment procedure, an extraction of the national requirements has been made from all the questionnaires received in order to create a National User Requirement Document (NURD) for each country. The aim of the NURDs has been to introduce the results of the analysis of the Users Requirements in each of the countries, basing in the answers provided in the User Requirements Questionnaires, and in the additional requirements surveys performed.

All these requirements have been allocated in various categories associated to the main functions clearly identified within the project scope, as well as to other functional areas in relation with the tasks assumed by the different stakeholders involved in the vine and wine sector. These categories are:

- Creation or updating of a vineyard inventory.
- Vineyard areas management.
- Support to the vine and wine sector.
- DOC areas management.
- Current systems and procedures.
- Data acquisition and processing.
- Operational requirements for the BACCHUS system development.

Some of the requirements extracted from the performed analysis, have been indicated as priorities for some of the organisations participating in the survey, which is also stated in the final document.

All the mentioned information was integrated in order to produce the National User Requirement Document, which has been one of the Deliverables generated within the project.

3.2. User Requirements Definition

The major objective of this activity was to perform an exhaustive analysis of the tasks and information needs of BACCHUS final users. A broad range of organisations belonging to different countries have provided key information,

allowing the consortium members to obtain a wide overview of which are the tasks, capabilities and needs of wine and vineyard managers in Europe, in relation with the use of EO data and their application to the vineyard inventory and management.

The rationale behind this process is based in the requirements collected in each of the countries which have members participating in the project (Portugal, France, Italy and Spain), and being expressed in the **National User Requirements Document (D7)** of the project. A further analysis has been performed taking into account the national requirements, which have been allocated in different requirements groups, and in addition, classified by categories and priorities. As a result, national requirements have been integrated into clearly-defined, common project user requirements.

The regulation of the wine and vine sectors is quite complex at National and European level, with a significant number of actors with different attributions involved in diverse tasks. According to this, the collection and selection of user requirements has been done taking into consideration the very significant variety of functions and operational contexts existing among BACCHUS system potential users. Concerning this issue, an overview of the general characteristics and technological state of the tools, devices and systems used by vineyard managers as support to their work, and even, about the existing background in the use of EO data and GIS techniques in these organisations was performed.

The Users Requirement Definition process has been carried out in each country through the following steps:

- Preparation of a questionnaire addressing main aspects for the organisation activities.
- Distribution of the questionnaire and collection of answers.
- Analysis and evaluation of the interview reports.
- Specification of the User Requirements.
- Prioritisation of the extracted User Requirements.

A national user requirements list was drafted in each of the four countries participating in the project (Portugal, France, Italy and Spain), that have been analysed in order to present the issues of major interest for the organisations according to the vineyard inventory and management, also giving recommendations about the final system to be developed considering the available human and technical resources.

As a result of this procedure, a detailed **list of User Requirements** for the activities under direct responsibility of vineyard management organisations was reported.

The main conclusion obtained relies in the fact that organisations in charge of the vineyard management need independently of the size of the area they administrate and of their specific structure, a sound support regarding their information requirements towards the carrying out of their work. All these requirements have been allocated in various categories associated to the main functions clearly identified within the project scope, as well as to other functional areas in relation with the tasks assumed by the different stakeholders involved in the vine and wine sector. These categories are:

- Creation or updating of a vineyard inventory.
- Vineyard areas management.
- Administrative support to the vine and wine sector.

In addition to this, further information has been gathered in relation to some interest matters related to the use of EO data and Spatial Analysis techniques, related to the existing systems and procedures, capabilities for the data acquisition and processing and global requirements for the development of the BACCHUS system, completing the analysis performed.

The list of User Requirements has been structured according to the following criteria:

- Each user requirements shall include an identifier.
- Each user requirement shall be classified according to the following types:

Responsibility <RS>: stating the functions assumed by a organisation.

Capability <CA>: dealing with abilities and possibilities available in an organisation.

Constraint <CO>: stressing restrictions and limitations.

Needs <ND>: describing the direct requirements to be covered.

- All known user requirements shall be included in the URD.
- Responsibility and Capability requirements do not show real requirements of the organisations in relation to the definition of the project expected goals, though have a great importance in order to depict the context and development frame for the specific functional requirements (constraints and needs requirements). Responsibility and Capability requirements are included as a descriptive text heading each categories and subcategories of specific requirements.

Herein, it is summarised the complete **List of User Requirements**, according to the groups and categories considered:

1) *Creation and updating of vineyard registers:*

This section includes an overview of the main requirements related to the creation of Vineyard Registers. At European level, there is a complex regulation, being all the countries obliged to develop an Official Register keeping a broad range of information describing their vineyard plots. Besides this, there is a strong need of elaborating other inventories in local and regional areas, some of them ruled by specific legislation.

Other requirements have been identified as input to the methodological approaches to be carried out for the vineyard detection.

The requirements considered in this category have been allocated in the following groups:

– Official Vineyard Register:

The Council Regulation (EEC) N° 2392/86 of 24 July 1986, establishes the obligation of implementing an official vineyard register for the countries belonging to the European Union. The organisations dealing with this labour are public bodies depending on central administration.

BACCHUS system should be able to get/generate information integrable with the national official vineyard registers, accordingly to a series of requirements have been requested.

– Local / Regional Vineyard Registers:

Beyond the existence of official vineyard registers, other organisations are charged or concerned in creating and maintaining other vineyard inventories containing specific data about the vineyards located within their competence area. The most extended examples are the Denomination of Controlled Origin (DOC) areas vineyard registers, whose creation and periodical updating use to be included in the obligations ruled by DOC consortia statutes. Within this context, the use of BACCHUS system could be highly interesting for different organisations dealing with the creation and updating of local and/or regional vineyard inventories, and having diverse capabilities for the fulfilment of these tasks.

– Vineyard plots mapping:

User Requirements intends to provide to the project methodological approaches with a useful output for the planning of the incoming work packages. The vine detection methodology approach shall take into account different requirements in relation to the discrimination and mapping of vineyard plots by the use of EO data, which are compiled in this section.

– Vineyard features detection.

Beyond the vineyard plots mapping, there are another features whose detection is highly interesting for vineyard managers. These elements are normally geometric features of the vineyard, other crops, infrastructures, buildings, etc, or

on the other hand situations as the existence of irrigation. The definition of these kind of requests is necessary as input to the WPs focused on the development of vine detection methodologies.

2) *Vineyard areas management:*

The recent advances in the fields of Remote Sensing, Spatial Analysis techniques and software programming may provide vineyard managers with more complete and updated information for their decision making processes. Within this section, four categories have been elected, considering the usefulness and possibilities that these technologies may suppose for organisations involved in the vineyard management. These categories comprise requirements, independent from the vineyard plots detection, specially focused on the application of EO data and GIS techniques to the vineyard plots and vineyard areas management, being considered:

- Use of remote sensing and spatial analysis techniques:

BACCHUS intends to fill the gap between new sources of information and the final users of this information, and will educate and train the end-user to make better use of space based Earth Observation data, integrated with other technologies such as ground and airborne Remote Sensing and GIS, through the implementation of a computer system tailored to face vine managers requirements.

The requirements here included draw the context of the current application of Remote Sensing and Spatial Analysis techniques for the management of vineyard plots and areas.

- Management of vineyard rights:

In compliance with the EC Regulations for the control of the potential production, Member States must monitor the abandonment, the restructuring and the conversion of vineyard plots receiving a contribution from the Community, and the prohibition of new planting. All these tasks are comprised in the control of the correct fulfilment of the utilisation of vineyard rights. The use of EO data for supporting to these organisations in these tasks has been strongly demanded:

Production monitoring: Control and monitoring of wine production has been deeply ruled by European Commission, establishing provisions on global and national production quotes (i.e. EC 1493/1999), to be accomplished by Member States.

The project scope is clearly in relation with the monitoring and improvement of the production, on one hand by the exploitation of new possibilities offered by Remote Sensing in the estimation of related parameters and on the other hand

by the application of techniques, as Precision Viticulture (PV), having a fast implementation and development in the last years.

DOC areas management: Besides some of the requirements already expressed in this document have been done by DOC management organisations, there are other needs regarding the project aims, and more specific of the nature of areas that are kept in this section.

3) Support tools for the Vine and Wine sector:

There is a long list of administrative tasks at different scales that vineyard managers need to cover. GIS and Remote Sensing technology can help to work them out by using Spatial Analysis and IT solutions integrated in a computer tool. Users have been asked about these issues and their answers have been divided in two sections:

- Generation of statistical data, documentation and dissemination of information:

BACCHUS system will have the aim of obtaining relevant information through the processing and analysis of EO data, integrated with other alphanumeric and geographical data. This information may be used with different general objectives, besides the support to decision making procedures.

- Support tools:

The role of wine producers consortia and associations is, amongst others, to provide tools, support and legal assistance to the associated vineyard managers and/or land owners. Depending on the statute and informal agreement some Corporation helps to the members of the consortium in their technical and economical decisions, providing orientation at every level.

This sector of activities of End Users could take advantage of an instrument able to increasing and up-dating territorial control (inventory) and ameliorating the quality and quantity of products.

In addition to this, the global operational requirements for the BACCHUS system were also drawn, giving an overview of the main characteristics that needed to be considered in the design of the BACCHUS prototype.

This study strived to go beyond the initial constraints of BACCHUS project, describing as completely as possible the resources, needs and deficits regarding the application of Remote Sensing and Spatial Analysis techniques for the vineyard management and the creation of related inventories.

3.3. SYSTEM DESIGN

The structure of the BACCHUS System Design is structured as follows:

Global model description: depicting a system model which generally describes, in an implementation-independent manner, the needs expressed by the surveyed user organisations.

System requirements specification: defining the System Requirements and describing the functional, operational and other software requirements that have been specified for the BACCHUS system.

System architecture: presenting the system architecture, introducing the main components of the global hierarchy of the system and describing the functions specifically referred to the vineyard inventory and management, results from the User Requirements Analysis and the State of the Art Review previously carried out. These functions, are proposed for their implementation, and described in detail as possible system components.

The *global model description* aims at giving a simplified description of the system used for reasoning about the software development. BACCHUS system is planned to be a tool designed for meeting the geographical information requirements of vineyard managers. These managers have (or are intended to have) large amounts of data, mostly included in different digital databases. These data, usually referred to vineyard plots ownership, delimitation and characteristics, need to be combined in most of the cases with geographical information which can be obtained from various sources, such as EO data (satellite and airborne images and photos), cartography, GPS measurements or other ancillary data.

The BACCHUS system must be able to handle all these data, allowing the performance of basic data management functions: i.e. data visualisation, combination or query. Besides this, the data analysis and processing will allow the production of specialised cartography and advanced products providing of different information layers to the users. All these modules shall be designed, so as to implement most of the user needs expressed in terms of operational and functional requirements for the system, and will be afterwards described in detail as being the heart of the system physical model. A global description of the logical components for the expected BACCHUS system is depicted in the figure 3.1.

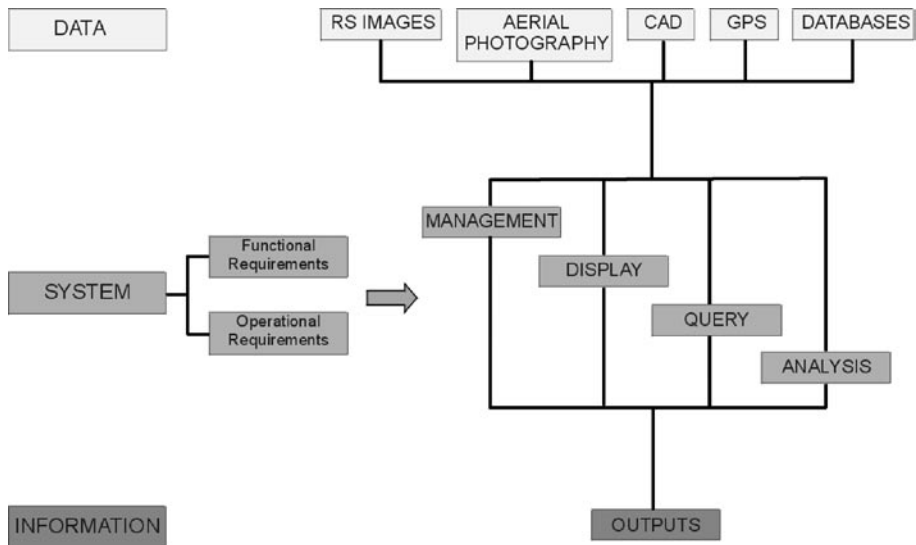


FIGURE 3.1. GLOBAL MODEL DESCRIPTION

The *definition of the System Requirements* was the next step performed for the development of the System Design.

The final selection of the user requirements to be implemented into the system has been planned at three steps:

1. The results of User Requirements Analysis, detailed in the User Requirements Document, have been analysed to detect all the main requirements from the potential user organisations, towards defining all the possible and desirable applications that users are interested in implementing, independently from the resources available for BACCHUS project.
2. Priorities for the implementation of all these functions have been proposed by user organisations, also taking into account the data availability, the human factors and the technical resources influencing the operation.
3. Finally, the main functions compatible with the constraints of this project (human resources, available time for implementation and funds) have been detected and analysed for the design of the **BACCHUS system**.

This means that all the detected user requirements have been translated into system requirements, describing what might be a suitable ideal menu description. A document containing the list of user requirements and the procedure used for their derivation was sent to the consortium in order to get a feedback and analyse

the user organisations priorities. This information has been used for fitting the main requirements to the project resources, determining the functionalities that shall be implemented as BACCHUS tools.

As a complement to this, direct interviews and visits to the project user organisations premises have been performed in order to, on one hand describe with detail the functionalities of BACCHUS system to their staff, and, on the other hand, set the type of information required, interchange formats and links among the work packages with the final system, obtaining the additional information needed for starting the System Architectural design.

System requirements must give further indications about what is the software going to do, covering all the requirements stated in the URD. These requirements must be verifiable, not including neither implementation details nor terminology and shall avoid specifying details about hardware or equipment.

The system requirements have been divided into functional and operational requirements, and codified with correlative numbers, under the structure **SR****, being **SR** the initials of System Requirement and ****** a two digits number.

A Functional Requirement «specifies a function that a system or system component must be able to perform». It illustrates what a process must do, defining the transformations to be performed on specified inputs to generate specified outputs. Otherwise, an Operational Requirement «specifies how the system will run and how it will communicate with human operators». Besides these, there are other types of software requirements to be considered which are commented in the third section of this chapter.

Functional requirements aim at describing the processes to be supported by the software to be developed, giving special importance to the specification of the main capabilities required. Each functional requirement has a title, includes a brief description and information related to four different matters: *theme*, *scale*, *applicability* and *frequency* (ESA, 1996) and (IPL, 2002).

Theme is referred to the general category of user requirements where the functional requirement has been derived from, it is also in correspondence with the general categories of the description of the system model.

Scale gives an indication of the operational geographical context where the functional requirements shall be applied. Four different scales have been considered: **plot** for operations to be performed within a vineyard holding, **loca**, for requirements applicable in small vineyard areas, **DOC area** corresponding to needs of managers of Appellations of Origin / regional areas, and **Wine regions** in case that the requirement shall be requested by organisations operating over geographical areas including an important extent of surface and generally, controlling the wine business.

Applicability is referred to the relation of the requirement with the project scope, in terms of possibility and/or need of use of Remote Sensing and Spatial Analysis techniques.¹

Frequency describes the updating period required for the information to be achieved with the performance of the functional requirement.

The list of functional requirements is herein described, containing the translation of all the system requirements and comprising the overall description of the ideal BACCHUS system:

SR01 Vineyard discrimination: Semi-automatic detection and discrimination of vineyard among other existent land surfaces, by the processing of georeferenced EO data.

SR02 Vineyard plots delimitation by cadastral parcel: Generation of vineyard parcels cartography with support of a digital agriculture cadastre.

SR03 Vineyard plots delimitation by holding: Semi-automatic generation of vineyard plots cartography using automatic methods for the delimitation of vineyard holdings.

SR04 Visualisation and edition of graphic data (vector data): Simultaneous visualisation of EO images, maps and any vector cartography (vineyard parcels, cadastre...). Editing of vector data.

SR05 Connection of graphical information with alphanumeric data: Linking of alphanumeric data, contained in the organisations databases to any graphical georeferenced or not data (mainly to graphic information related to vineyard generated from the processing of EO data).

SR06 Generation and storage of alphanumeric data: Creation of a open database structure in order to keep alphanumeric (possibly linked with vector data) either directly collected by the organisations or derived from EO data.

SR07 Detection and quantification of geometric features within vineyard plots: Semi-automatic detection and inclusion of plots geometric characteristics in vineyard inventories, as vineyard parcel's attributes. The vineyard geometrical elements considered as most significant are spacing of rows, plantation frame, alignment, type of plantation and plantation density.

SR08 Detection of other elements: buildings, infrastructures, other crops: Semi-automatic detection of other land features different than vineyard but related to vineyard dynamics such as other crops, buildings or infrastructures.

SR09 Detection of irrigation in vineyard: Semi-automatic differentiation between irrigated and not irrigated vineyard plots.

¹ Further information about applicability is available in the Review of the State of the Art Document, deliverable number09 of the BACCHUS project.

SR10 Management of vineyard rights by parcel / holding: Assignment and monitoring of vineyard rights exchanges both at parcel and holding scale.

SR11 Monitoring of the fulfilment of restructuration plans: Control and monitoring of the correct use of the aids provided for the vineyard plots restructuration.

SR12 Control and monitoring of vineyard planting/grubbing up: Control and monitoring of planting of new vineyards and the grubbing up of vineyards in relation to the exchange of vineyard rights, or the granting of new authorisations.

SR13 Detection of non-authorized plantations: Detection of vineyard plots not awarded with vineyard rights.

SR14 Estimation and monitoring of vine production: Use of related parameters estimated by the application of Remote Sensing for the monitoring of vineyard plots production. Estimation of the fulfilment of production plans and comparison of parcels production.

SR15 Use of models for the improvement of land productivity (plant protection, diseases control, erosion...): Integration of agronomic, agrometeorological, geographical and EO derived data into a calibrated model able to provide specific indications towards the improvement in the vineyards productivity, both in quantity and quality. Information related to plant protection, diseases detection or control of erosion shall be provided.

SR16 Detection of agronomic data: Estimation of agronomic data related to the vineyard production (in quantity and quality), such as plant vigour, ground cover or phenological state, by the use of EO data.

SR17 Application of precision farming techniques (level of fruit ripening, productivity in each sub-area, association of land properties to wine quality...): Application of advances technologies for the vineyard parcels management, detecting the internal parcel variability (that use to be stable in time) and establishing sub-areas in relation to agronomic and meteorological variables. It shall be possible to estimate the level of fruit ripening and productivity in each sub-area and associate land properties and plant vigour to parameters related to the wine quality.

SR18 Definition of viticultural vocation: Integration of agronomic and climatic data with vineyard maps and inventories containing vineyard features and characteristics in order to improve the knowledge about the land vocation and even, include new DOC areas, or search for new candidates areas.

SR19 Generation of statistical data: Generation of information elements (statistical data) related to productivity, vineyard characteristics and vineyard dynamics at different scales.

SR20 Generation of reports, documentation and maps: Generation of documentation or reports in order to assist land owners in administrative purposes and information related to geographic data.

SR21 Dissemination of information: Spreading of information generated in different organisations between land owners and other organisations.

SR22 Elaboration of a educational tool: Elaboration of a tool able to provide training and/or support to the commercialisation of products.

Considering the Operational requirements, the system shall take into consideration the following practical and technical groups of considerations:

SR23 Operating system, security and networking: The system should be programmed to run under Windows 95/98/2000/NT/XP.

The system shall work connected to corporate LAN or WAN, where pre-existent data might be available.

The BACCHUS system must have an adequate level of accuracy, as its products may be used for administrative purposes.

The BACCHUS system must ensure a fast and easy access to the information and resources, allowing a direct access to the organisations databases.

The system shall be sufficiently open to allow system administrators to define different user profiles, protecting the relevant information from illegal accesses. Privacy laws protecting the data included in the Official Vineyard Registers may be a strong constraint for the data access.

SR24 Data Input / Output: It should be possible to import a very wide range of data formats from many different sources.

The system outputs may be exported to a broad range of formats, because the organisations may need to export the handled information into other software.

Standard methodologies should be defined for the data acquisition and processing in order to standardise procedures between a wider group of data users.

The creation of a Metadata Catalogue shall be considered in order to correctly describe internally and externally the data, towards the purpose of procedures standardisation. The creation of a Spatial Data structure for the data management within the project, in agreement with OpenGIS standards, shall be also taken into account.

SR25 Data Handling: To be operative, the BACCHUS system needs to constantly update its database.

The system must handle tabular, vector and raster data.

The system shall be able to generate semiautomatic information from various data sources.

Most of the operations must be defined in space and time.

The system must have advance capabilities for storage, visualisation and printing. The system should be able to administrate, manipulate and transform data to produce the desired case oriented output products. These requirements are essential to allow quick updates and to produce specific information either for daily routinely work or for decision-makers within the customer organisations.

SR26 User Interface: The user interface shall be built with adequate customised functions, allowing the operation of non-expert staff.

A Windows-like Graphic User Interface (GUI) is highly advisable to allow a high degree of user-friendliness.

The BACCHUS system must allow, whenever possible, automatic procedures that trigger a pre-programmed sequence of operations to carry out the desired task, to allow an inexperienced user to follow complex decision making procedures. The system has to supply information with as minimal interaction with the user as possible.

GUI must be multilingual.

SR27 Licensing: An imposed condition is that the system should be license free, meaning that non commercial package with key protection can be used for the construction.

All the organisations are interested in working with software with no licenses maintenance needs.

The design criteria of the system structure, were established considering and evaluating the data and processes defined in the technical work packages and the possible or necessary data exchange among them.

The BACCHUS system does not use protected GIS manager software already commercially available for GIS User Interface building. This means that the specific modules required for the GIS operations already available in commercial packages have not been used.

BACCHUS intends to be a vineyard management system providing data management capabilities through simple User Interface (user-oriented menus). The design of the UI will meet the customer requirements. The system shall be able to handle a wide number of formats and data types, and shall allow the staff in charge of the day-to-day operations to generate information about important agronomic parameters. It should provide general capabilities of database management, GIS and RS operations without direct intervention of a GIS-RS expert.

According to this programming strategy, it is considered that two different groups of components must be specified within the system structure:

- The general GIS and database management functions.
- The specific tools for the vineyard inventory and management.

The main components of the system are kept in the global physical model of the BACCHUS system, which is depicted in a diagram in figure 3.2.

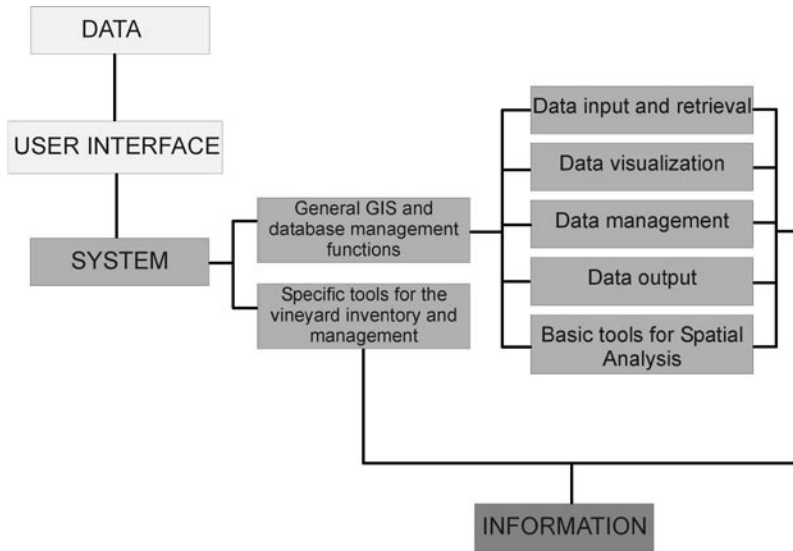


FIGURE 3.2. SYSTEM STRUCTURE

According to this structure, the following analysis dealt with the specification of the different types of components to be included in both general groups, showing the control and data flow between components, and introducing their hierarchical organisation.

The *system architecture* describes in more detail the thematic menus that have been considered according to the project User Requirements. The components of these thematic menus are characterised by the specification in tables of the input, output and data combination needed for their possible implementation and that are intended to be further detailed within the technical Work Packages.

These components cover the totality of the requirements expressed by the user organisations, providing a comprehensive approach to the potentialities of the **ideal** BACCHUS system.

The consortium is intended to establish clear priorities for the successive implementation of these requirements. It is envisaged that not all of them may be implemented in the frame of BACCHUS, due to the resource limitations.

This motivates that the final operational characteristics of the system are still not fully specified. Some of the defined components will not be implemented, leaving this possibility open for future developments.

The general description includes the **component name**, the **description of the information** that is desired to be obtained, the **function**, which describes what the component implements, the **theme**, which refers the components to the User requirements general grouping and, finally, the **scale of application**, which gives an indication about the operational geographical context where the component shall be applied.

The description of each one of the proposed components is shown hereafter.

SC01: VINEYARD AREAS DISCRIMINATION

General description: Semi-automatic detection and discrimination of vineyard areas among other existent land surfaces, by the processing of georeferenced EO data and basing in the analysis of the spectral behaviour of vineyard at different phases of its phenological development.

Function: Generation of georeferenced vineyard maps at medium/large scale.

Theme: Creation and updating of vineyard registers.

Scale of application: DOC area, Wine region.

SC02: DETECTION OF ELEMENTS DIFFERENT THAN VINEYARD

General description: Semi-automatic detection of other land features different than vineyard but related to vineyard dynamics.

Function: Discrimination of elements usually found in vineyard areas such as groups of other crops, buildings or infrastructures.

Theme: Creation and updating of vineyard registers.

Scale of application: Local, DOC area.

SC03: VINEYARD PLOTS DELIMITATION

General description: This component is divided in two sub-components, having a common first step, the generation of raster vineyard maps deriving from the analysis and processing of VHR EO data. These sub-components deal with the:

Generation of vineyard parcels cartography with support of a digital agriculture cadaster and the

Generation of vineyard plots maps using automatic segmentation methods for the delimitation of vineyard holdings.

Function: Generation of vineyard cartography at plot scale using different methods depending on ancillary data availability (cadastral cartography).

Theme: Creation and updating of vineyard registers.

Scale of application: Plot, local.

SC04: DETECTION AND QUANTIFICATION OF GEOMETRIC FEATURES WITHIN VINEYARD PLOTS

General description: Semiautomatic detection and inclusion of plots geometric characteristics in vineyard inventories, as vineyard parcel's attributes. The vineyard geometrical elements considered as most significant are spacing of rows, plantation frame, alignment, type of plantation and plantation density.

Function: Discrimination and quantification of geometric features related with vines structure within the plot. Characterisation of vineyard plots.

Theme: Creation and updating of vineyard registers.

Scale of application: Plot, local, DOC area.

SC05: DETECTION OF IRRIGATION IN VINEYARD

General description: Semi-automatic mapping of irrigated vineyard plots.

Function: Differentiation between irrigated and not irrigated vineyard plots.

Theme: Creation and updating of vineyard registers.

Scale of application: Local, DOC area.

SC06: PLANTING AND GRUBBING UP MANAGEMENT

General description: Performance of operations related to the management and control of the exchange of vineyard rights, including the monitoring of planting and grubbing up of vineyards in relation to the exchange of vineyard rights, the granting of new authorisations or the identification of illegal vineyard plots.

Function: Assignment and monitoring of vineyard rights exchanges both at parcel and holding scale. Monitoring of the evolution of changes in land use related to vineyard dynamics at different scales. Detection of vineyard plots not awarded with vineyard rights.

Theme: Operations for the management of vineyard areas.

Scale of application: Plot, Local, DOC area, Wine region.

SC07: FULFILMENT OF VINEYARD RESTRUCTURATION PLANS

Description of information: Performance of operations related to the control of the fulfilment of vineyard restructuration plans. These operations shall allow the identification of the legal situation of the vineyard plots which have applied for aids dedicated to the vineyard restructuration.

Function: Control and monitoring of the correct use of the aids provided for the vineyard plots restructuration.

Theme: Operations for the management of vineyard areas.

Scale of application: Local, DOC area.

SC08: ESTIMATION AND CONTROL OF VINEYARD PRODUCTION

General description: Performance of operations focused on features related to the estimation of vineyard plots production by the use of Remote Sensing and Spatial Analysis techniques. Agronomic data related to the vineyard production (in quantity and quality), such as soil type, plant vigour or phenological state, shall be estimated by the use of EO data. The aim of this component is to give detailed spatial information on vineyard plant vigour and qualitative potential production. The tool shall consist of an algorithm able to characterise the different zone of a single vineyard, on the base of a series of elements, like land characteristics, soil physical and chemical characteristics, climatic parameters, phenological vine model (Temperature based model and local vine thresholds), VHR multi-spectral satellite and/or aircraft images, cadastral information (property delimitation) and other data.

Function: Use of Remote Sensing for the monitoring of vineyard plots production. Estimation of the fulfilment of production plans and comparison of parcels production.

Theme: Operations for the management of vineyard areas.

Scale of application: Plot, Local, DOC area.

SC09: USE OF MODELS FOR THE IMPROVEMENT OF LAND PRODUCTIVITY

General description: Generation of information related to plant protection, diseases, detection or control of erosion through the use of previously existent models that shall be calibrated and integrated for their use within BACCHUS methodologies.

Function: Integration of agronomic, agrometeorological, geographical and EO derived data into a calibrated model able to provide specific indications towards the improvement in the vineyards productivity, both in quantity and quality.

Theme: Operations for the management of vineyard areas.

Scale of application: Local, DOC area.

SC10: DEFINITION OF VITICULTURAL VOCATION

General description: Integration of agronomic, climatic, geological and pedological data with vineyard quantitative and qualitative production information to characterise the viticultural vocation of land parcels.

The objective is to define a zoning methodology to be applied in different areas, at different resolutions and data completeness based on the following steps:

i) Identification of *land vocation* by clustering climatic/meteorological data, pedological maps and agronomic practices (breeding, ploughing, water management, fertilizing, soil work, etc.) into homogeneous macro zones.

ii) *Zoning* through the correlation of macro zones with productivity data (quantity and quality) as function of vineyard specific information (vegetative needs, pruning, grape-harvesting time, etc.).

Function: Improve in the knowledge about the land vocation and even, include new areas in DOCs, or search for new candidates areas.

Theme: Operations for the management of vineyard areas.

Scale of application: Local, DOC area.

SC11: GENERATION OF STATISTICAL DATA

General description: Generation of information elements (statistical data) related to productivity, vineyard characteristics and vineyard dynamics at different scales.

Function: Extraction of relevant information derived from the use of EO data.

Theme: Technical and administrative support to the vine and wine sector.

Scale of application: Local, DOC area, Wine region.

SC12: GENERATION OF REPORTS AND DOCUMENTATION

General description: Elaboration of predefined templates to be filled with information generated through the system.

Function: Assist to land owners in administrative purposes and supply information related to geographic data.

Theme: Technical and administrative support to the vine and wine sector.

Scale of application: Plot, Local, DOC area, Wine region.

In the following table are shown the relationships established between system requirements and system components, specifying the level of priority stated by the consortium for the system requirements implementation.

System Requirement	System component	Level of priority
SR01 Vineyard discrimination	SC01	1 st priority
SR02 Vineyard plots delimitation by catastral parcel	SC03	1 st priority
SR03 Vineyard plots delimitation by holding	SC03	2 nd priority
SR04 Visualisation and edition of graphic data (vector data)	Basic GIS and data management functionalities	1 st priority
SR05 Connection of graphical information with alpha-numeric data	Basic GIS and data management functionalities	1 st priority
SR06 Generation and storage of alphanumeric data	Basic GIS and data management functionalities	1 st priority
SR07 Detection and quanti-fication of geometric features in vineyard plots	SC04	2 nd priority
SR08 Detection of other elements: buildings, infra-structures, other crops	SC02	4 th priority
SR09 Detection of irrigation in vineyard	SC05	4 th priority
SR10 Management of vineyard rights by parcel / holding	SC06	1 st priority
SR11 Monitoring of the fulfilment of restructuring plans	SC07	1 st priority
SR12 Control and monitoring of vineyard planting / grubbing up	SC06	1 st priority
SR13 Detection of non-authorized plantations	SC06	1 st priority
SR14 Estimation and monitoring of vineyard production	SC08	1 st priority
SR15 Use of models for the improvement of land productivity	SC09	3 rd priority
SR16 Detection of agronomic data	SC08	3 rd priority
SR17 Application of precision farming techniques	SC08, SC09, SC10	3 rd priority
SR18 Definition of viticultural vocation	SC10	3 rd priority
SR19 Generation of statistical data	SC11	2 nd priority
SR20 Generation of reports, documentation and maps	SC12	2 nd priority
SR21 Dissemination of information	Basic GIS and data management functionalities	3 rd priority
SR22 Elaboration of a educational tool	Basic GIS and data management functionalities	3 rd priority

The flow diagram for the full set of the specific functional requirements is shown in the figure 3.3 of annex III, defining the relationships between the components and establishing a logical hierarchy between them. In this diagram, the exposition of the functional components of the system is used to draw a comprehensive view of the global potentialities able to be implemented in the system. Also, these components are related with the main groups of User Requirements, and the data obtained as output of the different processes are put in relation with the remaining components.

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4. TEXTURAL AND STRUCTURAL ANALYSIS

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4.1. INTRODUCTION

This chapter presents the methodologies that have been developed during the BACCHUS project concerning the automatic detection and characterisation of vineyard plots in satellite and aerial images based on their structural properties, as well as the main results obtained in representative test areas of the project. They include a segmentation stage based on textural and shape criteria, followed by a more precise characterisation of the detected vineyard parcels.

Three main steps are defined: i) various textural criteria, based on co-occurrence matrices, are computed in order to determine the probability of any pixel to be a vineyard pixel. ii) This probability information is combined with geometrical and regularity constraints on the parcel shape to achieve the image segmentation, by means of active contours. iii) Finally, the last step of characterisation, based on a Fourier analysis, also helps in revising the parcel enumeration. In the following, we present successively these various steps.

4.2. TEXTURAL ANALYSIS

4.2.1. Textural parameters

Texture analysis is a branch of image processing that began to be studied thirty years ago. Although the concept of texture was difficult to define (and is always), studies showed that spatial statistics computed on the grey levels of images were able to give good descriptors of the perceptual feeling of texture (for a review, see Haralick et al, 1973). Such textural descriptors are still developed today for classification tasks or segmentation problems (Ojala et al, 1996). In the present

case, we have adapted the textural approach to satellite and aerial images, which present red (R), green (G) and near-infrared (NIR) channels.

The textural analysis is based on co-occurrences matrices. A co-occurrence matrix is the histogram, in a given neighbourhood for each pixel (e.g. 16x16), of the grey-level transitions when considering a given translation in a given direction. For K possible grey-levels, it consists of a KxK bidimensional array, on which various parameters can be computed (Haralick et al, 1973).

In our case, we consider 8 elementary translations $(x,y) \rightarrow (x + \Delta x, y + \Delta y)$ where:

- (x,y) are the pixel coordinates
- $(\Delta x, \Delta y) \in \{ (1,0), (1,1), (0,1), (-1,1), (-1,0), (-1,-1), (0,-1), (1, -1) \}$
- $K = 32$ (number of grey level classes).

The 8 corresponding co-occurrence matrices are then summed up to obtain a unique matrix $M(i,j)$ ($0 \leq i < K$ and $0 \leq j < K$).

Five Haralick parameters are then computed as defined in Table 4.1.

Table 4.1. Definition of Haralick parameters ($M(i,j)$: $K \times K$ co-occurrence matrix)

Energy: $E = \sum_i \sum_j (M(i, j))^2$	Directivity: $D = \sum_i M(i, i)$
Correlation: $Cor = \frac{1}{\sigma_i \sigma_j} \sum_i \sum_j (i - \mu_i)(j - \mu_j) M(i, j)$	
<i>where μ_i, σ_i (resp. μ_j, σ_j) are the mean and standard deviation of $M(i,j)$ on the line i (resp. on the row j).</i>	
Entropy: $H = \sum_i \sum_j M(i, j) \log(M(i, j))$	Contrast: $C = \sum_{k=0}^{K-1} \left(k^2 \sum_{ i-j =k} M(i, j) \right)$

Let us consider now a multispectral image, coded on n channels C1, C2,... Cu,...,Cn. The previous co-occurrence matrix definition can be extended for any pair of channels (Cu, Cv) by counting the transitions from grey levels in channel Cu to grey levels in channel Cv, which is leading to an histogram array $M_{u,v}(i,j)^2$.

The pairs of channels that we have considered are (NIR,NIR), (R,R), (G,G), (NIR,R), (NIR,G), (R,G). We also compute the five Haralick parameters on the NDVI index given by:

$$NDVI = \frac{NIR - R}{NIR + R} \tag{1}$$

2 The case $u=v$ corresponds to the standard co-occurrence matrix for the channel Cu.

This finally leads to 35 different textural features (7x5). Some examples of such computations are given in Figure 4.1.a (see the original image in *Figure 4.1.b*, in Annex): each feature is represented as a new image, which is normalised and can be used to compute multivariate criteria.

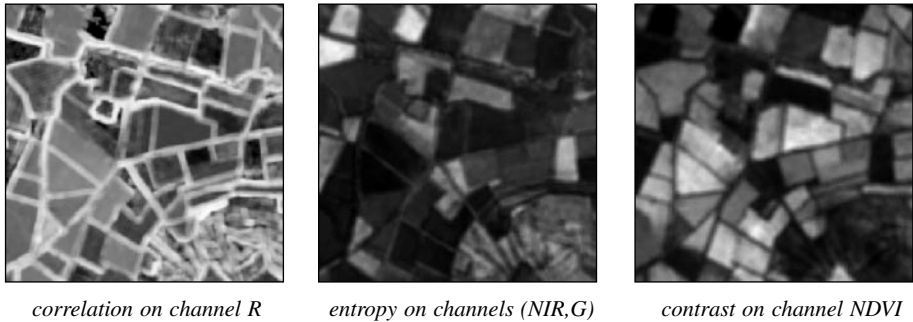


FIGURE 4.1.A. REPRESENTATION OF SOME TEXTURAL FEATURES (ORIGINAL IMAGE IN *FIGURE 4.1.B* IN *ANNEX III*)

4.2.2. Vineyard probability index computation

A multivariate algorithm has been developed to combine the textural features described above into a vineyard probability index, that reflects the probability that a pixel belongs to a vineyard area or not. It is based on a Discriminant Factor Analysis which chooses the best textural features and/or their linear combination according to vineyard and non-vineyard classes.

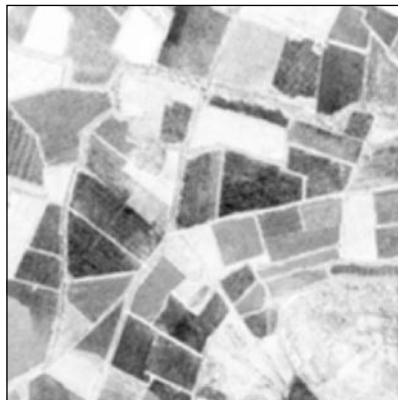


FIGURE 4.2. VINEYARD PROBABILITY INDEX COMPUTATION ON «BASSIN DU ROUJAN», FRANCE: DARKER AREAS CORRESPOND TO A HIGHER VINEYARD PROBABILITY (ORIGINAL IMAGE IN *FIGURE 4.1.B*, IN *ANNEX III*)

The resulting value for a pixel is in the interval [0,1], the lower values corresponding to the highest vineyard probabilities (*Figure 4. 2*).

4.3. PARCEL SEGMENTATION AND CHARACTERISATION

4.3.1. Methodological choices

In the previous part, various textural criteria have been considered, their purpose being to highlight the image areas which exhibit a vineyard structure. However, such a local approach is often insufficient to make a satisfactory segmentation, due to remaining ambiguities in some image areas. More global considerations, such as the homogeneity and shape regularity of the parcels, are then required.

For this reason, the parcel segmentation procedure is based on the grey-level probability image computed above (noted I in the following), in which each pixel value represents a probability of belonging to a vineyard rather than an actual textural classification result. Various approaches for region identification can be considered at this stage. Anisotropic diffusion (Perona & Malik, 1990) attempts to smooth local grey-level heterogeneities while preserving edges in the image. Region-growing algorithms, such as the Union-Find (Fiorio & Gustedt, 1996), allow labelling of homogeneous sub-areas (oversegmentation), which then can be merged according to shape criteria.

In the present study, however, we have chosen an edge-based approach, the *geodesic active contours*, because it facilitates the introduction of regularity and shape constraints on the boundaries of the detected objects. Geodesic contours have been introduced by Caselles et al. (1997) as a new formulation of the classical «snakes» (Kass et al. 1988). They are based on the generic work of Osher and Sethian (1988) on front propagating curves. We have added «region forces», as proposed by Paragios and Deriche (1999) in order to take better advantage of the probability image information. Finally, a *contour shape analysis* has also been implemented during the process, introducing more global shape criteria.

4.3.2. Geodesic Active Contours implementation

Geodesic contours rely on the idea that active contours can be seen as minimum length curves (or geodesics) in the image I , according to the particular metrics $g_I(x,y)$. If $g_I(x,y)$ is nearly null in the high gradient areas of I , these contours will naturally follow the salient edges in the image, in order to minimise their length.

Minimisation problems related to active contours are usually solved iteratively, using a time differential equation to guide the curve evolution toward the solution (starting from an initial position). But in the case of geodesic curves, a level-set implementation becomes possible: curves are considered as the intersection of a 2D functional, the Ψ function, with the horizontal plane $Z=0$. A differential equation is then applied on the Ψ function, rather than on the contours themselves, to converge to the solution. Therefore, topological changes can occur during the process (Figure 4.3).

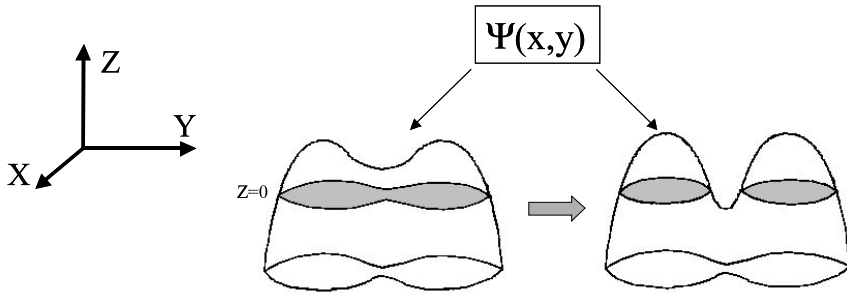


FIGURE 4.3. TOPOLOGICAL CHANGE OF ACTIVE CONTOUR BY LEVEL-SET IMPLEMENTATION

The initialisation of $\Psi(x,y)$ is not critical, because of these possible topological changes. In our case, it is determined in such a way that the corresponding initial contours ($\Psi(x,y) = 0$) draw a grid of «seeds», in order to be sure to reach every vineyard parcel edge during the contour propagation.

Our «metric function» (or distance function) g_I is defined by:

$$g_I(x, y) = \exp\left(-\frac{1}{10} \cdot \frac{|\nabla I(x, y)|^2}{\langle |\nabla I|^2 \rangle}\right) \quad (2)$$

where $|\nabla I(x, y)|^2$ is the square of the gradient of the image I at the considered pixel location and $\langle |\nabla I|^2 \rangle$ is its average for the whole image.

As in Paragios and Deriche (1999), a «region function» R_I has also been defined for every pixel (x,y) by:

$$R_I(x,y) = I(x,y) - s \quad (3)$$

where s is a tuneable threshold value. The role of R_I is to introduce the region forces which cause the active contours to expand themselves in the image areas containing pixels with values below the threshold s (high probability to be a vineyard area) and to retract themselves otherwise.

Finally, according to Caselles et al. (1997) and Paragios and Deriche (1999), we obtain the following evolution equation:

$$\frac{\partial \Psi}{\partial t}(x,y) = g_I(x,y) \cdot \kappa |\nabla \Psi| + \nabla g_I \cdot \nabla \Psi + \beta \cdot R_I(x,y) \quad (4)$$

where t is the time, κ is the curvature of the Ψ function, ∇g_I and $\nabla \Psi$ are respectively the gradient of g_I and Ψ , and β is a tunable coefficient for the region force term.

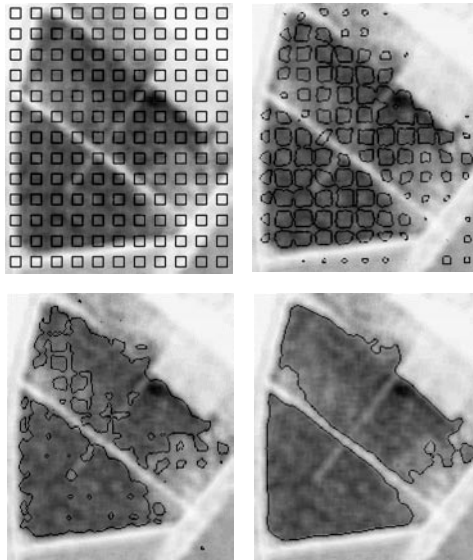


FIGURE 4.4. CONTOUR EVOLUTION AT VARIOUS ITERATION STEPS

A discrete form of equation (4) is applied iteratively³. Figure 4.4 shows an example of the active contours evolution at various iteration steps. The iterative process is automatically stopped according to a criterion based on the evolution speed of the total area of the negative parts of Ψ (i.e. of the total area of detected vineyard parcels, as according to the level-set implementation, the vineyard boundaries are given by $\Psi(x,y)=0$).

³ At each iteration k : $\Psi_k(x,y) = \Psi_{k-1}(x,y) + \frac{\partial \Psi}{\partial t}(x,y) \cdot \Delta t$, where Δt controls the evolution speed.

4.3.3. Region threshold management and contour shape analysis

The introduction of region forces in geodesic active contours allows us to select only parcel edges, rather than any grey-level transitions in the image. However, it requires definition of a threshold value s in equation (3) that should be well-adapted for the whole image, which brings us back to a very classical (and impossible to solve) binary segmentation problem.

To overcome this problem, the following scheme has been implemented:

1. the whole process of geodesic active contour propagation is repeated with several increasing and arbitrary values of the thresholds.
2. at the end of each step, the boundaries of each detected parcel are analysed. The pieces of boundary that seem to correspond to real vineyard edges are then «locked», so that they are not lost when applying further higher threshold values.

The basic idea of this boundary analysis is that parcel edges are generally quite long and rectilinear. Therefore, each parcel contour is first approximated as a polygon. Each polygon edge is then checked, according to its length, to the $g_I(x,y)$ values along its length and to the grey-level difference in image I between each of its sides. Moreover, an iterative relaxation procedure⁴ is then applied on the selected polygon edges, in order to optimise their position and their length before locking (Figure 4.5). The locking itself consists of artificially re-enforcing the image source grey-level on the external side of the contour.

Finally, when the higher threshold value has been applied, a list of detected parcels is produced in vector format. Figure 4.6 shows the result obtained at this stage, for the original image presented in Figure 4.1.b. Remaining segmentation errors are also indicated.

4 This relaxation procedure combines attraction by the low values of $g_I(x,y)$ and constant extension forces, the polygon edge being considered as a «rigid» snake.

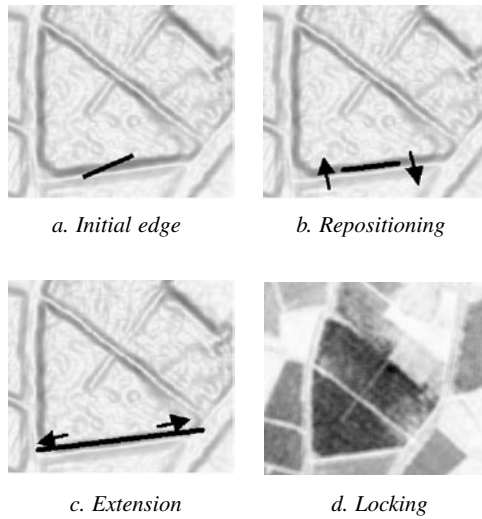


FIGURE 4.5. EDGE RELAXATION AND LOCKING PROCESS (A,B,C: IMAGE OF $G_i(X,Y)$ D: SOURCE ANNEX III)

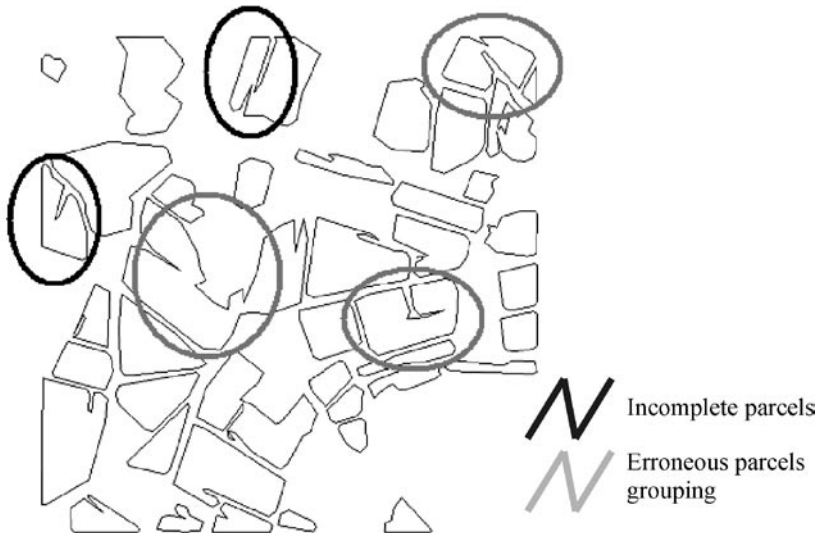


FIGURE 4.6. VINEYARD PARCEL DETECTION BY GEODESIC ACTIVE CONTOURS

4.3.4. Parcel revision and characterisation

Once the parcels have been detected, the last stage consists in determining some basic agronomic characteristics for all of them: distance between rows, orientation, etc. The inter-row and the orientation can easily be accessed by a Fourier analysis. However, some of the parcels identified by the previous step, due to detection errors, are made up of different parts with different characteristics. For this reason, the characterisation step includes a checking process, which allows revision of the parcel list.

The core of this checking process is a very selective bandpass filtering (Gabor filter), computed in the Fourier space. The main original point, compared to classical filtering approaches, is the following: because we start from a previously defined vineyard parcel candidate, we are able to set precisely the frequency and the orientation of the sinusoidal wave corresponding to the filter centre, and thus to be very selective. This filter centre is determined by looking for the amplitude peaks in the current Fourier spectrum, leading to a very efficient parcel selection, as illustrated in Figure 4.7.

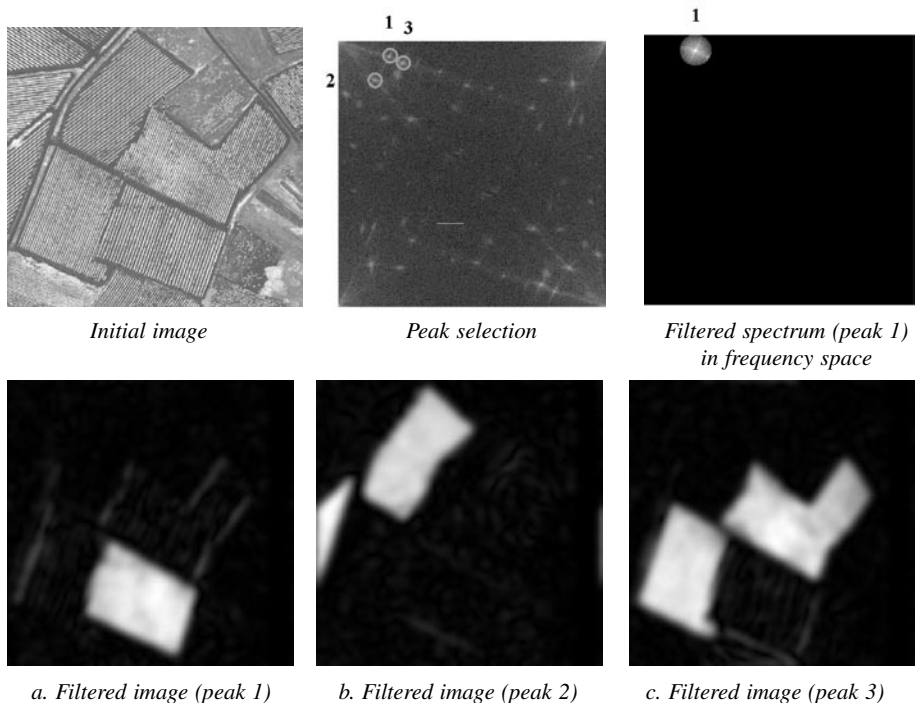


FIGURE 4.7. VINEYARD PARCEL IDENTIFICATION AND CHARACTERISATION BASED ON A SELECTIVE FILTERING PROCESS IN THE FOURIER SPECTRUM.

In order to identify every possible vineyard plot, the following recursive scheme is applied (Figure 4.8):

i) For each detected parcel from the initial list, its bounding box in the *original* aerial image (in grey-level) is considered and the corresponding Fourier spectrum is computed.

In this spectrum, various amplitude peaks are present and correspond to various periodical structures in the image. The peak with the maximal amplitude is selected as representing the characteristics of the considered parcel (inter-row distance and orientation).

ii) A sharp pass-band filter centred around this maximal peak is then applied so that the modulus of the inverse Fourier transform only highlights the image areas with the corresponding characteristics.

iii) Every new object obtained is considered as a parcel, except if it intersects a bounding box edge. In this last case, a new bounding box is defined around this truncated object with an enlargement on the side where the object is incomplete, and the process is reiterated. By this way, the initial detected object can be completely recovered in a few steps.

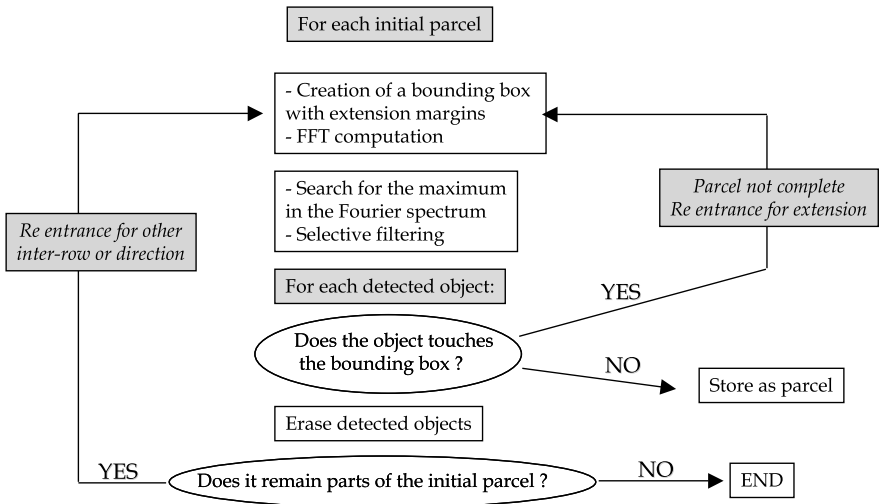


FIGURE 4.8. FFT BASED RECURSIVE SCHEME FOR PARCEL IDENTIFICATION AND CHARACTERISATION

iv) Finally, the process is reiterated on the initial bounding box after erasing the new detected parcels, so that other significant Fourier spectrum peaks can be selected and processed, to recover the parcels with different frequency or orientation.

A revised list of vineyard parcels is then produced, as shown in Figure 4.9.

The final outputs of the method are text files that give the number of vineyard parcels identified and for each parcel:

- its area,
- the position of its limits,
- the interrow distance, and
- the row orientation.

In order to separate trellis (or wire trained) vines from goblet vines, additional information is provided. Goblet vines suppose the presence of one (in case of square planting) or two additional alignments (in case hexagonal planting). As a consequence, the software examines the frequency space and looks for additional peaks situated at 90° (for square planting) or at 60° and 120° (for hexagonal planting). It computes 3 ratios: ratio90, ratio60 and ratio120. Each ratio represents the ratio between the height of the maximum detected along this complementary orientation and the one of the initial and original peak. A later classification will decide whether ratio90 or both ratio60 and ratio120 are sufficiently high to qualify the detected vine as being trained in goblets.

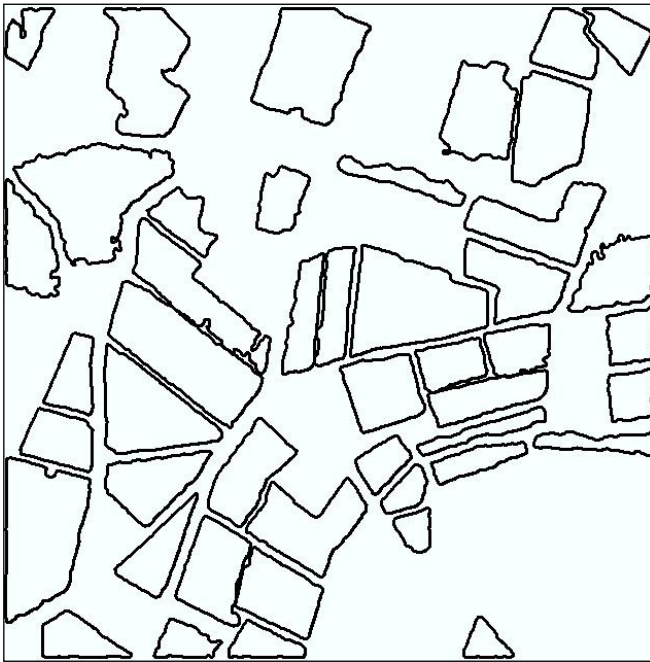


FIGURE 4.9. FINAL RESULT OF PARCEL SEGMENTATION (VECTOR FORMAT)

4.4. EVALUATION OF RESULTS

The results presented here have been obtained on two test sites of the BACCHUS project, Limoux (Languedoc region, France) and Tarazona de la Mancha (Castilla La Mancha region, Spain). The Limoux test site has been selected as it is representative of vineyard areas where vines are predominantly grown with trellis. Furthermore the test site has been covered with two types of VHR data, aerial (AMDC data acquired by INTA) and satellite (QuickBird data). A second test site has been selected as representative of vineyard areas where vines are predominantly grown in goblets. This test-site is situated in Spain, near Tarazona de la Mancha.

4.4.1. Data used

The software for the segmentation of vine compartments has been tested with data extracted from two types of remote-sensing images of very high spatial resolution, INTA AMDC orthoimage and QuickBird panchromatic data. General information on the data available on the two sites are presented in Table 4.2..

Table 4.2. Remote-sensing data used for the segmentation of vine compartments for the Limoux (France) and Tarazona (Spain) test sites

	INTA Limoux	QUICKBIRD Limoux	QUICKBIRD Tarazona
Type	Aerial orthophotography	Satellite image	Satellite image
Date of acquisition	29/05/2004	25/06/2002	31/07/2003
Spatial resolution	50 cm	62 cm	63 cm
Spectral bands used	Red, Near infrared and Panchromatic	Panchromatic	Panchromatic
Size of the extract	4800 x 5300 pixels (636 ha)	4000 x 4416 pixels (636 ha)	2500x2500 pixels
Surface area of vine (photo-interpretation)	≈290 ha (258 compartments)	≈280 ha (257 compartments)	-

4.4.2. Evaluation criteria

Four different levels of accuracy in vine detection can be distinguished:

1. Good detection (example on Figure 4.10, left):
 - The detected compartment and the real compartment share more than 80% of common surface area.
2. Average detection:
 - The detected compartment and the real compartment share more than 60% of common surface area.
 - A detected compartment groups together several real compartments (under-segmentation).
 - Several compartments are detected for a single real compartment, and detected compartments share more than 60% of common surface area with the real compartment (over-segmentation, cf Figure 4.10, centre and right).

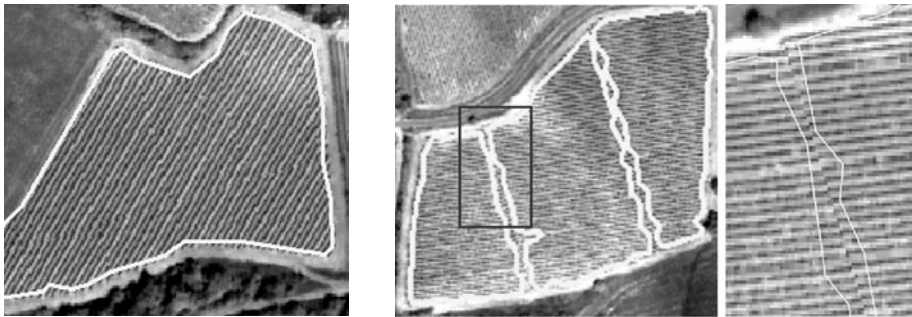


FIGURE 4.10. EXAMPLE OF GOOD DETECTION (LEFT) AND OVER-DETECTION BECAUSE OF A DEFECT IN THE IMAGE (CENTRE AND DETAIL, RIGHT). POSSIBLE SOURCE: ZONE OF ASSEMBLING BETWEEN TWO AMDC IMAGES

3. Insufficient detection (example Figure 4.11):
 - The detected compartment(s) and the real compartment have less than 60% common surface area.
4. Non-detection.

The first two levels constitute ‘acceptable’ detection of compartments.

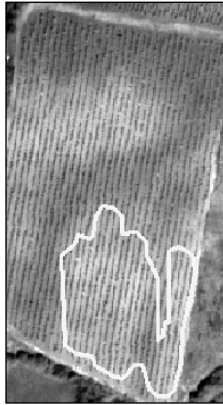


FIGURE 4.11. EXAMPLE OF INSUFFICIENT DETECTION

4.4.3. Results of vineyard plots identification and delineation on the Limoux test-site

Table 4.3 summarises the segmentation results on the Limoux test site for the two extracts of 636 ha presented in Table 4.2. Results are listed for each detection level as a percentage of the total number of compartments and a percentage of total surface area under viticulture. Illustrations of the precision of detection with the different data and bands are shown in annex, on Figure 4.12 to Figure.4.16.

Table 4.3. Results of the segmentation for the Limoux test site (percentage of compartments and surface area)

	INTA Red (Figure.4.12, Annex)		INTA NIR (Figure.4.13, Annex)		INTA Red + NIR (Figure.4.14, Annex)		INTA Pan (Figure.4.15, Annex)		Quickbird Pan (Figure.4.16, Annex)	
	% Plots	% Sur- face area	% Plots	% Sur- face area	% Plots	% Sur- face area	% Plots	% Sur- face area	% Plots	% Sur- face area
1. Correct detection	36	49	39	40	-	-	27	31	25	31
2. Average detection	27	29	23	32	-	-	18	18	33	29
1+2: Acceptable	63	78	62	72	79	91	45	49	58	60
3. Faulty detection	15	9	8	9	-	-	23	31	10	17
4. Non detection	22	13	30	19	-	-	32	20	32	23
3+4: Unacceptable	37	22	38	28	21	9	55	51	42	40

4.4.4. Results of vineyard plots identification and delineation on the Tarazona test-site

The Tarazona test site is interesting because complementary to the Limoux test site, due to the dominance of goblet vineyards. The results of vine identification and delineation are shown on Figure 4.17 and details of this segmentation on Figure 4.18. They show that detection of goblet vineyards is operative. However the detection is limited by certain characteristics of the test-site (heterogeneity of soil and vine plants development, contrast or absence of contrast of field borders with neighbouring area). These points will be discussed below.



FIGURE 4.17. RESULT OF THE SEGMENTATION ON THE PANCHROMATIC CHANNEL OF THE QUICKBIRD IMAGE, 2500x2500 PIXELS EXTRACT, TARAZONA TEST-SITE (SPAIN)

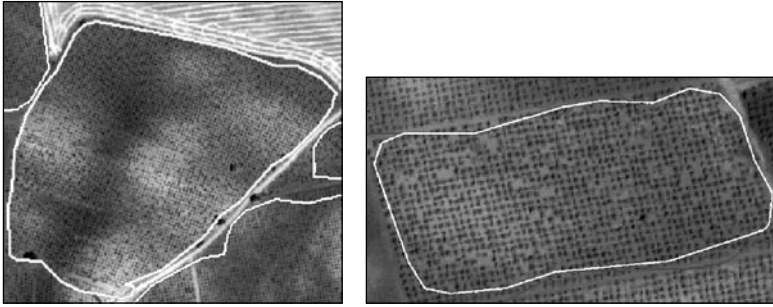


FIGURE 4.18. DETAILS OF SEGMENTATION ON GOBLET VINEYARDS, QUICKBIRD IMAGE, TARAZONA TEST-SITE (SPAIN)

4.4.5. Results of vineyard plots characterisation

Once a vineyard has been identified and delineated, it is de facto in the same time characterised, and with a good quality. Indeed if the parcel has been identified, it means that a significant peak is present in the frequency space, and through its polar coordinates (θ , r) this peak provides the information on interrow distance (related to r via the pixel size) and row orientation (θ). It should be kept in mind however that the precision in the determination of these parameters depends on the size and homogeneity of the plot: smaller and less homogeneous plots will lead to less precise parameters. Anyhow the user demand for precision in these parameters is not to the cm and the degree. A last remark is related to the identification of goblets. Once again, badly maintained goblet vines cause problems: when they are identified as vineyards, they are more liable to be not recognised as goblets and to remain identified as trellis.

4.4.6. Causes of errors in detection

The following causes of errors in detection have been identified: heterogeneity within the plot, young vines, detection of artefacts and bad detection of certain goblet vines. Details related to these faulty detections are presented hereafter.

Heterogeneity of the plot:

The heterogeneity of the compartment is the major cause of bad detection. It can have several origins:

- Differences in vine vigour within the compartment (Figure 4.19, left), often caused by differences in supply of water and nutritional elements, themselves related to the terrain contours.

- Heterogeneity in the soil colour: soils with a clear colour provide a better contrast with vegetation in the visible bands whereas darker ones lead to less contrast (see an example on Figure 4.19, right). However areas with darker soils may appear more contrasted in the near infrared domain.

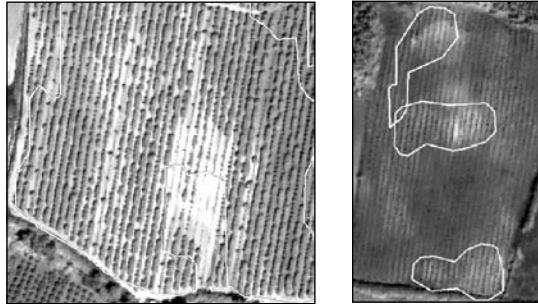


FIGURE 4.19. PROBLEM OF DETECTION CAUSED BY HETEROGENEITIES OF VINE VIGOUR. LEFT: HETEROGENEITY OF VINE VIGOUR, THE AREA DEVOID OF VEGETATION IS EXCLUDED FROM THE VINEYARD. RIGHT: HETEROGENEITY OF SOIL COLOUR: ONLY THE AREAS THAT ARE THE MOST CONTRASTING ARE DETECTED.

Young vines:

Some vines are not detectable because their level of soil coverage is low. These are most notably young vines (*'plantiers'* in French), one or two years old (Figure 4.20).

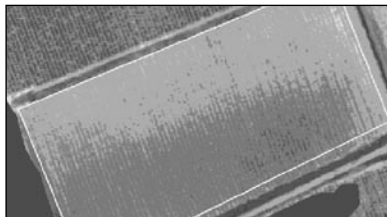


FIGURE 4.20. EXAMPLE OF A YOUNG VINE: THE ROWS ARE BARELY DISCERNIBLE

Detection of non-vine:

It is very rare for a compartment to be detected where there is no vine. Whenever this happens, it is often due to ditches between two compartments or roads that present an oriented texture (Figure 4.21). The latter case of false detections may be later suppressed through post processing.



FIGURE 4.21. EXAMPLE OF NON-VINE (HERE A HIGHWAY) DETECTED AS VINE

Vines trained as goblets:

On the Limoux test site, vines trained as goblets i.e. pruned as bushes (untrained vines) are not easily detectable for at least three reasons. Firstly these vines are generally old (50 years and above), and generally not very well maintained, with a high level of missing vine plants. Furthermore the vines are not trimmed, which leads to a lower contrast, and finally they are grown on small plots (Figure 4.22). In the Limoux area, where the profession is dynamic and most of these vineyards have been uprooted and replanted with higher quality varieties, these goblet vineyards represent only 2 to 3% of the total.



FIGURE 4.22. EXAMPLE OF VINE TRAINED AS GOBLET (LIMOUX)

4.4.7. Analysis and interpretation of results

From the analysis of the above results, the following comments can be made:

- With good conditions of contrast, the detection of vineyards, either in trellis (as in Limoux) or in goblets (as in Tarazona), is operative
- Very few non-vine compartments were detected as vine (see a counter example on Figure 4.21).
- Results are always better for surface area than for the number of compartments. In fact, compartments that were incorrectly detected or non-detected are usually the very smallest ones.
- Panchromatic channels do not seem to be suitable for detecting viticulture compartments in the Limoux region.
- In spite of the slightly lower resolution of the Quickbird image, its results are distinctly better than those from the panchromatic channel of the INTA image. This can perhaps be explained by the fact that Quickbird's panchromatic channel covers a wider spread of wavelengths, in particular for the near infrared, when compared with the panchromatic channel of the INTA image, which only covers the wavelengths of the visible domain.
- On the Limoux test-site, the best results are provided by processing the red channel. However, the results of the processing on the near infrared channel are complementary: **79% of compartments (91% of viticulture surface area) are detected by the red channel and the near infrared channel** (Table 4.3). The use of the panchromatic channel does not lead to any additional improvements.
- The presence of a certain heterogeneity on the vineyards borders, with lower contrast (vine plants of lower vigour) or gaps in the row (missing plants) is not favorable to a reliable definition of the parcel limits. In order to obtain more representative limits, a specific post-processing step would be necessary.

Some incorrect detection can also be explained by an insufficient image resolution, specially for inter-row widths smaller than 2 m. Figure 4.23 shows an example of segmentation of an image of 20 cm resolution, obtained by Cemagref using an ULA. In this case, for a total of 20 compartments, only one was not detected, one was incorrectly detected, and there were two groupings of compartments.

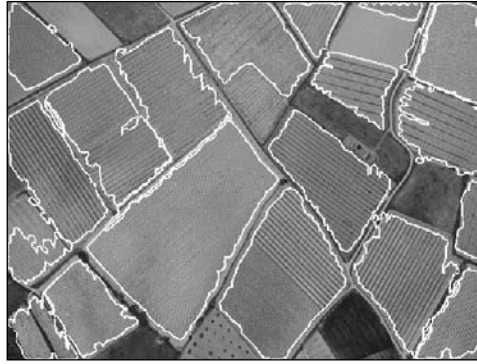


FIGURE 4.23. EXAMPLE OF SEGMENTATION OF AN ULA IMAGE OF 20 CM RESOLUTION

4.5. DISCUSSION AND CONCLUSION

In the Limoux region (and the corresponding appellation zone) and in the Tarazona region, there is an overall homogeneity of vines, with, in particular, the inter-row or inter-plant distances being generally greater than 2 m. These distances are specific to the vine in the region, other crops grown in rows (maize, sunflower...) having a much smaller separation (0.80 m) and there is no possibility of confusion. With these kinds of patterns, the algorithm developed in the BACCHUS project is generally operative.

The causes of insufficient detection have different origins. The first cause is heterogeneity in vine appearance. This heterogeneity depends on terrain contours, soil colour, soil depth and the relative supply of water and nutrients, all these factors being tightly interlinked. Yet another factor for heterogeneity is related to crop practices (tillage and/or total or partial weeding). Secondary causes of bad detection are the small size of plots (not favourable for obtaining a 'good' Fourier transform), young vines (less than two or three years old) and bad level of vine maintenance (numerous missing vine plants, 'dirty' vines, as with the old goblets vineyards in France).

As a consequence, the methodology developed in the BACCHUS project can produce good results, as on the Limoux test site, where 91% of the viticulture surface area has been detected. However these results directly depend on a good legibility of vineyards on the original remotely sensed images and cannot be generalised without taking a few precautions. And in any case they require a visual post-processing to correct detection defects before inclusion in the GIS data base.

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5. MULTISPECTRAL ANALYSIS

Calera A., Quintanilla A. & García de Vicuña A.

5.1. INTRODUCTION

In the past three decades, the scope of remote sensing has been considerably extended, from the use of the conventional aerial photographs to satellite imagery acquired in multiple spectral bands. New generations of satellite sensors are providing higher spatial and spectral resolution data leading to a wider application of remotely sensed products and further emphasising the need for more automated forms of image processing and analysis. Furthermore, remote sensing is distinguished by its relatively low cost when compared with the high cost of ground surveying, and by the frequency with which each region on the earth's surface is covered, making possible the temporal monitoring of natural phenomena and earth resources. These advances require the development of new data processing techniques, in order to allow information to be processed promptly and accurately. The range of image processing techniques has greatly expanded in recent years in relation to the methods used in mapping, from classical statistical approaches to neural network methods, as well as in the number and the type of features used in the thematic mapping process by incorporating spatial (texture, contextual analysis), spectral (multispectral analysis) and temporal information (multitemporal analysis).

A human analyst attempting at classifying features in an image, uses the elements of visual interpretation (photointerpretation) to identify homogeneous groups of pixels, which represent various features or land cover classes of interest. In either case, the objective is to assign all pixels in the image to particular classes or themes (e.g. water, coniferous forest, deciduous forest, corn, wheat, etc.). The resulting image is comprised of a mosaic of pixels, each of which belong to a particular theme, and is essentially a thematic «map» of the original image.

Thus classification techniques comprise the wide set of methodologies designed to generate classes, themes, land uses or land cover categories, from remotely sensed digital satellite data.

This chapter presents a general view of well-known multitemporal and multispectral techniques for crop mapping. Besides, it also focuses on approaches that have been specifically designed to vineyard inventory. The structure of the chapter is as follows. First a general description of classification methods is presented in order to show the capabilities and limits of every one of them. Then, a review of multitemporal and multispectral approaches applied over vineyard is included. And finally the BACCHUS project approach to multitemporal classification of vineyard is proposed and the advantages of this method are indicated. The main conclusions of this investigation are drawn in last section of this chapter.

5.2. METHODS OF CLASSIFICATION

5.2.1. The classification procedure

Classification of remotely sensed data is used to categorise the image information according to relevant characteristics, with the aim of discriminating

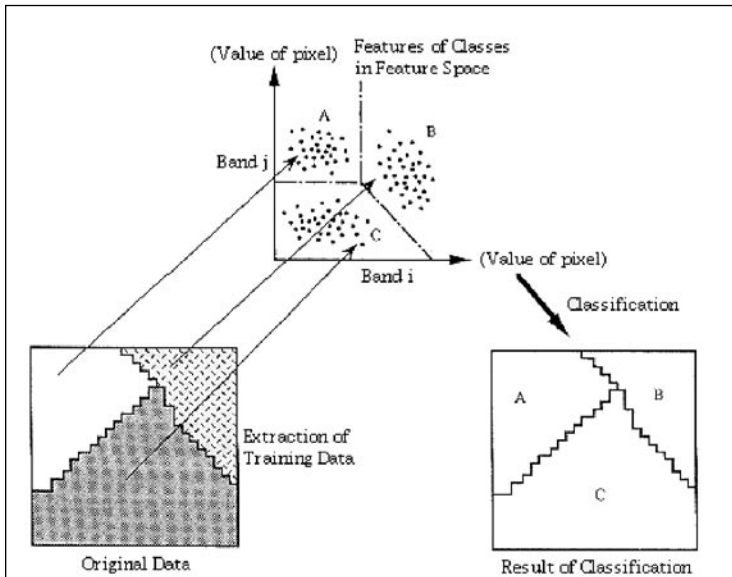


FIGURE 5.1. CLASSIFICATION PROCEDURE

multiple objects from each other within the image. Classification will be executed on the base of previously defined features, such as spectral densities, temporal behaviour or texture etc., in the multidimensional space of these features. It can be said that classification divides this feature space into several classes based on decision rules. The Figure 5.1 shows the concept of digital classification.

In the last decades a great number of methodologies have been developed in order to tackle the generation of thematic maps. However, there is a sequence of steps that are general in the classification procedure. These steps are represented in Figure 5.2 and can be summarised as follows:

- Definition of Informational Classes (Legend of work).

The «Informational Classes are those categories of interest that the analyst is actually trying to identify in the imagery, such as different kinds of crops, different forest types or tree species, different geologic units or rock types, etc, and that will constitute the legend of work. Depending on the objective and the characteristics of the work area, these informational-classes should be investigated and clearly defined by the analyst. It is important to distinguish between these informational-classes and the classes that correspond to groups with homogeneous characteristics on the space of features (i.e. homogeneous reflectivity values, or similar temporal evolution, similar contextual character). We will call these classes as featured-classes. The analyst's objective is to match the featured-classes with the informational-classes of interest.

- Selection of Features.

The selection of features to discriminate between classes is critical in the process of classification and should be established based on the expertise of the analyst, additional information on the features of the classes and the available digital information. The most common features used for this purpose consist of multispectral and/or multitemporal digital data but also texture and contextual information.

- Sampling of Training Data.

It consists in the selection of representative pixels from each of the selected cover. The selected pixels are referred to as the training pixels or data that will be used in posterior steps to determine appropriate decision rules. The selection of these data can be performed using supervised or unsupervised approaches (see section 5.2.2).

- Estimation of Universal Statistics.

These selected pixels (training data) are then used to define the parameters of each particular class. These parameters define the probability model that establishes the partition of the multispectral space in different classes.

- Techniques of Classification.

Depending upon the decision rule, all pixels are classified in featured-classes. Afterwards, the analyst will try to find the equivalence between featured-classes and informational-classes of interest. In some cases this correspondence featured / informational-classes is not one-to-one and more than one featured-classes may correspond to one informational-class and vice versa (See section 5.2.3). Herein, we can distinguish between approaches designed to be applied on a pixel per pixel basis or approaches that work on a per-field basis, i.e. with respect to segmented areas.

– Verification of Results.

The output of the classification procedure must be checked and verified for assessing their accuracy and reliability.

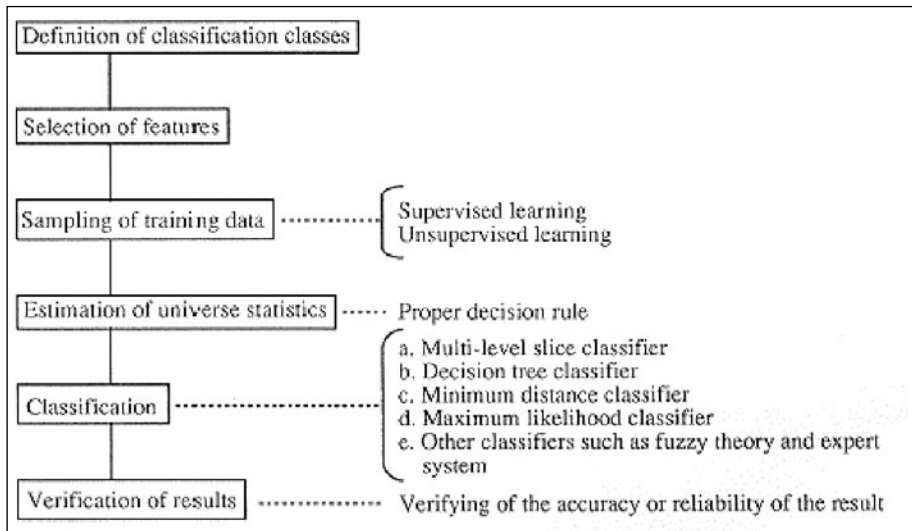


FIGURE 5.2. STEPS IN THE CLASSIFICATION (AFTER PROCEDURES OF CLASSIFICATION, 1996)

5.2.2. Techniques in the pre-classification phase (Unsupervised procedure)

Unsupervised algorithms require very few inputs in this phase of data processing. In an unsupervised classification the identities of the land cover types are not usually known. This can be because ground information is unavailable or covers are difficult to identify on the images. The computer selects natural groupings of pixels based only on their feature space properties. Since it is an automatic enough process, this kind of algorithms comprise both training and classification phases. Thus, once the classification is performed, the only

posterior step consists in the identification featured-classes versus informational-classes.

Clustering algorithms are used to determine the natural (statistical) groupings or structures in the data. Usually, the analyst specifies how many groups or clusters are to be looked for in the data. In addition to specifying the desired number of classes, the analyst may also specify parameters related to the separation distance among the clusters and the variation within each cluster. The final result of this iterative grouping process may result in some classes that the analyst will want to subsequently combine, or classes that should be broken down further - each of these procedures requiring a further application of the clustering algorithm. Thus, unsupervised process is not complete without human intervention, though it does not start with a pre-determined set of classes as in a supervised process.

a) Isodata algorithm

Probably the most common unsupervised classification algorithm is the Iterative Self Organising Data Analysis Technique (ISODATA). ISODATA calculates class means distributed in the data space and then iteratively clusters the remaining pixels using minimum distance calculations. Each iteration recalculates means and reclassifies pixels with respect to the new means. Iterative class splitting, merging, and deleting are done based on input threshold parameters. All pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, which may lead to the unclassification of pixels not meeting the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached. Therefore, input parameters of this algorithm are: (1) the maximum number of clusters; (2) the maximum percentage of pixels whose class values are allowed to remain unchanged between iterations; (3) the maximum number of iterations; (4) the minimum number of members in a cluster; (5) the maximum standard deviation for every class; and (6) the minimum distance between cluster means.

b) K-means algorithm

The K-means method analyses the input raster set to determine the location of initial class centres. In each iteration, cells are assigned to the nearest class and new class centres are calculated. The new class centre is the point that minimises the sum of the squared distances between points in the class and the class centre. With each iteration class centres shift and the class assignments for

some cells change. The process repeats until the shift in class centres falls below a specific value or the maximum number of iterations is reached. Therefore, input parameters of this algorithm are: (1) the maximum number of classes; (2) the maximum number of iterations; (3) the minimum threshold that stands for the percentage of class centres that must become steady in order to accept the current set of classes; and (4) the maximum sample size.

c) Supervised techniques

In a supervised classification, the analyst identifies homogeneous and representative samples of the different surface cover types (information classes) of interest in the imagery. These samples are in this case the training areas. The selection of appropriate training areas is based on the analyst's familiarity with the geographical area and on his knowledge of the different surface cover types in the image. The numerical information in all spectral bands for the pixels comprising these areas is used to define training areas. The characterization of the training areas allows the computer to recognise similar areas in the image. Thus the «spectral signatures» for each training class are determined and then each pixel in the image is compared to these signatures and labelled as the class it most closely «resembles» digitally. Therefore, in a supervised classification we are first identifying the informational-classes, which are then used to determine the corresponding featured-classes.

d) Mixed techniques

They consist in the combined use of supervised and unsupervised methods. Both supervised and unsupervised techniques have advantages and disadvantages. The first one can become biased, since the analyst is establishing a priori classes without considering the features of these classes on the images. The unsupervised technique does not guaranty that the featured-classes are equivalent of an element of the legend. Mixed approaches try to solve these troubles by using combined approximations, as example (Chuvieco, 1996):

The use of the supervised technique to condition the unsupervised technique, i.e. the analyst makes use of his/her knowledge of the area in the search of the homogeneous groups. For example, the analyst can introduce the initial values of the digital numbers for the categories of interest.

The independent application of supervised and unsupervised techniques in order to synthesise both sets of results by using a hieralquical algorithm.

The improvement of the classification accuracy of a supervised classifier by using information coming from an unsupervised process and on the other hand the integration of large amounts of unlabelled data in a supervised learning process.

5.2.3. Techniques in the classification phase.

Some of the most widely accepted techniques used in the phase of classification are presented below.

a) *Maximum Likelihood*

Maximum Likelihood works under the assumption that the training data for each class is normally distributed (See Figure 5.3). For each training class, the classifier calculates the mean (spectral, temporal, spatial...) signature and a covariance matrix for every band using the training data. When the classifier is applied to the image, a complex equation uses featured signature of each pixel and the class statistics to calculate the probability that has each pixel belonging to each class. Pixels are assigned to the class with highest probability.

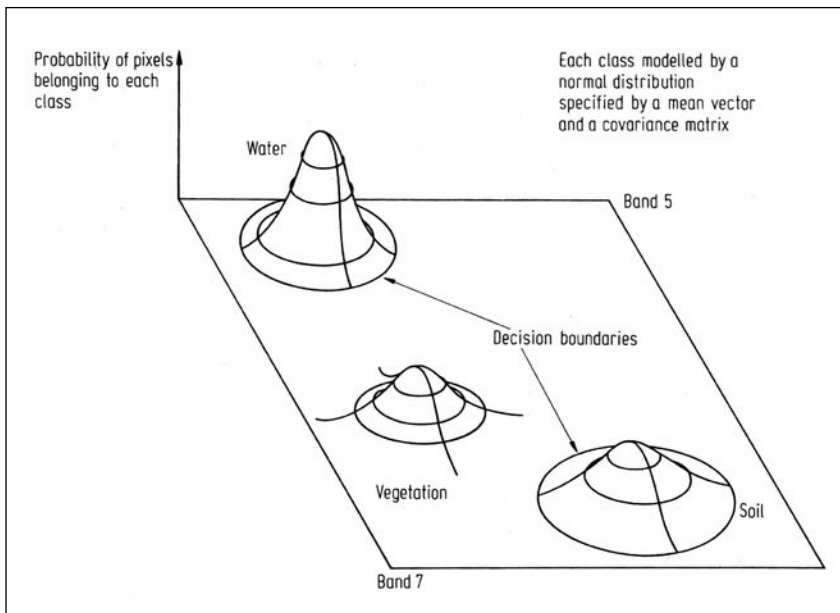


FIGURE 5.3 – MAXIMUM LIKELIHOOD CLASSIFICATION ALGORITHM (AFTER RICHARDS, 1986)

There are a number of optional parameters, which can be implemented in Maximum Likelihood to refine the process of class assignment.

– *A priori probabilities* - standard Maximum Likelihood assumes that all classes occur equally on the landscape; prior knowledge of the expected probabilities of occurrence for each class can modify the output to more strongly favour those classes that are more common in the study site.

– **Threshold** - this is a chi-squared value that represents the distance from each class mean beyond which any pixels remain unclassified.

Maximum Likelihood is one of the most commonly used supervised classifiers. It generally outputs class maps with high classification accuracy, and, given the speed of modern computers, is relatively efficient in its computational demands.

b) Minimum Distance to Means

This is the simplest of the supervised classification algorithms. When the training data are provided to the classifier, the mean signature for each class is calculated. Then, once the classifier is trained and is applied to the image, the Euclidean distance between the spectral signature of each individual pixel and the mean-signature of each class is calculated. Each pixel is assigned to the class to which this distance is the lowest.

The Minimum Distance to Means approach results in all pixels being assigned to a class. While this is usually desired, it is not always the most accurate output. It is possible that a pixel that in no way resembles any of the classes will be assigned to one class using this method. This can lead to lower accuracy in the classification.

c) Parallelepiped

The parallelepiped classifier calculates a «class limits» so as to determine if a given pixel falls within the class or not. The class limits specify the dimensions (in standard deviation units) of each side of a parallelepiped surrounding the mean of the class in the feature space.

When the classifier is applied to the image, those pixels falling within a particular class's parallelepiped are assigned to that class. Those pixels, which do not lie within any parallelepiped, are assigned to an unclassified category. However, in the case where two or more parallelepipeds overlap and the pixel falls within more than one, it is assigned to the first class to which it is compared.

Parallelepiped is a more accurate method than Minimum Distance to Means. By restricting the assignment of classes to only those pixels, which fall within one standard deviation of the class mean, it ensures greater certainty in the final class assignments. However, the drawback is that the final output contains pixels, which are not assigned to any classes. One way to remedy this situation is to extract the unassigned pixels and classify them using another classifier, such as Maximum Likelihood. The parallelepiped classifier is typically used when speed is required.

d) Decision tree classifier

The decision tree classifier is a hierarchically based classifier, which compares the data with a range of properly selected features. A decision tree recursively partitions a data set into smaller subdivisions on the basis of tests applied to one or more features at each node of the tree. The selection of features is determined from an assessment of the distributions or separability of the classes on the feature space. A decision tree classifier can perform automatic feature selection and complexity reduction, while the tree structure gives easily understandable and interpretable information.

To construct a classification tree, a dataset consisting of feature vectors and their corresponding class labels is needed. The features are identified based on specific knowledge about the problem. The decision tree is then constructed by recursively partitioning a dataset into more homogeneous subsets on the basis of a series of tests applied to one or more attribute values at each node in the tree. The steps to be followed for using this method consist in: split nodes, determine which nodes are terminal nodes and assign class labels to terminal nodes.

A tree is composed of a root node (containing all the data), a set of internal nodes and a set of terminal nodes. Each node in a decision tree has only one parent node and two or more descending nodes. A data set is classified by subdividing it according to the decision defined by the tree. (See Figure 5.4 for an example).

The main advantages of the decision tree classifier are that computing time is less than the maximum likelihood classifier and by comparison the statistical errors are avoided. However, the accuracy depends fully on the design of the decision tree and the selected features.

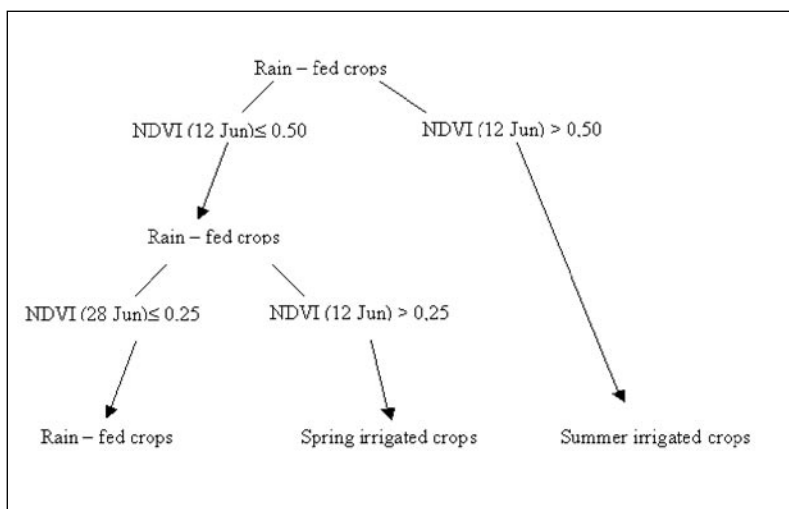


FIGURE 5.4. DIAGRAM SHOWING AN EXAMPLE OF DECISION TREE CLASSIFIER (AFTER CALERA, 2000)

e) Contextual classifier

Contextual classification methods uses more than a single pixel to categorise and generalise thematic map land use patterns. These methods make use of information from neighbouring pixels as well as of the information associated with the pixels being classified. The application of contextual classifiers can be performed in combination with other classifiers and at different levels of phases in the whole process of classification. Thus we can distinguish between approaches that consider the application of this classifier at the beginning, during or after the process of classification.

Contextual methods perform post classification revision of results from a first – pass classification based on examination of the classification of neighbouring pixels. Thus, one of the simplest ways of using contextual classifiers is through the use of filters. In occasions the objective is the elimination of residual borders miscalculated. To this end the class assigned to the border is compared with the classes of neighbouring in order to reassign it.

5.3. DIGITAL INFORMATION USED IN CLASSIFICATION

Most of the techniques above described can be used with different types of digital information. The selection of the information to be incorporated as

bands of the multidimensional space of work is critical since the results of the classification will depend on it. So, the analyst has to evaluate the properties of the informational-classes in this space in order to assure the separability of the classes of the legend, and in case it is convenient reconsider a new set of digital information for the classification. The digital information can be used either in their original format (after applying corrections such as geometric, radiometric and atmospheric ones), or as simple combinations of the original bands, or transformed to synthesise the maximum amount of information in the minimum number of bands. Features often used are: Spectral reflectances, spectral indexes (e.g. NDVI), multitemporal data, principal components, tasseled cap components and spatial data (textural and contextual information). Next a description of these kinds of data is included.

5.3.1. Spectral information

One of the most relevant and traditional approaches is the Multispectral classification. In this procedure the spectral information represented by the digital counts in one or more spectral bands is used to classify each individual pixel. In this case, «featured-classes» are groups of pixels that are uniform (or near-similar) with respect to their brightness values in the different spectral channels of the sensor/s and are named «spectral-classes». Figure 5.5 illustrates this approach.

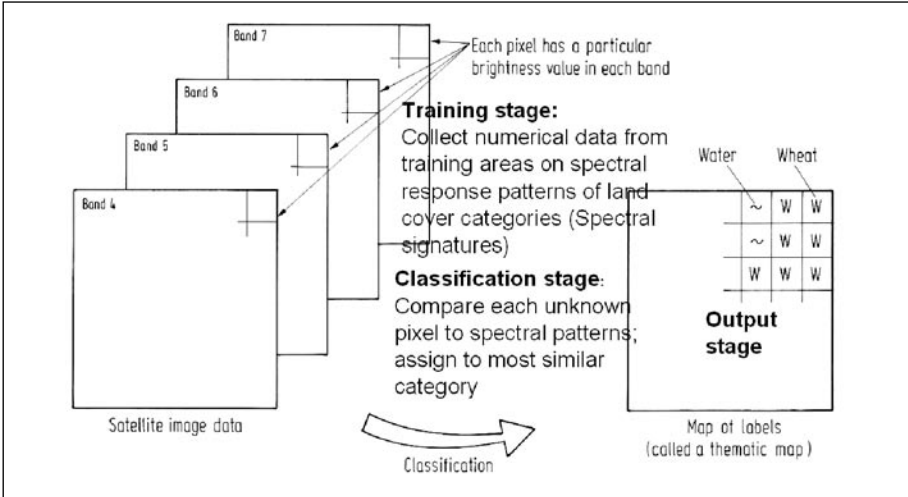


FIGURE 5.5 – MULTISPECTRAL CLASSIFICATION PROCEDURE (AFTER CALERA, 2000)

The value of multispectral approaches resides in the amount of research that exists in the subject of the spectral characterisation of natural surfaces. This research constitutes the basis for the development of specific classification approaches that incorporate this knowledge on spectral signatures. Besides, the appearance in last years of new hyperspectral instruments increases the potential of multispectral classification. The incorporation of spectral data into the classification can be done under different formats: The simplest way is as the Digital Number (DN) that represents the brightness of the surface in the spectral region that defines a given channel in an airborne or spaceborne instrument. Other possibilities include combinations of DNs from different spectral bands as ratios, vegetation indices (See next section), or vectors resulting from more elaborated transformation. Two of these transformations are Principal Component Analysis (PCA) and Tasseled Cap Transformation (TCT). The necessity of these transformations resides in finding ways to reduce dimensionality without sacrificing accuracy. The accuracy and reliability of a classification or prediction model will suffer if highly correlated variables or variables that are unrelated to the outcome of interest are included in the process. Superfluous variables can increase the data-collection and data-processing costs of deploying a model on a large database.

Principal component analysis is a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components. The objective of PCA is to reduce the dimensionality (number of variables) of the dataset but retain most of the original variability in the data.

Tasseled cap transformation is a useful tool for compressing spectral data into a few bands associated with physical scene characteristics. It produces an orthogonal transformation of the original data into a new three-dimensional space. The calculation of the Tasseled Cap vegetation index produces a three dimension vector for each pixel, being its values referred to a 3D orthogonal reference system whose axis are associated to soil Brightness, vegetation Greenness, and Wetness (moisture content). The higher value in Greenness indicates more healthy vegetation. Soil Brightness provides information on the soil condition. Wetness is another indicator for vegetation condition, indicating a higher content in wetness that vegetation is healthier. It must be noticed that before applying this transformation to satellite images, these must be corrected for atmospheric effects.

a) *Vegetation indices*

The increasing number of approaches that incorporate vegetation indices in crop inventory leads as to include this section devoted to this kind of indices. Vegetation Indices are robust spectral measures of the amount of vegetation present on the ground in a particular pixel, and are often used in mapping vegetation attributes and conditions. They typically involve transformations of two or more bands focused on the enhancement of the vegetation signal and allow for precise inter-comparisons of spatial and temporal variations in terrestrial photosynthetic activity. Several studies have shown that vegetation indices, (e.g. NDVI) are related to plant biophysical properties, such as leaf area index, percent green cover, green biomass content and amount of photosynthetically radiation absorbed by the canopy.

The advantages of the vegetation indexes are the simplicity of implementation, the low computational cost and the reduction in data volume that permits the monitoring, mapping, and resource management of the Earth's terrestrial vegetation. On the other hand, disadvantages of vegetation indices are the influences exerted by factors related to soil background, atmosphere and other non-photosynthetic components of vegetation (Richardson and Wiegand 1977; Huete, 1988, Kaufman and Tanré, 1992).

The selection of the best vegetation indices for a particular purpose is not easy, due to the wide combination of bands and transformations that are possible. While several vegetation indices are redundant in information content, some of them emphasize specific vegetation attributes. There are indices designed to reduce perturbations such as soil brightness changes and atmospheric effects, and indices designed to minimise saturation and linearity problems.

Vegetation indices can be classified in the following categories according to Rondeaux et al. (1996):

Intrinsic indices: These types of indices only consider in the formula the reflectivity values measured in Red and Near Infrared bands. For example:

- Ratio Vegetation Index:

$$RVI = \frac{NIR}{R} \quad (\text{Pearson and Miller, 1972})$$

- Normalised Difference Vegetation Index:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \quad (\text{Rouse et. al, 1974})$$

Indices that use the soil line in the formula: These types of indices consider in the formula parameters that represents the soil line. The objective of these indices is to reduce the influence of soil background.

In next formulae a and b are the coefficients that define the soil line ($NIR_s = aR_s + b$), and subscripts s and c refer to soil and vegetation, respectively.

- Perpendicular Vegetation Index:

$$PVI = \sqrt{(NIR_c - NIR_s)^2 + (R_c - R_s)^2} \quad (\text{Richardson and Wiegand 1977})$$

- Weighted Difference Vegetation Index:

$$WDVI = (NIR - aR) \quad (\text{Clevers and Verhoef, 1993})$$

- Soil Adjusted Vegetation Index:

$$SAVI = (1 + L) \frac{(NIR - R)}{(NIR + R + L)} \quad (\text{Huete, 1988})$$

with $L = 0.5$

- Transformed SAVI:

$$TSAVI = \left[\frac{a(NIR - aR - b)}{(R + a(NIR - b) + 0.08(1 + a^2))} \right] \quad (\text{Baret and Guyou, 1991})$$

Indices that reduce the atmospheric effects: These types of indices reduce the influence of the atmosphere. It is possible to obtain them modifying the above type of indices.

- Atmospherically Resistant Vegetation Index:

$$ARVI = \frac{(NIR - RB)}{(NIR + RB)} \quad (\text{Kaufman and Tanré, 1992})$$

where: $RB = r - \gamma(B - R)$, a combination of the reflectivity in the visible Blue, B and in Red, R. γ is parameter according to the aerosol content. A typical value of γ is $\gamma = 1$

- Soil – adjusted and Atmospherically resistant Vegetation Index SARVI: It can obtain modifying SAVI, RB will be put in the formula instead of R. (Kaufman and Tanré, 1992)

- Global Environmental Monitoring Index:

$$GEMI = \frac{\eta(1 - 0.25\eta) - (R - 0.125)}{(1 - R)} \quad (\text{Pinty and Verstraete, 1992})$$

$$\text{where } \eta = \frac{[2(NIR^2 - R^2) + 1.5NIR + 0.5R]}{(NIR + R + 0.5)}$$

Normalised difference vegetation index (NDVI): NDVI is the most commonly used vegetation index and the reasons are multiple. Other indices have a more complex calculations or require additional information, also because NDVI minimises atmospheric and illumination perturbation. NDVI calculation is based on the principle that for vegetation the energy is absorbed strongly in the red region and in the near infrared the reflection is very strong. Thus, NDVI is calculated from the visible and near-infrared light reflected by vegetation. NDVI values range from 1.0 to -1.0. Higher values indicate higher concentrations of green vegetation and lower values indicate nonvegetated features, such as water, barren land, ice, snow or clouds. Besides, it is related to the proportion of photosynthetically absorbed radiation. It is a parameter that measures the amount of green vegetation Fractional ground cover) in an area.

NDVI is a good indicator of the phenological evolution of crops, Moran et al. (1997); so, temporal signature of crops will be drawn by the temporal evolution of NDVI. The information underlying NDVI values makes this index appropriated for multispectral and multitemporal approaches to monitor crop development and to describe several canopy biophysical parameters.

5.3.2. Temporal information

Information from multiple images taken over a period of time is referred to as multitemporal information and classification techniques that use this kind of data are referred to «Multitemporal classification». In this context, «multitemporal» may refer to images taken days, weeks, or even years apart. Other applications like environmental monitoring and change detection also require the evaluation of images from different acquisition times. A valuable multitemporal tool is the observation of vegetation phenology (how the vegetation changes throughout the growing season), which requires data at frequent intervals throughout the growing season. Therefore a key factor in this kind of analysis is the time difference

between the images. They have to be acquired so as to be able to monitor changes on land cover.

Change detection can be carried out at pixel or at object level. Approaches that detect differences at pixel level require a perfect co-registration of the data sets. Furthermore they are limited to the comparison of images from the same sensor platform and they are very sensitive to variations in illumination, weather conditions, and perspective of view. This type of application requires consistency in illumination (solar angle or radar imaging geometry), weather conditions and perspectives of view to provide consistent and comparable classification results.

Also in multitemporal classification the digital data from different dates can be incorporated in a series of formats, as for multispectral approaches (i.e. simple DN in a band, combinations between bands, vegetation indices, and vectors from PCA or TCT). Besides it is possible to use only one kind of data, for example the NDVI for different dates, or a mixture of formats. Particular attention deserves principal components in multitemporal classifications because of its ability to summarise the most significant information of the scene. They have also been used to detect changes between images of different dates (Chuvieco, 1996).

5.3.3. Spatial information

Spatial pattern recognition makes use of spatial context to distinguish between different classes. It involves the categorisation of image pixels on the basis of their spatial relationships with pixels surrounding them: Image texture, pixel proximity, feature size, shape, directionality, repetition, and context. Spatial pattern recognition involves both the enhancement and the segmentation (or classification) of interesting regions within the pattern. Enhancement is done to make interesting parts of the pattern more apparent or to provide alternative representations of the patterns. Segmentation is undertaken to separate regions of interest from the background pattern, so that they can be compared. Pixels are assigned into homogeneous groups.

Notice that spatial context can be applied over digital data in a series of formats (i.e. simple DN in a band, combinations between bands, vegetation indices, and vectors from PCA or TCT).

5.4. MULTISPECTRAL AND MULTITEMPORAL ANALYSIS FOR VINEYARD INVENTORY

Relatively few studies have employed pure multispectral Remote Sensing techniques to identify vineyards. The reasons are numerous: vine canopy

densities vary due to stress (water and disease), vine age and vine spacing; There may be portions of a vineyard that are so young or stressed that they are unlikely to be classified as vineyard. Besides the terrain variation, differences in sun angle and in natural vegetation with altitude, may lead to confuse vineyard with other crop types (Gong et al. 2003). These difficulties stress the necessity of using VHR spatial and/or spectral data to allow discrimination between vine varieties or fraction of vegetation cover. Thus, Lacar et al. (2001) showed the necessity of working in very narrow spectral regions to identify spectral differences resulting from the variety of the vine. This work is based on field measurements and therefore does not take into account the problem of the spatial scale when working with remote sensors. On the other hand, Wassenaar et al. (2001) concluded that Very High spatial Resolution imagery allows not only the identification of vineyard but also the quantification of vine vegetation cover, and the discrimination between shadow and sunlit elements. This approach combines multispectral data with texture techniques, besides the authors proposed the use of reflectance intensities in the red channel instead of band ratios. Hall et al. (2003) is another example of using high-spatial-resolution images of vineyard for more specific analysis on vineyard identification. They proposed a method based on converting imagery into vegetation index for identifying vine rows and then extract vine canopy size. Another work also using airborne imagery is Gong et al. (2003). The authors compared a number of techniques in image classification, and finally proposed a mixed technique that combines bands of reflectance intensities, with NDVI and brightness band from orthogonalization transformation.

Most multispectral studies applied to vineyards generally exploit the spectral features of the crop radiometric signal ignoring the influence of the soil surface. Precedents works were based on empirical approaches. Thus, Trolier et al. (1989) reported vineyard inventory in the State of New York using Landsat TM imagery in the summer after distinguishing vineyards from other vegetation cover types with a maximum likelihood classification algorithm. To increase the accuracy of vineyard inventory Rubio et al. (2001) proposed the use of two different selections of bands in the classification to maximise the separability of vineyard class with respect to one or several land cover uses.

Viability of vineyard inventory over large regions by using very high spatial and/or spectral resolution digital data (i.e. QuickBird, Ikonos, airborne digital camera imagery) is hampered by the cost and limited availability of this kind of data and then only appropriated for pilot zones and study cases. Operational monitoring of vineyard is only affordable by using the active spaceborne instruments such as Landsat with the additional benefit from the temporal frequency of acquisitions

of this kind of sensors. Studies base on this kind of digital data constitute the well-known Multitemporal approaches.

As it is known, in these techniques the phenological development of the canopy is the main criteria to discriminate classes. The «spectral signature» of a class is here replaced by the «temporal signature» that describes its evolution in time. Featured-classes are selected according to similarities in the phenological development of the individual crops. Some advantages to use these criteria are:

- The use of the concept «similar development in the time» allow us to assign each class a similar «evaporative power of atmosphere» during crop growing season and so, a similar «class water requirement». The «evaporative power of atmosphere» is defined by means of «reference evapotranspiration, ETo (Allen et al.1998).
- Ancillary data about phenological development of crops and natural vegetation can be used to define the classes of legend when no training data are available.

In these methodologies the crop temporal evolution is described by the temporal evolution of a featured data such as NDVI. In particular NDVI is a good candidate as indicator of the crop phenological evolution according to Moran et al. (1997). So temporal signature of crops can be drawn by the «Temporal Evolution of NDVI». In principle other spectral vegetation indices could be used to describe the crop temporal evolution with similar results, however literature review shows clearly a preference for using NDVI against these other spectral vegetation indices.

5.4.1. BACCHUS approach to vineyard inventory

An approach to different type of crops inventory is presented in Calera (2000). This work is based on the use of multitemporal Landsat images to classify the crops presented in a Spanish site. It focuses basically in the identification of unirrigated crops, although in the classification process other land uses are recognized. The methodology proposed for the inventory of crops focuses on study of their phenological evolution. Figure 5.6 shows typical signatures of the main crops in the studied Spanish site. This figure gives an idea of which cultures can be easily differentiated from vineyard and which classes have a response more similar to vineyard.

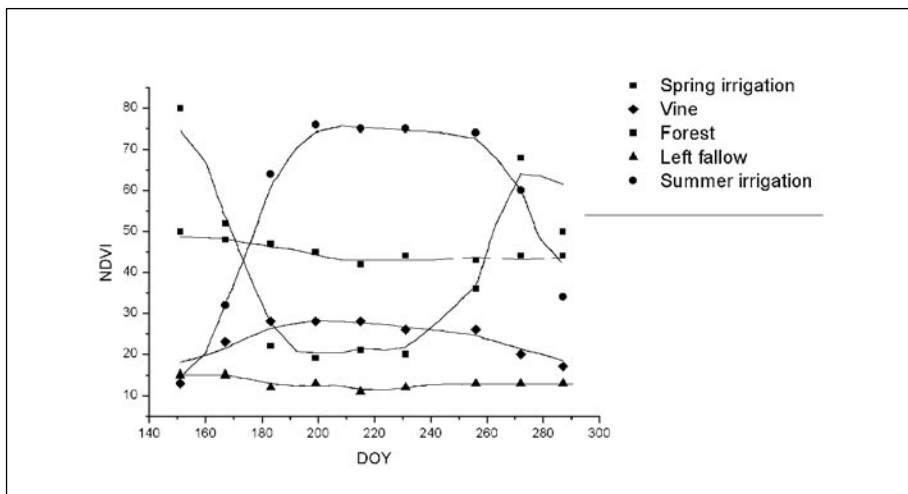


FIGURE 5.6. NDVI TEMPORAL EVOLUTION OF SOME CROPS (AFTER GARCÍA DE VICUÑA ET AL., 2005)

In BACCHUS an operational procedure, based on phenological development of the canopy, is implemented to discriminate vineyard from other crops. This classification procedure can be defined as a multitemporal approach, based on NDVI digital data used in combination with ancillary information in a multiple scheme that had allowed assessing the accuracy of the resulting inventory. Figure 5.7 contains a diagram of this procedure. It's requiring a deep knowledge (ancillary data) about crops and natural vegetation phenology, soils, meteorology and topography. This knowledge enables to select the adequate time for the images to be used, so as to define the legend of thematic map. The digital classification it is carried out by means of a supervised classifier that performs much better than the unsupervised ones, combining a Maximum likelihood, Decision Tree and Contextual classifier. Experimental results (García de Vicuña 2005) verify the effectiveness of the proposed methods in the identification of vineyard using different spatial resolution images.

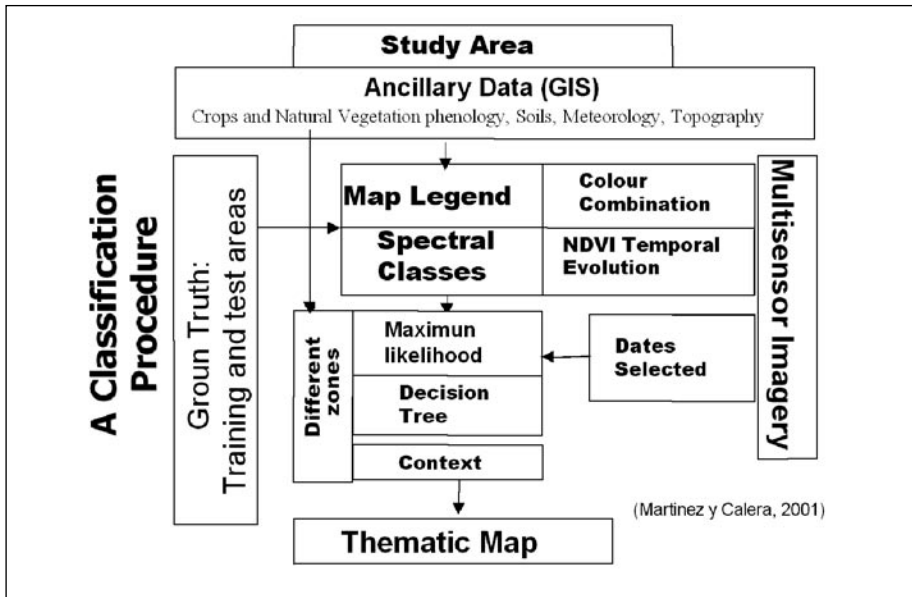


FIGURE 5.7. CLASSIFICATION PROCEDURE SCHEDULE (AFTER MARTINEZ AND CALERA, 2001)

Therefore, the basic classification criterion is the temporal evolution of vineyard spectral signature. And the phenologic cycle of vineyard through the agronomic year is recorded in an image sequence of two consecutive years, using a minimum of two scenes per year. In the procedure different multispectral high resolution sensors (e.g. Landsat, Quickbird, airborne digital camera imagery) can be used, as show in fig. 5.8 and 5.9.

Some advantages of the multitemporal NDVI approach

The advantages of using NDVI to describe the vineyard temporal evolution can be summarised as follows: (1) NDVI allows us to use multiscale and multisensor approach to monitor crop development, so in the framework of BACCHUS two sensors of different spectral and spatial resolution such as Landsat and QuickBIRD has been used, and (2) NDVI can be used to obtain several canopy biophysics parameters, such as: basal Crop coefficient (K_{cb}), fractional ground cover, Leaf Area Index (LAI), the fraction of Absorbed Photosynthetically Available Radiation (fAPAR) and biomass, amongst others. The importance of these parameters in establishing the health of plants has been clearly showed in the literature.

Multitemporal approach provides a tool to study also the evolution in time of these parameters, and then, gives sense to the idea of monitoring vineyard. Some examples of NDVI temporal evolution of vineyard is showed in fig. 10.

- NDVI is related linearly with green fractional cover (Calera 2000).

This parameter is relevant for the quantitative description of the vegetation canopy and the interaction of radiation with both canopy and soil. Ground cover plays an important role in determining the crop coefficient. The growing period can be divided into four distinct growth stages, viz., initial, crop development, mid season, and late season, according to the ground cover evolution (Allen et al., 1998). The corresponding ground truth is complex and cumbersome to obtain from fieldwork. Choudhury et al. (1994), e.g., use visual inspection. It is possible to use a simple and fast procedure proposed by Calera et al. (2001). An example of this procedure based in the classification of digital pictures is showed in figure 11.

- NDVI is related linearly with Basal Crop (cover) Coefficient, (Kcb) (Bausch and Neale, 1987).
- NDVI is related with primary production (dry biomass) by means of Light Use Efficiency (LUE) models (Monteith, 1977) (Asrar, et al. 1984) (Gower et al. 1999).

$$P = \int_0^t (a \cdot \text{NDVI} + b) \cdot \text{PAR} \cdot \epsilon \cdot W \cdot dt$$

where P is primary production, PAR is Photosynthetically Active Radiation, ϵ is the efficiency to transform PAR into dry mass, and W is a stress water coefficient. So Biomass could be estimated from cumulative NDVI, according to Yang (1998). Biomass is an excellent indicator of crop growth, condition, and their yield potential. Biomass of crops have shown better relationship with spectral data than LAI (e.g., Thenkabail et al., 1994), and it is also an excellent indicator of leaf or crop moisture (Penuelas, et al. 1993).

- NDVI is related linearly with the fraction of absorbed photosynthetically active radiation (fAPAR) . (Sellers et al. 1997)
- NDVI is related exponentially with Leaf Area Index (LAI) (Gilabert et al. 1996)

Since LAI measures the surface involved in radiation absorption and turbulent transfers between vegetation and the atmosphere, it can be considered as a controlling parameter for air-surface exchange processes associated with the canopy. LAI is

known to be one of the first plant responses to stress because it is a structurally more specific variable of plant community, directly related to exchange of energy, CO₂, and mass from plant canopies (Fassnacht and Gower, 1997). An accurate estimation of LAI from EO data can only be obtained from inversion by canopy reflectance models, which requires multi-angular observations.

Practical implementation of BACCHUS approach

Multitemporal/multispectral approach has been validated in different test sites in France, Italy, Spain and Portugal due to the different vineyard practices (different framework, varieties ...) in each area. The results of this study illustrate the potential of multitemporal/multispectral classification techniques. Besides, it is verified that for plots with size equal or bigger than 2 hectares, classification based on Landsat-TM imagery provides accuracy results. Besides, an increase in the spatial resolution of used multi-spectral imagery (from 30x30 m of Landsat to 3x3 m of Quickbird) doesn't improve the vineyard classification maps for plot with this specified threshold size plot. For identify plots smaller that 2 hectares we need use very high resolution images. Fig. 12 shows the classified image from Quickbird imagery. It is clear that the threshold size plot to be identified is related with the sensor spatial resolution, it is pixel size. Therefore we need, at least, a plot size of 5x5 pixel of utilized imagery to obtain an adequate identification using the multitemporal approach.

The use of, at minimum, selected two scenes per year, for two type of images (Landsat and Quickbird), is enough in vineyard detection to describe the phenological evolution of the crop in La Mancha area. And the confusion errors in young vineyard detection, due to its phenological development, are the same using both sorts of images. The use of consecutive year be able establish the vineyard presence for young vineyard.

It must be stressed the economic advantage of HR images (e.g. Landsat), that allows to work in a regional scale reducing several times the cost by hectare, comparing to VHR. Thus, the operational monitoring of vineyard (in vast areas) is only affordable by using the active spaceborne instruments such as Landsat with the additional benefit from the temporal frequency of acquisitions of this kind of sensors.

5.5. CONCLUSION

This chapter presents a review on the State of Art in vineyard inventory concerning multitemporal and multispectral approaches. The first part is devoted

to describe the most widely used classification procedures distinguishing between techniques applied in the first phases of the classification and the algorithms used in the proper phase of assignment. Most of these methods can be applied over a range of types of data. It is stressed the importance of the selection of the digital bands that will be used in the classification. This selection should be performed according with the objective of the study though sometimes it can be forced by the availability of data. Capabilities, limitations and examples of multispectral, multitemporal and contextual approaches are introduced. Then a revision of the research undertaken in multitemporal and multispectral studies for vineyard inventory is included, stressing the difficulties inherent to the identification of vine against other crops.

It has been shown that very few studies focus on vineyard detection by using EO data. Some of these methods classify vineyard using masking techniques, which consist in successive classifications of the different classes eliminating after each classification the crop class properly classified. Therefore, the classification of the other crops and natural vegetation is still required. It is also shown the convenience of multitemporal approaches versus methods based only on the spectral response of vegetation. The literature in this area shows a preference for using vegetation index as input data, in particular the use of NDVI is widely accepted by the scientific community. Finally, it is indicated some of the advantages that have the use of NDVI since it is connected with important biophysical parameters of the vegetation.

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6. VINEYARD ANALYSIS

Conese C., Rapi B., Romani M., Bonora L. & Dambra C.

6.1. INTRODUCTION

European grapevine producers pay great attention to reduce vineyard variability and yield quality fluctuations, with proper vine canopy management. The success of the final production often depends on the interventions carried out for the optimisation of light interception and the improvement of microclimatic conditions into the vineyard. On the other side, spatial variability is an unalienable element of natural and anthropic systems, which make difficult work scheduling, bringing to different quality of the final product (Smart, 2001). The knowledge of vineyard characteristics and the understating of internal variability, allow the improvement of the management practices, with significant advantage in terms of field work rationalisation and grape quality homogeneity.

Vineyard Analysis Module, developed by CNR-IBIMET in the framework of the BACCHUS Project, represents an Integrated Approach to face the problem of land characterisation and variability evaluation at vineyard scale. This BACCHUS module can be used for a preliminary land potentiality assessment, in respect to a number of vine cultivars, giving the opportunity to weight local climate, soil, morphology and management factors, but their aims also to support grapevine producers during the growing season for vine growth monitoring, comparison between years or zones, field works scheduling, etc. To describe land differences and plant responses, the system takes into consideration a number of factors and variables that can be adapted to different productive realities, on the base of final user characteristics and requirements. A minimum meteorological and geographical dataset, commonly available, is required in order to describe the potentialities of each cultivar in the considered environment. The use of detailed information, like agronomic practices or Very High Resolution images (VHR),

collected from satellite or aircraft, increases the capability of discrimination between similar conditions and the reliability of the system outputs (Lamb, 2000) and (Hall et al., 2002). In Vineyard Analysis Module this data are recommended but not mandatory, because the system can be used also to perform preliminary evaluations of the area of interest (land characterisation) or of the local potentiality, without the exigency of very high spatial detail. In this chapter we will explain the adopted methodologies and criteria, trying to give an idea of the system potentiality in the vineyard analysis support.

6.2. THEORETICAL BASIS AND ASSUMPTIONS

As land analysis, we mean a series of operations required to detect and delimitate homogeneous areas on the base of vine and environment interaction (Fregoni et al., 1998). Since «Vine Zoning» consists in the evaluation of different productive elements over a given area, in function of wine production, it can be also considered the result of the interaction between plants and climate, soil and productive techniques. Starting from the works of Becker (Becker, 1988), the extensive scientific contribution on land zoning is known and well organised. The interest towards these applications is justified by the increasing demand of wine quality, which can be obtained partly by the optimisation of genetic, environmental and cultural interactions. Among the possible ways to obtain this task, an important role is assigned to the interaction between plants and environment, selecting cultivars and improving vineyard's internal equilibrium (Scienza, 1999). The production of a good wine is, in fact, the result of a number of factors, like grape variety, geographical, and edaphic elements, working condition, vineyard characteristics, and oenological practices and so on. In many cases, the classification of productive areas thus becomes decisive, but the results are often complexes and have to be simplified to be correctly used. For this reason, vineyard growing area characterization demands a multidisciplinary approach, allowing the weighting of different elements and the representation of more or less hidden relationships. A combination of GIS and GPS can help in the exploration of the vine cultivation potentiality, the evaluation of existing realities and the determination of the best areas of production (Dra, 2003). In effects, we observe that grapes are sensitive to different environmental conditions, determining the request of a given growing area to obtain a wine of quality. Some of these factors (including latitude, elevation, slope, aspect, precipitation and soils) are generally analysed and weighted by means of the GIS techniques, particularly suited for the management of the spatial attributes associated with crops, vineyard management and decision making (Peterson et al, 2000) and (Coggan, 2000).

Nowadays, operational projects are carried on all over the world to realise systems able to support vineyard managers in the most delicate operations, by means of Decision Support Systems or Precision Farming Applications. At the same time, climatic study and environmental characterisation of vine production areas has developed as one of the most interesting topics for farmers (Moriendo et al., 1998).

By means of these parameters, for instance, the prediction of the main phenological phases or the description of the evolution of the grapes in relation to the meteorological behaviour is possible, with evident advantages under many points of view (plant protection, activity planning, etc). Unfortunately, the understanding of the answer of the plants to a given factor is not easy to understand and the use of specific indices is often necessary. In any case, for this kind of studies, temperature remains the leading parameter, both for its relevance in biological process and for its general availability. Among the most diffused indices used for the climatic characterisation for vine we find the sum of active temperatures of Winkler, the heliothermic product of Huglin, the thermal excursion and the heliothermic product of Branas.

Moreover, specific models can be used to predict phenological phases or to describe grapes maturation in relation to the annual meteorological trend (Williams et al., 1985) As demonstrate by many scientific papers, the contribution of Earth Observation Systems (EOS) is decisive, not only for the provision of basic information as land use or plant density, but also for the possibility to intercalibrate methodologies, getting to most reliable conclusions. EO systems could become the principal source of information in land control and management, maintaining many fundamental informative layers updated and giving a continue contact with real world changes (Hall et al., 2002). These techniques can be used to obtain updated information on spatial and temporal variability, recording modifications and changes occurred on the territory, directly or with the integration of this product in most complex systems. Site characterisation procedures for vine growing have been summarised comprehensively in bulletins and in a large literature (Caronneau, 2003). Other researchers have produced maps of land vineyard suitability for many countries, like British Columbia, Germany and Italy, using RS, GIS and modelling, in order to perform this particular task. The methodology settled during the EU Bacchus Project for Vineyard suitability and Variability evaluation integrates many of the present knowledge on GIS, modelling and EO techniques application for viticulture. Vineyard Analysis Module gives the possibility to perform specific analysis on land and vineyard potentiality by means of dedicated tools, adding the opportunity to manage a quantity of vineyard detailed data for Precision Viticulture applications.

6.3. VINEYARD ANALYSIS MODULE: WINE AND LAND MANAGEMENT SYSTEM

The following paragraphs show the procedures and the tools developed in the framework of the BACCHUS Project and organised, for a preliminary testing, into Vineyard Analysis Module, an ArcGIS 8.3 extension. After their evaluation and optimisation, the procedures were transmitted for the implementation into the BACCHUS software. The software use typical GIS techniques and functions (Romani, 2001), integrating land and spatial analysis procedures, EO data and Agrometeorological Modelling.

This module is the results of over 15 years of activity in the sectors of environment, agrometeorology and resource management, applied to viticultural sector (Maracchi et al., 1999). The integration of these tools with the final user's specific knowledge allow the evaluation of the local conditions in an objective way, from different points of view and in close contact with the productive reality. Vineyard Analysis Module's offers the possibility to use advanced tools also where limited economic resources generally hindering computer science applications, because it is organised in a modular way. This flexibility is a necessity, for example, in Italy, where farm dimensions, management practices and datasets vary strongly. After a brief period of database population, system setting and tuning, it can be used by final user, without further interventions or modifications, producing required outputs with desired spatial and temporal scales.

6.3.1. General structure

As shown in the figure (Fig.6.1), the main components of Vineyard Analysis Module are: a geographic database, GIS tools for vineyard management and the analysis of different scenarios, a vine growth simulation model and a module for VHR image integration.

In this version, the system supports different DB software (MySQL, Oracle, Access, etc.) to store the input data for the computation module, and a graphic interface allows their initialisation.

6.3.2. Vineyard Analysis Module Procedures

The following simplified scheme (Fig.6.2) shows the main components of the present version the module.

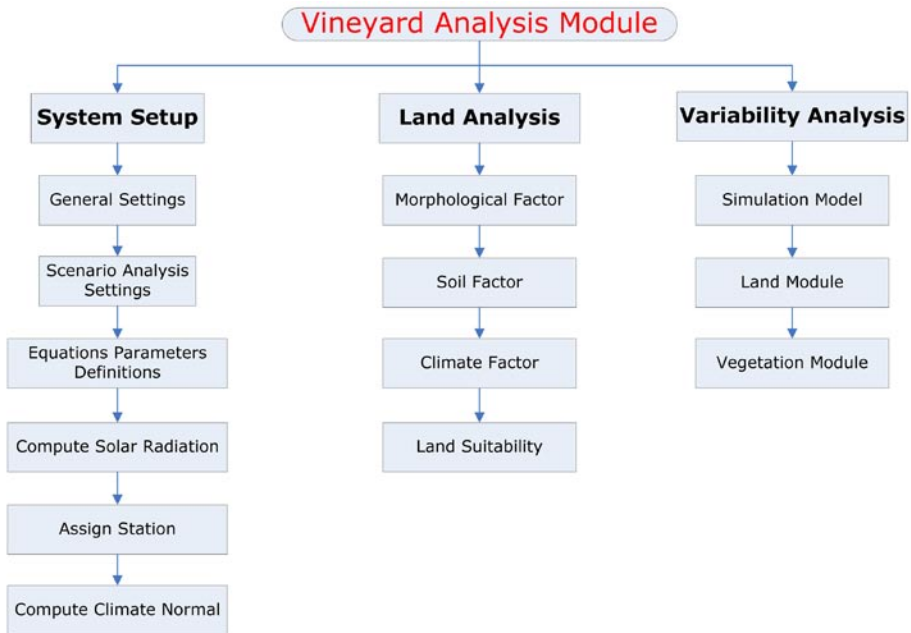


FIGURE 6.2. MAIN COMPONENTS

At the moment, the system is driven by a toolbar with 3 main menus: System Setup, Land Analysis and Variability Analysis.

- **System Setup** provides all the functions to initialise the system parameters and database.
- **Land Analysis** contains the modules to prepare the inputs layers for the identification of homogeneous areas and the evaluation of the Land Suitability for vine growing.
- **Variability Analysis** holds the modules to perform the analysis at cadastral scale. This tool enables the estimation of the vineyard variability in term of plant vigour, productive potentiality and potential product quality.

The outputs of the system are maps of variability or land classes, produced on the base of the available information on the environmental characteristics and on vine cultivar exigencies.

6.4. DATA REQUIREMENTS

Vineyard Analysis Module requires the availability of geographic layers and data, provided in specific formats, geo-referenced or with precise spatial

indications and relationships with the other elements of the territory. For a correct interpretation of the final results, data should be provided with technical comments and documentation. The models take advantage from data with high spatial and temporal resolution, which should be homogeneous on the whole considered area.

Among the required data, the most important are: Digital Terrain Model (DTM); Land use digital maps; Soil digital maps; Series of daily meteorological data (temperature and rainfall) Aircraft or satellite images (at least one at the blooming) and Agronomic information (plant density, techniques, etc.).

About meteorological data, the system uses a logic criterion of attribution, providing weights to the different series on the base of the distance between the point of computation and the available stations. In this version, data requirements are limited and only a reduced set has been considered mandatory for a general characterisation of the area. The situation changes if a detailed analysis is required and the user needs to take into account more specific parameters. Aiming to produce operational outputs, the BACCHUS module accepts a series of very detailed information for model setting and tuning: field measurements of LAI, biomass, grape production, grape quality, etc.

6.5. ANALYSIS SETTING

This component consists of a series of procedures for system and data management, parameter setting and analysis adaptation, introduced into two modules, called «General setting» and «Analysis of scenarios».

6.5.1. General Settings

This section contain all the most common functions to be used to set the working environment (cell size, area boundaries, etc), proposing also a series of tools for the definition of specific operations.

6.5.2. Analysis Scenarios

The user can fill the lookup tables introducing the information required for the classification of the input layers for Land Analysis: Morphology (Elevation, Slope and Aspect), Soil (AWC, Depth, Drainage and pH) and Climate (Huglin Index). The setting has to take into account the influence of the current parameters on the vine production and vigour. For the Variability Analysis, the user has to populate the DB cultivar table, containing the parameters needed to run the simulation

model. By means of this section, other local values can be settled, with the aim, for instance, to evaluate different cultivars, varieties and/or technical choices. For the variability analysis can be settled two different working situations: *General scenarios* – working at the scale of farm or consortium; *Local scenarios* – working at cadastral scale (single vineyard).

General Scenario:

A comparison among different parcels can be performed by means of this tool, using homogeneous values over the whole area of interest or introducing different information for each vineyard or sub-zone. This analysis has to be made in agreement with local situations and final user exigencies, without significant changes of the models. For each polygon, final user may set a different cultivar or to modify related coefficients, for the analysis of local phenological trends, quality production or the comparison of different vineyard managements.

Local Scenario:

The variability into a given vineyard or the comparison of sub-zones of a single farm can be performed only if very detailed information is available. The main parameters used to evaluate local scenario can then be defined on the base of specific elements, collected under the classical voices: «physics», «pedology» and «management».

Local management and vineyard information (like vines age, actual plant density, date of green pruning and the relative green biomass percentage reduction), will drive the system in the individuation of local heterogeneity and in the determination of relative potentiality. To perform this kind of evaluation, the availability of aircraft or satellite images is strongly recommended.

6.6. LAND ANALYSIS

The Vineyard Land Suitability Evaluation is performed combining information derived from the analysis of edaphic, climatic and geomorphologic aspects (Fig. 6.3).

The procedures identify homogeneous areas for the cultivation of specific vine cultivars and indicate the relative land vocation in the production of a given grape. The result of the analysis is a map with five classes of suitability: Not suitable, Poorly suitable, Moderately suitable, Well suitable and Very well suitable. The methodology can be applied at areas with different spatial resolutions, driving

the system in the analysis by means of specific weights. Under GIS environment, land suitability provides an easy way to estimate the vineyard potentiality, without need of real data on productivity, even if the availability of this kind of information allows a more detailed land zoning. In any case, a preliminary validation of the procedure, based on proper set of data on grape production, have to be performed. In fact, meteorological data are used to define homogeneous areas from a climatic point of view, but field data are required to define grape production and quality. To evaluate environmental characteristics, the computation of agrometeorological indices (thermal - Winkler and/or helio-thermal - Huglin) is performed.

6.6.1. Introduction of soil parameters

Starting from a soil maps, provided in input, BACCHUS Vineyard Analysis Module take into consideration a series of soil parameters: Drainage, AWC (Available Water Content), Depth and pH. These factors can be classified directly by the user, on the base of his knowledge. In this version, the system reads the file and gives only the possibility to change relative weights for the definition of the final Soil Factor.

The soil factor will be compute according the equation:

$$(Drain * W_{drain}) + (AWC * W_{AWC}) + (Depth * W_{depth}) + (PH * W_{PH})$$

6.6.2. Computation of the Climate factor

The first step of this passage is the application of a meteorological index for the evaluation of the level of satisfaction of vine thermal exigencies. Meteorological data are used to define homogeneous areas from a climatic point of view, considering mainly rainfall and temperature. Meteorological data can be used into thermal and helio-thermal agro-meteorological indices or other similar ones (Degree days, Temperature excursion, etc.), allowing a specific evaluation of the environmental correspondence to the exigencies of the selected vine cultivar (Mancini et al., 1999). The differences among climatic exigencies of each viticultural target are significant and each area can be considered more or less adapt to a given kind of wine. The values obtained by this analysis are only indicative and it is sometimes possible to obtain good productions also in areas with different values due to lack in meteorological data representatively. Also in this case, the participation of final user is decisive to obtain useful information. Among the available indices (i.e. Degree Days, Winkler, Selaninov etc.), the index of Huglin seems the most adapt for BACCHUS purposes:

$$IH = \sum_{04}^{09} \frac{(t_{medg} - 10^{\circ}C) + (t_{maxg} - 10^{\circ}C)}{2} \times K$$

In fact, this well known index can be easily interpreted, giving the possibility to evaluate local suitability on the base of the temperature cumulated from April to September. To each value of Huglin it is possible to indicate a variety, using the index for the expression of a certain climatic aptitude for his cultivation. For example: Muller Thurgau – 1500; Riesling or Pinot blanc – 1600; Chardonnay or Pinot Noir or Sauvignon – 1800; Merlot or Cabernet Franc – 1900. etc. In Vineyard Analysis Module, agro-meteorological data are interpolated into the system, by means of a regularized «spline with tension» function.

6.6.3. Extraction of Slope and Aspect from DEM

The morphological factor is based on three components (Elevation, Slope and Aspect, or solar radiation), but locally the influence of the three components can be different. For this reason, a specific form is presented to the user, enabling him to input the weight values for each component. The user can adapt those values according to local situation, activating the function to perform the weight overlay between the layers:

$$Morpho = (Elev * W_{elev}) + (Slope * W_{slope}) + (Aspect * W_{aspect})$$

6.6.4. Land Analysis Outputs

The final land suitability computation is performed applying a weighted overlay on the previous layers (Fig. 6.4). For the production of this map, only morphology and climate are mandatory layers, while soil is optional, but strongly recommended.

This BACCHUS output has been verified on the Italian test sites (Frascati and Prosecco) and deeper studies are in progress, to evaluated possible system improvement. Proposed methodology is based on widespread land management approach, simplified to make it applicable in a number of European realities. In fact, required information is generally available in the E.U. countries at level of public administration and the procedure can be adapted to different exigencies.

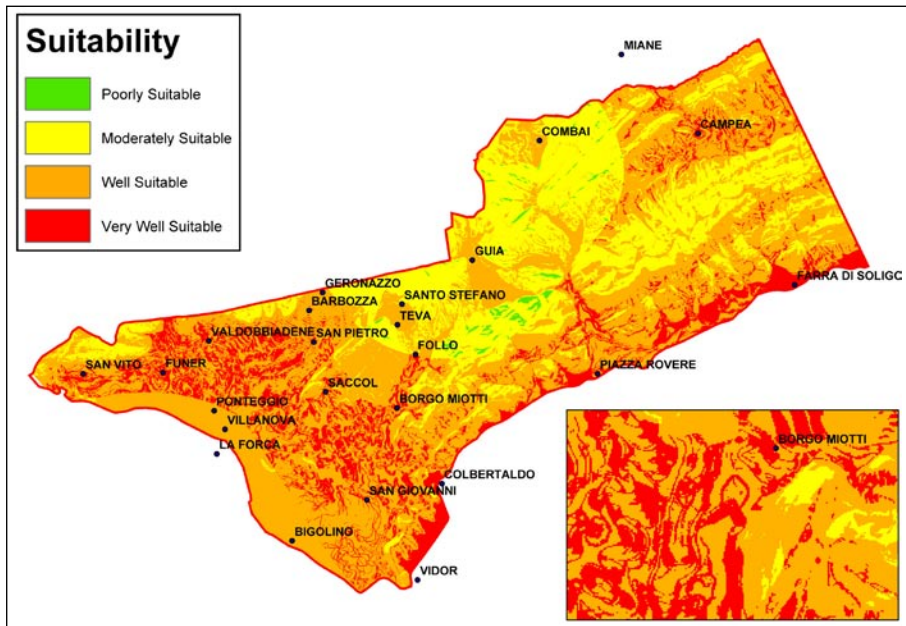


FIGURE 6.4. AN EXAMPLE OF LAND SUITABILITY

6.7. VARIABILITY ANALYSIS

This component provides detailed spatial information on vineyard plant vigour and potential productivity. The tool consists in an algorithm able to characterise the different zones of a single vineyard, on the basis of a series of elements, in part already considered for the Land Suitability. The main important layers used for this analysis are: DEM derived parameters (Elevation, Slope, and Aspect), meteorological data, high resolution multi-spectral satellite and/or aircraft images, cadastral information, agronomic practices, plant physiological and phenological parameters, etc. Starting from digital data, BACCHUS Vineyard Analysis Module is able to estimate plant development (mainly Leaf Area Index and plant biomass) and production (quantity and quality) variability at different spatial scales, by means of specific models and indices. Main outputs of the tools are detailed maps at cadastral level, showing the spatial variation of interesting indices or factors. The simulation can be carried out at reduced scale (consortium) or at very detailed one (vineyard), allowing an easy adaptation of the Vineyard Variability Evaluation tool to different productive realities. For

this reason, maintaining the philosophy of the software, also in this section the number of mandatory data is strongly reduced and data set can be adapted to local exigencies, for local condition weighting.

To perform the Variability Analysis (Fig. 6.5), BACCHUS module integrates a series of tools:

- **Agrometeorological**, which includes a vine growth model for the simulation of plant growth and production forecasting (Bindi et al., 1997) and (Bindi et al., 1997b). The output are **potential values** of the following factors:
 - **Leaf area Index (LAI)** – daily values on a reference surface;
 - **Plant vigour** – Daily values of dry matter per plant;
 - **Productivity** – Production of grape (kg) per plant;
 - **Quality Index** – Ratio between plant vigor and productivity
 - **Phenology** – date of phenol-phase manifestation.
- **Geographical**, which gives a weight to the different morphological factors in the reduction of potential values;
- **Managerial**, which allows the introduction of a series of detailed elements on vineyard management, fundamental for the description of specific productive realities. In facts, these elements change the parameters considered by the vine growth model and this aspect has to be opportunely weighted.
- **Vegetational**, which, by means of High Resolution satellite or airborne images, assign a temporal weight to the real vegetation vigour and variability observed on the vineyard at a given data.

The simulation is carried out on each polygon (vineyard), interpolating the meteorological data provided by the five nearest stations by means of a modified Shepard Method. The availability of a significant number of stations is recommended to obtain more reliable simulation. In this version, meteorological data are loaded and corrected on the base of the elevation, while the solar radiation is estimated according to the theoretical solar radiation on the plane and to the daily temperature range. In the DB, for each parcel, the system stores the outputs of the model: daily value of LAI and green biomass, the date of the phenological phases as Day Of Year (from 1 to 365/366), the grapes yield for vine at the maturation date and the quality index.

6.7.1. Land module

It allows the correction of the potential values, produced by the model, on the base of the available information on the role of local morphology factors

(elevation, slope, aspect or solar radiation). To obtain best results, the use of the solar radiation layer is recommended instead of the «aspect» one. To be used, the solar radiation should be computed between the 1st of April and the 30th of September. The correction layers are built according to a polynomial equation (e.g. a 4th Degree Polynomial Fit $y=a+bx+cx^2+dx^3+ex^4$) using the equation parameters stored into the system database. These parameters fit the local trend of production, vigour or product quality in relation to elevation, slope, aspect or solar radiation. In this release a specific tool is implemented into the system to compute those coefficients from final user indication on local effect of considered factor on the detected parameter (plant vigour, production or quality). Each layer or weight can be changed at once, selecting the variable that have to be corrected, the name of grid, etc. The operation of correction is a map algebra operation and after this first correction vineyard internal variability start to be perceived.

6.7.2. Vegetation module

This module extracts information from VHR remote sensing images, provided by QuickBird sensor or airborne camera like AMDC (by INTA). The image has to be geo-references and ortho-rectified before the use into the system, which at the present not compute directly image elaborations. The Normalised Difference Vegetation Index (NDVI) is used for the extraction of vine rows by means of simple thresholds, and the production of the correction factor. To take into consideration the loss of representativity of the image, a specific procedure is introduced into the system for the automatic weighting of the image contribution in variability analysis, on the base of the elapsed time (days) between image acquisition and system interrogation (Fig. 6.6).

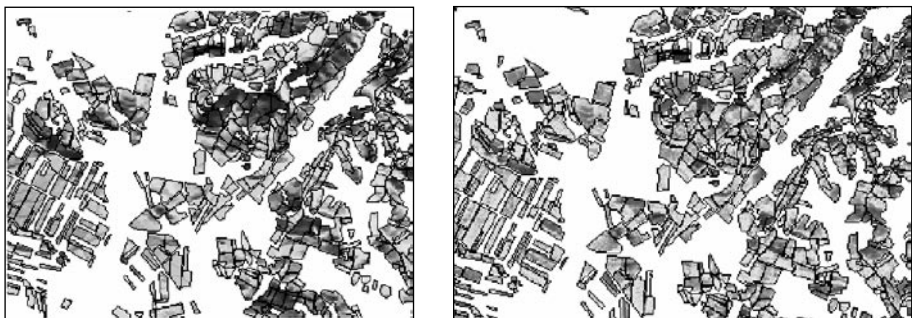


FIG. 6.6. OUTPUTS OF THE VARIABILITY ANALYSIS MODULE: BEFORE (LEFT) AND AFTER (RIGHT) THE APPLICATION OF THE IMAGE INDEX

6.8. VINEYARD ANALYSIS MODULE OUTPUTS

The outputs of this BACCHUS Module potentially correspond to the all products that can be obtained by means of the integration of VHR images, GIS tools and agro-meteorological models. In this version, the system outputs are represented by maps, showing the existing differences into a given area of interest or describing the spatial variability of indices or the values of parameter during the whole season of growth. Since the procedures used in this module are substantially extracted from GIS and geo-statistical standard, outputs and layouts of the system should be defined with the contribution of each end-user, in order to produce dedicated documents and information. Potential values given by the model could be used to compare the higher level of production and real data with the waited ones, setting the system and obtaining more and more reliable data. One opportunity for model and system setting consists in the use of long series of meteorological data and final yield, for years with homogenous management conditions. This may reduce the time required to obtain fully operational information, because an attentive statistical evaluation of the model and system outputs may improve greatly the system discrimination capability.

Some examples of VISAVES outputs are given into the annex III.

6.9. CONCLUSIONS

System test and output validation are carried out in different test sites, with the aim to face specific problems and to obtain a reliable and simple operational tool. The present version of the BACCHUS Vineyard Analysis Module may be upgraded introducing a series of other functions and models, to satisfy precise exigencies of final users. For this reason, the future of this module is largely driven by final user indications, which better then whoever can appreciate system potentiality, requiring interventions on the software, for adjustments or integrations of specific components.

As consequence, the present version has to be considered the first step toward a rational and effective procedure of vineyard variability evaluation, required both for operational management and for product marketing. Variability is often due to not optimal management and affects greatly field work and cost, but European productive realities are strongly diversified and demand different approach for the determination of this elements in the field. Where morphology and soil show high variability, jointed with an extremely segmented productive reality (vineyard of few hectares), as in many part of Italy, it is difficult to imagine an extensive use of this tools by vine growers, whereas consortium or winery may be interesting

in the evaluation of seasonal evolution or production forecasting in the area of interest. For little producers the activation of a service, provided for example by the own consortium, seems to be the most interesting way for the obtainment of the required information. Different is the situation where important producers manage large area of land (many hectares) in not too complex orography, because in this case Vineyard Analysis Module may answer to a precise exigency of organisation and control. The possibility to realise a WEB service, based on the sharing of knowledge and data, is also under evaluation, but for the activation of a BACCHUS module network a series of problems have to be faced and solved.

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ANNEX I. FLY CAMPAIGN WITH MULTISPECTRAL CAMERA

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One of the BACCHUS purposes was to investigate the potentialities and limitations of multispectral digital aerial photography, to assess the advantages of multispectral digital photos against conventional aerial photography and explore the additional information that could be extracted from the spectral signature of vines.

A multispectral digital camera AMDC (see annex II figure I.1) operating from an aircraft was used to acquire high spatial resolution digital imagery of vineyards.

In BACCHUS framework, two sets of specific flight campaigns were conceived and deployed during summer 2003 and summer 2004 over representative test sites spread out in the States of the partners participating in BACCHUS programme, in order to gather a representative data set of digital aerial photography at 0.5 m and 1 m spatial resolution, to be used as base material for the subsequent studies and analysis.

It is supposed that the very high resolution of the captured data and the possibility of adapting the acquisition parameters to the scientific needs of the project will allow simulating the quality of the impending satellite imagery.

Special attention was paid to the georeferencing issues regarding the imagery. A direct georeferencing approach was addressed, based on on-board positioning and attitude measurements synchronised with imagery collection events.

First of all, digital camera geometry was characterised through tests carried out at laboratory.

Later, an INS+GPS system was installed and integrated with the camera. An IMU was fixed to the camera frame, in order to get the accurate enough positioning and attitude measurements during the data collection (see annex II figure I.2).

The whole system, aircraft, imaging sensor and positioning/orientation module was geometrically characterised through on ground measurements first, and results were fine-tuned with a «boresight» flight.

I.1. AIRBORNE DIGITAL CAMERA AMDC DESCRIPTION

The AMDC (Airborne Multispectral Digital Camera) is a «frame camera» type of aerial multispectral sensor which provides remote sensed images at high spatial and geometric resolution (see annex I figure I.1).

Their AMDC Principal Characteristics:

- Array size (columns x rows): 2024 x 2041 pixels
- Detector element size: 9µm x 9µm
- Lens focal length: 28 mm (selectable)
- Lens distortion: < 2%
- FOV (Field Of View): 36° x 36°
- IFOV (Instantaneous Field Of View): 0.32 mrad
- Lens aperture adjustment: f/2.8 to f/22
- Spectral coverage: 0.42 – 0.77 µm
- Number of spectral images per frame: 2 – 5 images
- Exposure time : 5 – 50 ms
- Frame rate: 8 – 20 s

Their Spectral Configuration:

Spectral Bands		Band Edges	
		Lower µm	Upper µm
1	Blue	0.420	0.495
2	Green	0.515	0.565
3	Red	0.600	0.670
4	NIR	0.738	0.772
5	Panchromatic	0.530	0.680

I.2. SUMMER 2003 AERIAL SURVEYS

Study area: The 2003 campaign was designed to acquire data on two study areas in La Mancha (Spain). These areas are labelled Villarobledo and Tarazona.

An sketch with the flight track pattern is shown in annex II figure I.3.

It was decided «on real time» to perform an extra flight line to record images over the Utiel-Requena area. The initial motivation was to acquire data on the so-called «Valencia Anchor Station», a geographical area used for validation of low-resolution spaceborne Earth Observation instruments (as GERB onboard MSG or the future microwave mission SMOS). As Utiel-Requena is one of the main vineyard regions in Spain, it was felt that the framework of BACCHUS was suitable for such activity.

I.2.1. Data acquisition methodology

Two different data acquisition systems were installed together in a CASA-212-200 aircraft modified to perform remote sensing flight campaigns (see annex II figure I.4). They were compatibilized in order to get data simultaneously:

- AMDC as primary system, aimed to get high spatial resolution images in the VIS-NIR range.
- Daedalus 1268 as a complementary system to extend the spectral range, even if at a lower spatial resolution.

As commented above, an inertial navigation system (*POS/AV 410*, from Applanix) was installed on board and linked to the AMDC to provide position and orientation information for the AMDC acquired data.

I.2.2. Data analysis methodology

a) Data pre-processing

The raw image files, one per spectral band, were imported, and then, all selected bands were co-registered to build a single file for each scene. This was done using a specific software procedure which corrects for the spatial shift between bands due to the instrument sequential acquisition.

AMDC imagery was provided in different formats and level of process (the extension field of the filenames identifies the image format and processing level).

Extension	Format	Comments
raw	generic binary raw AMDC data (one file per spectral band)	2024 cols x 2041 rows, 1 byte/pixel
img	ERDAS 8.*	
pix	PCI-Geomatica format	
tif	geoTIFF	as exported by Geomatica-PCI

b) Processing of images

No radiometric correction or calibration was applied to the individual AMDC images.

The mosaic images were subject to a radiometric normalization and gray-level blending in order to minimize brightness discontinuities in the image-to-image junctions.

c) Geometric positioning of images

The data was geo-referenced for a proper integration with the other partner's data. The georeferencing was achieved by the following steps:

Step	Algorithm used	Comments
Processing of the INS data, merging the POS-AV information with GPS data from a reference station	POSPac (a specific tool for POS-AV)	Reference station for GPS located in Albacete (dual frequency station from the spanish IGN network)
Co-registration of the AMDC bands to align multispectral information	AMDCregister (a specific tool for AMDC) -nearest neighbour interpolation	Only when multispectral data are available
Generation of DEM	Resampling to 5 m pixel size of existing 1:25000 DEM from IGN	Altitude resolution 10 m
Orthorectification by direct georeferencing (no Ground Control Points)	Orthoengine Geomatica 9 -cubic convolution interpolation	Output coordinate system is UTM-ED1950-international ellipsoid 1909
Mosaicking	Geomatica 9	Automatic cutline with min. relative difference radiometric blending and normalization during the mosaicking

I.2.3. Results

a) Flight Campaign

Aircraft: C-212-200 from INTA

Instruments: Airborne Multispectral Digital Camera («AMDC») + Daedalus 1268 Airborne Thematic Mapper («ATM»)

Meteorology: clear sky

Flight altitude (above ground level) : 2750 m on nominal tracks; 1375 m on «medium altitude» lines

Line-to-line side overlapping: 30%

b) Instruments configuration

Parameter	AMDC	ATM
FOV	36° x 36°	85°
IFOV	0.32 mrad => 1 m pix size on nominal data => 0.5 m pix size on hi-res data	2.5 mrad => 7 m pix size on nominal data => 3.5 m pix size on hi-res data
scene size	2000 m x 2000 m	5100 m x ≈10000 m
in-track overlapping for AMDC frames	70%	NA
spectral configuration	see table below	see table below

AMDC channel	1 (blue)	2 (green)	3 (red)	4 (infrared)	5 (panchro.)
Wavelength (micrometers)	0.420 - 0.495	0.515- 0.565	0.600- 0.670	0.738- 0.772	0.530- 0.680
Gain Tarazona	12	8	8	12	8
Gain Villarrobledo PM04 PA03,PA04,PA05,PA06	10	6	6	10	6
Gain Villarrobledo PA01,PA02,PA07,PA08	8	4	4	8	4

ATM ch	1	2	3	4	5	6	7	8	9	10	11	12
Wavelength (microm.)	0.42- 0.45	0.45- 0.52	0.52- 0.60	0.60- 0.62	0.63- 0.69	0.69- 0.75	0.76- 0.90	0.91- 1.05	1.55- 1.75	NA	3.0- 5.0	8.5- 13

The campaign was planned according to the inputs from the IDR team concerning sites, dates and instruments configuration. A document reporting the Flight Plan was distributed by INTA team before the flights.

The campaign was performed as planned.

Once the campaign was over, recorded imagery were archived and backed-up at INTA premises during early August.

c) Data acquired

ZONE: Tarazona de la Mancha. Date: 25-July-2003

Identific.	Line	Track	Time UTC	Raw frames id	Imported frames id	Remarks
PA00	001	??	??	001-003	NA	<i>test flight on June 24th all AMDC channels available</i>
PA0	002	??	??	005	NA	<i>only one AMDC channel</i>
PA04	003	128°	10:15	008-029	6-28	«
PA05	004	308°	10:27	032-054	29-52	«
PA03	005	128°	10:40	057-079	53-76	«
PA06	006	308°	10:53	082-109	77-104	«
PA02	006	128°	11:05	110-189	105-185	«
PA07	007	308°	11:18	192-227	186-221	«
PA01	008	128°	11:32	229-250	222-244	«
PA08	010	308°	11:56	262-284	253-276	«
PM04	011	128°	12:12	287-307	277-298	« medium height (0.5 m AMDC pixel)

** several extra frames were recorded out of the study area*

ZONE: Villarrobledo. Date: 26-July-2003

Identific.	Line	Track	Time UTC	Raw frames id	Imported frames id	Remarks
<i>PA0</i>	<i>001</i>	<i>??</i>	<i>??</i>	<i>001-003</i>	<i>NA</i>	<i>test flight all AMDC channels available</i>
PM04	002	308°	09:43	005-029	4-29	all AMDC channels pixel 0.5m
PA04	003	308°	10:04	032-053	30-52	«
PA05	004	128°	10:16	054-080	53-77	«
PA03	005	308°	10:27	081-107	79-105	«
PA06	006	128°	10:39	108-135	106-131	«
PA02	007	308°	10:50	136-163	132-158	all AMDC channels available
PA07	008	128°	11:03	164-188	159-170	only one AMDC channel
<i>PA01</i>	<i>009</i>	<i>308°</i>	<i>11:14</i>	<i>189-210</i>	<i>NA</i>	<i>only one AMDC channel</i>
<i>PA08</i>	<i>010</i>	<i>128°</i>	<i>11:27</i>	<i>211-234</i>	<i>NA</i>	«

ZONE: Utiel – Requena. Date: 27-July-2003

Identific.	Line	Track	Time UTC	Raw frames id	Imported frames id	Remarks
--	<i>V-011</i>	<i>??</i>	<i>??</i>	<i>237</i>	<i>NA</i>	<i>Test flight</i>
PM01	V-012	318°	09:25	239-366	239-356	Flight over «Valencia Anchor Station» all AMDC channels available

d) Data quality

The raw images were reviewed to check the instrument performance and any relevant feature concerning image quality. This was performed by visual inspection and by analysis of the image statistics (mean, maximum, minimum, mode) generated on purpose. The results of this exercise are summarised below:

Zone	Spectral	Radiometric	Geometric	Others
Tarazona	only one spectral channel available, corresponding to the panchromatic band	good radiometric range in spectral positions 2,3 and 5 too high signal in positions 1 and 4	good	good meteorology solar irradiance increases from $\approx 90\%$ to $\approx 100\%$ * during the flight
Villarrobledo	all 5 spectral channels available except for PA7, PA1 and PA8, where only the panchromatic band is available	good except for channel 3 in flight lines PM4, PA4, PA5 PA3 and PA6	good	good meteorology solar irradiance increases from $\approx 87\%$ to $\approx 97\%$ during the flight
Utiel-Requena	all 5 spectral channels available	too high signal in channels 3 and 5, and some times in channel 1	good	good meteorology

* 100% is the irradiance at solar noon (maximum for that day)

As seen in the table above, the initial check of the images showed an anomaly in the AMDC data: for nearly half of the flight lines, only one channel was available (channel 5, panchromatic). Unfortunately, this was not detected on real time during the flight.

A radiometric problem was detected when looking to surfaces imaged in two scenes. Radiometric value of the same element of surface was different depending on the image in which it was measured. This fact was attributed to an effect of the camera imaging geometry and mechanism (a conic projection, where each pixel is imaged under a different observation angle and this angle may change from $\approx +15^\circ$ to $\approx -15^\circ$ in the overlapping areas along or across track) and the non-lambertian behaviour of the surveyed surfaces (mainly soils and vegetation). The changes in gain settings between Villarrobledo P02 and P03, intended to correct for increasing solar irradiance, could account for part of the differences in this specific case.

e) Processing

Applanix POS-AV 410 data processing was performed successfully. The system reported accuracy achieved is within the requirements for image georeferencing:

	Δx (m)	Δy (m)	Δz (m)	$\Delta roll$ (°)	$\Delta pitch$ (°)	Δyaw (°)
Mean	-0.207	-0.143	0.116	0.01967	-0.03406	0.00015
Std Dev.	0.177	0.180	0.124	0.04915	0.03500	0.09648

Co-register of AMDC multispectral images was successful in all cases.

Generation of DEM from AMDC images was not successful. The reason was the radiometric differences between scenes described above: the DEM generation tool looks for homologous points in the two overlapping images to build the elevation model, but the grey-level differences were too big.

Resampling of the IGN DEM at scale 1:25000 gave a model that result good enough for low relief areas as Tarazona and Villarrobledo.

Orthorectification was performed to 0.7 m cell size, a figure empirically selected as given the best-looking result. Orthorectification accuracy was estimated in the range of 2 pixels. It was, as expected, not uniform across the study area.

Mosaics were exercised several times before selecting the optimum configuration of outline and colour balancing.

Output coordinate system was UTM, datum ED-50, Ellipsoid International 1909.

f) Delivered products

The delivered products are characterized in the table below:

Format	Product	Deliverable
raw	Raw AMDC data (one file per spectral band)	no
img	Co-registered AMDC data (one file per scene), in ERDAS format	yes
pix	Orthorectified AMDC scenes (one file per scene), in PCI-Geomatica format	no
pix	Mosaic of AMDC scenes (one file per test zone), in PCI-Geomatica format	yes
txt	Auxiliary information acquired along the flight or during the processing, in text format	no

Next table summarises the products generated by test site and format:

Zone	File name	*.raw	*.img	*.pix	*.tif
Tarazona	individual scenes S250703_TARAZ_P*.*	INTA	BAC	--	--
Tarazona	orthorectified scenes oS250703_TARAZ_P*.*	--	--	INTA	--
Tarazona	single pass mosaic S250703_TARAZ_P04M.*	--	--	BAC	--
Tarazona	overall mosaic S250703_TARAZ_ALL*.*	--	--	BAC	--
Villarrobledo	individual scenes S260703_VILLA_P02 -> _P07	INTA	BAC	--	--
Villarrobledo	orthorectified scenes S260703_VILLA_P02 -> _P07	--	--	INTA	--
Villarrobledo	single pass mosaic S260703_VILLA_P04M.*	--	--	BAC	--
Villarrobledo	overall mosaic S260703_VILLA_ALL*.*	--	--	BAC	--
Utiel-Requena	individual scenes S270703_UT-RE_P*.*	INTA	INTA	--	--
Utiel-Requena	orthorectified scenes S270703_UT-RE_TEST1*.*	--	--	INTA	--
Utiel-Requena	pass mosaic S270703_UT-RE_*.*	--	--	INTA	--

Code:

INTA: available at INTA

BAC: deliverable for Bacchus partners

--: not generated

I.3. SUMMER 2004 AERIAL SURVEYS

Study area: The 2004 campaign was designed to acquire data from all BACCHUS study areas. After consultation with the partners, the selected target areas were:

Country	France	Italy	Portugal	Spain
Areas	Saint Chinian Champagne Limoux Bordeaux	Prosecco Frascati	Douro Bairrada	Villarrobledo Tarazona de la Mancha

Each was around 10 km x 10 km in size.

Due to different problems, the Champagne, and Bordeaux areas were not included in the flight programs.

I.3.1. Data acquisition methodology

Multispectral image data were gathered with a multispectral frame camera manufactured by Argonst (former Sensytech), known as *Airborne Multispectral Digital Camera (AMDC)*. Surveys were conducted in May, June and July 2004 over eight test sites spread out in Italy, France, Portugal and Spain. Figure 5 shows the crew participating in surveys over the Spanish test sites.

Main features of the flight design were:

- Flight altitude (above ground level): 2750 m for 1 m/pix; 1375 m for 0.5 m/pix
- Along-track overlapping for AMDC frames: 60%
- Line-to-line side overlapping 30%

I.3.2. Data analysis methodology

a) Data pre-processing

Raw image files, one per spectral band, were imported from the flight tape to a standard computer files in generic binary format, with no processing at all.

First campaign deliverable was this set of raw images, with their acquisition auxiliary info in a text file, the AVA quick-look in jpg format, and metadata in Microsoft Excel files using the BACCHUS template (one metadata file per test site).

b) Quality check

Quality check was performed just after importing the raw data, using the specific tool *AVA.jar* to produce quick-looks and image statistics, and the MATLAB tool *avastats.m* to produce campaign-level statistics from the individual scene statistics.

c) Geometric positioning of images

After being imported and quality checked, the data were geo-referenced for a proper integration with the other partners data. Geo-referencing was achieved mostly using the **Geomatica© 9.1** environment, through the steps presented in the next table:

Step	Algorithm used	Comments
Processing of the INS data.	POS-AV processing suite (<i>POSPAC</i>), using default settings for airborne data.	GPS reference station data required.
Synchronization of POS-AV info and AMDC images.	Manual match of AMDC acquisition time and POSAV event time tag. Separation of the different bands and renaming of files with a specific tool developed in java <i>AMDCdesigner.jar</i> .	
Conversion of ellipsoidal height (provided by INS) to orthometric height.	Geoid undulation from web sources (gibs.leipzig.ifag.de)	Validated with Spanish geoid heights from IGN (www.ign.es).
Creation of Geomatica image files.	Specific tool developed for Geomatica <i>AMDC_raws.eas</i> .	
Preparation of DEM.	Translation to a Geomatica compatible format. Re-projection to the output geographic reference system.	
Orthorectification by direct georeferencing (no ground control points).	Orthoengine from Geomatica.	Each band is orthorectified independently.
Co-registration of the AMDC bands to align multispectral information.	Specific tool developed under Geomatica <i>auto4mos.eas</i> .	
Radiometric normalization.	Specific tool developed under Geomatica <i>normalization.eas</i> .	A correction factor is used to normalize the image radiometry within a test area when: a) different gains are used, or b) when differences in solar irradiance exceeds 10%.
Mosaicking.	Orthoengine from Geomatica.	Automatic cutline through edge features. No radiometric normalization. No blending.

d) Radiometric processing of images

No radiometric calibration is applied to the individual AMDC images.

I.3.3. Results

a) Data acquisition

Flight campaign reports, flight program and campaign report, were distributed by INTA remote sensing team.

Following tables summarise the images acquired.

ZONE: FRANCE - ST. CHINIAN. Date: 25-May-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
--	001	--	--	--		NOT VALID
P5	002	139	10:09	5,30	0.5	
P4	003	319	10:19	32,51	0.5	
P6	004	139	10:29	53,74	0.5	
P3	005	319	10:38	76,97	0.5	
P7	006	139	10:47	99,122	0.5	
P2	007	319	10:56	124,146	0.5	
P8	008	139	11:05	148,171	0.5	
P1	009	319	11:14	173,196	0.5	
P9X	010	139	11:23	198,217	0.5	NOT VALID
P9	011	319	11:32	219,239	0.5	

ZONE: FRANCE – LIMOUX. Date: 29-May-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
--	001					NOT VALID
<i>P4X</i>	<i>002</i>		<i>28-may</i>			<i>NOT VALID (clouds)</i>
<i>PIX</i>	<i>003</i>		<i>28-may</i>			<i>NOT VALID (clouds)</i>
--	004					NOT VALID
P3 P3X	005 012	90 90	07:25 08:36	75,106 314,347	0.5	two repetitions
P5 P5X	006 013	30 270	07:42 08:47	108,141 349,382	0.5	two repetitions
P2 P2X	007 014	90 90	07:47 08:59	143,175 384,418	0.5	two repetitions
P1	008	90	07:59	177,210	0.5	
P6	009	270	08:07	212,240	0.5	
P7	010	90	08:18	242,277	0.5	
P4	011	270	08:26	279,312	0.5	

ZONE: ITALY – PROSECCO. Date: 31-may-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
P1	--	--	--	--	--	not performed
P4	001	243	09:12	1,34	1	
P5	002	63	09:24	36,67	1	
P6	003	243	09:34	69,99	1	
P7	004	63	09:43	101,134	1	
P8	005	243	09:54	136,167	1	
P3	006	63	10:06	169,200	1	
P2	007	243	10:15	202,232	1	

ZONE: ITALY – FRASCATI. Date: 07-June-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
P6	001	259	09:07	1,20	0.5	
P5	002	259	09:17	22,39	0.5	
P4	003	79	09:24	41,58	0.5	
P3	004	259	09:31	60,79	0.5	
P2	005	79	09:37	81,101	0.5	
P1	006	259	09:45	103,123	0.5	
P7	--				1	not performed
P8	--				1	not performed

ZONE: PORTUGAL – BAIRRADA. Date: 16-June-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
--	001	--	09:43	--		NOT VALID
P4	002	90	10:00	11,27	0.5	
P5	003	270	10:11	29,44	0.5	
P3	004	90	10:21	46,62	0.5	
P6	005	270	10:34	64,80	0.5	
P2	006	90	10:41	82,98	0.5	
P7	007	270	10:53	100,117	0.5	
P1	008	90	11:03	119,140	0.5	

ZONE: PORTUGAL – DOURO. Date: 16-June-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
P1	009	90	11:44	--		NOT VALID
P3	010	270	11:56	--		NOT VALID
P1	011	90	12:12	204,233	0.5	
P2	012	270	12:24	235,265	0.5	
P3	013	90	12:38	267,296	0.5	

ZONE: SPAIN – TARAZONA. Date: 14-July-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
--	001	--	--	--		NOT VALID
P10M	002	35	10:21	5,24	0.5	NOT DELIVERABLE
P7M	003	305	10:32	26,48	0.5	NOT VALID
P7M	004	125	10:43	50,72	0.5	«BONUS»
P7A	005	305	10:56	74,95	1	
P4A	006	125	11:07	97,118	1	
P10A	007	215	11:19	120,140	1	NOT DELIVERABLE
P1A	008	305	11:31	142,164	1	
P2A	009	125	11:40	166,187	1	
P3A	010	305	11:50	189,211	1	
P5A	011	125	11:59	213,234	1	missing POSAV data
P6A	012	305	12:09	236,259	1	
P8A	013	125	12:18	261,281	1	
P10A	014	215	12:30	283,314	1	NOT DELIVERABLE
P9A	015	35	12:41	316,336	1	NOT DELIVERABLE

ZONE: SPAIN – VILLARROBLEDO. Date: 16-July-2004

Identific.	Line	Track	UTC Time	Raw frames id.	Pixel size (m)	Remarks
--	001	--	--	--		NOT VALID
P4M	002	305	10:03	5,27	0.5	«BONUS»
P4A	003	305	10:23	29,51	1	
P5A	004	125	10:35	53,75	1	
P3A	005	305	10:47	77,100	1	
P6A	006	125	10:57	102,124	1	
P8A	007	305	11:10	126,153	1	
P7A	008	125	11:22	155,178	1	
P2A	009	305	11:32	180,204	1	
P1A	010	125	11:42	206,228	1	

Once the campaign was over, the images were archived and backed-up at INTA premises in Madrid.

I.3.4. Data processing

a) Data pre-processing

Ingestion of AMDC images was performed without problems.

b) Quality check

Raw images were analysed to check the instrument performance and any relevant feature concerning image quality. This analysis was performed by visual inspection and by reviewing the image statistics (mean, maximum, minimum, mode) generated on purpose. Results of this exercise are summarised in the table below:

Others	Zone	Geometry	Radiometry
OK	FR - Saint Chinian	OK	OK (minor saturations)
OK	FR - Limoux	«	OK
no clouds but cloud's shadows causes differences in surface illumination	IT - Prosecco	«	OK, except for a few scenes showing blank data in band 5
some clouds	IT - Frascati	«	OK
OK	PO - Douro	«	saturation over extense surfaces
OK	PO - Bairrada	«	«
OK	ES - Villarrobledo	«	OK
OK	ES - Tarazona	some INS data missing	OK

A radiometric effect was notice when looking at surfaces imaged in two scenes: there are significant changes in the radiometric digital value for an element of surface depending on which image is measured. The analysis of image statistics did not show any systematic behaviour that could be used to model this effect. Therefore, it was not possible to design an automatic algorithm to overcome this inconsistency, while empirical solutions were discarded due to their cost in time and effort.

c) INS/GPS data processing

Applanix POS/AV 410 data processing was performed as expected. The accuracy reported by POSPAC was within the requirements for image geo-referencing.

For all the zones, «lever arms» and «boresight» values were fixed. Lever arms were measured on-site. Obtained values were:

Axis	X	Y	Z
offset antena-camera	-0.27 m	-0.01 m	-2.23 m
offset camera-IMU	-0.08 m	0.11 m	-0.34 m

Boresight angles were measured from the analysis of a dedicated test flight on June 2004. The values obtained are:

Axis	X	Y	Z
angle	9.77 arcmin	32.66 arcmin	-10.16 arcmin
error	2.14	1.80	3.92

Specific parameters for the different zones were detailed in the POSPAC processing report.

d) Synchronization

Synchronization of AMDC images and POS/AV data was performed successfully.

e) Orthorectification

Orthorectification was performed independently for each band. Common parameters were:

CCD size: width=18.216 mm (9 micrometers x 2024 cols), height=18.370 mm (9 micrometers x 2041 rows)

Principal point offset: 0,0 (see below for exceptions)

Radial distortions and other corrections factors: 0

Rotate kappa: 90°

Focal length: 28.3 mm, computed empirically from image analysis (see below for exceptions)

Zone-specific parameters were:

Zone	Parameters	Results
Limoux	output projection: Lambert II etendu output datum: NTF based on ellipsoid Clarke 1880 DEM: dem_limoux.pix, translated to Geomatica format from the DEM provided by CEMAGREF (native format ARC/INFO) Output cell size: 0.5 m	OK ⁽¹⁾
Saint Chinian	output projection: Lambert II etendu output datum: NTF based on ellipsoid Clarke 1880 DEM: chin04_dem_lambII_ntf.pix, translated to Geomatica format from the DEM provided by CEMAGREF (native format ARC/INFO) Output cell size: 0.5 m	OK
Prosecco	output projection: UTM zone 32 N output datum: WGS84 DEM: pros04_dem_utm32_wgs84.pix, translated to Geomatica format from the files provided by CNR-IBIMET (native format ARC/INFO adf) Output cell size: 0.8 m	OK
Frascati	output projection: UTM zone 33 N output datum: WGS84 DEM: original files provided by CNR-IBIMET (native format ARC/INFO adf) output cell size: 0.5 m	OK
Bairrada	output projection: UTM zone 29 N output datum: WGS84 DEM: dem_bair_utm29_wgs84.pix, translated from the ASCII file provided by IGEO output cell size: 0.5 m	OK
Douro	output projection: UTM zone 29 N output datum: WGS84 DEM: dour04_dem_utm29_wgs84.pix, translated from the ASCII file provided by IGEO output cell size: 0.5 m	OK
Tarazona	output projection: UTM zone 30N output datum: ED50 European DEM: MDT25_IGN_5m_h30.pix, translated from Spanish IGN MDT25 (native format ASCII raster), re-sampled to 5 m, no re-projection from native datum (IGN ED50) output cell size: 0.8 m (0.5 for PM) focal: 28.42 ⁽¹⁾ principal point offset for AMDC4: (dx=-0.036, dy=0.018) ⁽²⁾	a few orthoimages show anomalies
Villarrobledo	output projection: UTM zone 30N output datum: ED50 European DEM: dem_utm30S_ed50.pix, source unknown output cell size: 0.8 m (0.5 for PM) focal: 28.42 ⁽²⁾ principal point offset for AMDC4: (dx=-0.036, dy=0.018) ⁽³⁾	OK

(1) Orthoimages were created successfully, but the observed mismatch between adjacent images could be caused by minor errors in the orthorectification parameters

(2) Optimised following validation of orthorectified imagery with Spanish IGN digital cartography (note that digital cartography is not available for other sites, and so detailed optimisation of focal length was not feasible)

(3) Principal offset shifted for band 4 to simulate the observed mis-registration with bands 1 to 3 (see next section)

A text file reporting the Orthoengine configuration for each test site and spectral band was made available.

f) Co-registration

VIS and NIR AMDC 1 to 4 spectral bands were co-registered to produce a multispectral file, while band 5 (panchromatic) was processed independently. Then, a 4-band mosaic was produced as multispectral image of the test area (*XS mosaics*), and a separate one as panchromatic image (*PAN mosaics*).

Co-registration of AMDC multispectral images was performed on orthorectified imagery: the estimated co-registration accuracy was in the order of 1 pixel in AMDC1 to AMDC3 spectral bands. AMDC4 band seemed to be spatially shifted a few pixels with respect to the other bands, with a magnitude depending on flight track.

After co-registration, only the pixels with image data in all 4 multispectral bands were kept, while the rest were set to 0.

g) Radiometric normalization

Radiometric correction factors were calculated and applied to imagery got at Saint-Chinian and Limoux test sites.

The rest of flight lines were not modified.

h) Mosaicking

Mosaicking was performed automatically, but some manual work was later required in order to adjust anomalies or replace cloudy frames.

Zone	Parameters	Results
Limoux	Coordinates: <i>see metadata files</i> Output cell size: 0.5 m	OK
Saint Chinian	Coordinates: <i>see metadata files</i> Output cell size: 0.5 m	OK
Prosecco	Coordinates: <i>see metadata files</i> Output cell size: 0.8 m	OK
Frascati	Coordinates: <i>see metadata files</i> Output cell size: 0.5 m	OK
Bairrada	Coordinates: <i>see metadata files</i> Output cell size: 0.5 m	OK
Douro	Coordinates: <i>see metadata files</i> Output cell size: 0.5 m	OK
Tarazona	Coordinates: <i>see metadata files</i> Output cell size: 0.8 (0.5 m in PM7)	OK
Villarrobledo	Coordinates: <i>see metadata files</i> Output cell size: 0.8 (0.5 m in PM4)	OK

A text file reporting the Orthoengine configuration for each generated mosaic was made available.

i) Validation

Each mosaic was validated using reference cartography provided by BACCHUS partners. Details of this step are shown below.

Zone	Cartography	Estimated results
Limoux	Orthophotos in Lambert II etendú/ NTF from CEMAGREF.	< 3 pixels rms
Saint Chinian	«	«
Prosecco	Digital cartography in Gauss Boaga/Rome 1940 from CNR- IBIMET, reprocessed at INTA.	< 10 pixels shift, most likely due to datum/projection conversion problems, with ≈5 pixels rms
Frascati	scanned maps from CNR- IBIMET	not checked
Bairrada	digital cartography in UTM/ WGS84 from IGEO.	< 3 pixels rms
Douro	«	«
Tarazona	digital cartography 1:25000 from Spanish IGN, in UTM/IGN ED50.	< 5 pixels shift due to differences between ED50 datum in IGN and POSAV data, with ≈5 pixels rms.
Villarrobledo	«	«

j) Delivered products

The different delivered products are characterized in the table below:

Product	Deliverable
Raw AMDC data (one file per scene), generic binary BSQ format.	yes
Auxiliary information acquired along the flight, in text format.	yes
Individual scenes quicklook, in jpg format.	yes
Raw AMDC data (one file per scene), Geomatica «pix» format.	no
Co-registered AMDC data (one file per scene), Geomatica «pix» format.	yes
Orthorectified AMDC scenes (one file per scene), Geomatica «pix» format.	no
Mosaic of AMDC scenes (one file per test zone), Geomatica «pix» format.	yes
Mosaic of AMDC scenes (one file per test zone), tif format.	yes
Mosaic quicklook, in jpg format.	yes
Metadata in the excel template designed for Bacchus.	yes

I.3.5. Conclusions

Multispectral and panchromatic mosaics were produced and distributed for all test areas selected for the BACCHUS 2004 campaign.

The delivered products were close to the initial requirement of 3 pixel rms geometric accuracy, but with a higher effort (and cost) and delivery time than foreseen. The differences between actual performance, estimated in < 5 pixels rms, and the 3 pixel requirement were mainly due to instrument limitations, namely lack of camera calibration information; these camera limitations were not properly evaluated when the image requirements were set.

The radiometric mismatch between adjacent frames was a major problem in the final mosaic: this fact was also a camera limitation, which was known a priori: but it was not been possible to model the problem and so to develop an efficient solution.

The extra effort and time required in the image processing was a result of different contributions, the main ones being:

- Development of workarounds for instrument limitations
- Difficulties in handling the different geographic information required, from images through DEM to reference cartography; in this sense, metadata turns out to be a critical point in pan-European cartographic programmes.

In the annex III, there are final images of INTA airborne fly.

ANNEX II. BACCHUS METADATA

Caetano, M. & Oliveira, A.

Within the early BACCHUS project phase, one essential aim was the establishment of an organized metadata structure that could provide organized storage and management of project dataset characteristics, thus avoiding the data loss or dispersion that is usually one of the causes of poor performance in this kind of achievement. This metadata structure was designed to record key points related to BACCHUS Datasets (Data Title, format, reference system...), taking in account ISO (International Standards Organization) instructions.

The first step was to design a document presenting guidelines that could be followed by technical partners to fill in the metadata structure. This version was prepared accordingly to comments received from BACCHUS partners. Secondly, all partners involved fed the structure with the characteristics of their project data, and returned it back to IGP who compiled them in the final framework.

II.1. METADATA STANDARDS AND OTHER DEVELOPMENTS

Despite the choice of the ISO standard as a reference in the context of this project, several other metadata standards were also considered in an initial phase, as well as other related developments. All these are presented below in this chapter.

The ISO Standard for Geographic Data

ISO stands for *International Organization for Standardization*. ISO is a network of the national standards institutes of 156 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system. ISO is a non-governmental organization: its members

are not, as is the case in the United Nations system, delegations of national governments. Nevertheless, ISO occupies a special position between the public and private sectors. This is because, on the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations. Therefore, ISO is able to act as a bridging organization in which a consensus can be reached on solutions that meet both the requirements of business and the broader needs of society, such as the needs of stakeholder groups like consumers and users.

The metadata structure developed within BACCHUS tries to comply as much as possible to International Standard ISO 19115 – Geographic Information – Metadata. This International Standard defines the schema required for describing geographic information and services. It provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data.

Though ISO 19115 is applicable to digital data, its principles can be extended to many other forms of geographic data such as maps, charts, and textual documents as well as non-geographic data.

This International Standard is applicable to:

- The cataloguing of datasets, clearinghouse activities, and the full description of datasets;
- Geographic datasets, dataset series, and individual geographic features and feature properties.

This Standard defines:

- Mandatory and conditional metadata sections, metadata entities, and metadata elements;
- The minimum set of metadata required to serve the full range of metadata applications (data discovery, determining data fitness for use, data access, data transfer, and use of digital data);
- Optional metadata elements – to allow for a more extensive standard description of geographic data, if required;
- A method for extending metadata to fit specialized needs.

FGDC Standards

FGDC stands for Federal Geographic Data Committee. It is an initiative of the government of the United States of America; it consists on a 19 member interagency committee composed of representatives from the Executive Office of

the President, Cabinet-level and independent agencies. The FGDC is developing the National Spatial Data Infrastructure (NSDI) in cooperation with organizations from State, local and tribal governments, the academic community, and the private sector. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data.

The main idea behind this standard is to facilitate the development, sharing, and use of geospatial data. The FGDC develops geospatial data standards for implementing the NSDI, in consultation and cooperation with State, local, and tribal governments, the private sector and academic community, and, to the extent feasible, the international community.

Thus, the framework data standard is intended to establish common requirements for data exchange for seven themes of geospatial data that are of critical importance to the National Spatial Data Infrastructure (NSDI), as they are fundamental to many different Geographic Information Systems (GIS) applications. The seven geospatial data themes are: geodetic control, elevation, orthoimagery, hydrography, transportation, cadastral, and governmental unit boundaries. These themes are known as NSDI framework themes.

Framework data standards specify a minimal level of data content that data producers, consumers, and vendors are expected to use for the interchange of framework data, including through Web services. Each of the framework data standards includes an integrated application schema expressed in Unified Modeling Language (UML) developed through the Object Management Group (OMG). The application schema specifies, as appropriate, the feature types, attribute types, attribute domain, feature relationships, spatial representation, data organization, and metadata that define the information content of a data set.

While the framework data standards do not specify a single structure for the interchange of data, an implementation using the Geography Markup Language (GML) Version 3.0 developed through the Open Geospatial Consortium, Inc. (OGC) has been created.

FGDC standards were considered by IGP during the planning phase of the BACCHUS metadata framework. However, FGDC descriptors seem to be essentially adapted to a North American context. Therefore, being global, the ISO proposal seems a more logical approach to use, even strictly within the European context.

CEN Standards

CEN stands for *Comité Européen de Normalisation*. The European Committee for Standardization was founded in 1961 by the national standards bodies in the

European Economic Community and EFTA countries. Based in Brussels, CEN is presently contributing to the objectives of the European Union and European Economic Area with voluntary technical standards which promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmes, and public procurement.

Regarding CEN standards for geographic information, the main development resides in the work of the Technical Committee CEN TC 287. This was constituted in October 1991, integrating 22 countries. The several documents produced by this committee, CR (Committee Report) and ENV (European Pre-standards), provide a means to represent Geographic Information, along with the necessary mechanism and definitions to enable geographic data to be used by different computer systems, in different environments and for different applications.

Thus, the ENV 12657 pre-standard defines a conceptual schema for the definition of metadata for geographic datasets. It includes information about dataset contents, representation, extent, (geometric and temporal), spatial reference system, quality and administration. The document also specifies the items that are mandatory for describing geographic datasets, and that constitutes the minimum set of metadata required to characterise geographic data.

However, the ISO initiative (started in 1994, presided by Norway, and integrating 25 collaborating countries and 13 observer countries) is a more global effort to normalization than CEN TC287 (started in 1991, integrating 22 countries), which will remain a pre-standard (Gouveia *et al*, 2001). This was one of the main reasons for the adoption of the ISO standard in BACCHUS, instead of CEN standardization.

INSPIRE

INSPIRE stands as Infrastructure for Spatial Information in Europe. An initiative of the European Commission, INSPIRE aims essentially at promoting the availability of spatially located information that can be used in the preparation, implementation and evaluation of environmental policies within the European Union.

Its main goal is the establishment of a legal framework for the progressive and harmonious generation of the European Spatial Data Infrastructure (ESDI).

The need for such initiative comes from the general situation on spatial information in Europe, which is one of fragmentation of datasets and sources, gaps in availability, lack of harmonisation between datasets at different geographical

scales and duplication of information collection. These problems make it difficult to identify, access and use data that is available.

Fortunately, awareness is growing at national and at EU level about the need for quality geo-referenced information to support understanding of the complexity and interactions between human activities and environmental pressures and impacts. The INSPIRE initiative is therefore timely and relevant but also a major challenge given the general situation outlined above and the many stakeholder interests to be addressed.

INSPIRE is complementary to related policy initiatives, such as the Commission proposal for a Directive on the re-use and commercial exploitation of Public Sector Information.

Once built, the ESDI will provide each user with the capability of being able to gain access and identify geographic information coming from various sources, from the local to the global level, in an interoperate fashion, and for a great diversity of applications

INSPIRE includes workgroups for Reference Datasets and Metadata; Architecture and Standards; Legal Issues and Data-related Policies; Funding and Implementation Structures; Impact Analysis, Thematic Environmental Information.

Since clear definition and storage of metadata is a critical part of the whole process of developing the ESDI, INSPIRE has the potential of acting at the European level as a stimulus for the development and improvement of metadata standards; it can also help promoting its widespread use.

Other metadata-related developments in IGP

Besides the metadata framework developed specifically for the context of documenting the characteristics of BACCHUS datasets, IGP has been developing MIG (*Metadados de Informação Geográfica*) Editor.

An on-going effort, MIG Editor is an XML-based tool specifically designed to assist in the filling-up of geographic information metadata. It is compliant to the ISO 19115 Standard and also with the specifications issued by the workgroup presently developing the ISO 19139 Standard (related to the digital implementation of metadata for geographic information).

The MIG Editor is a MIG component. MIG is the name by which the metadata infrastructure of SNIG (*Sistema Nacional de Informação Geográfica* – the official Portuguese public platform for sharing geographic information and related metadata) will become generally known. MIG Editor is a desktop tool, developed in the .NET platform.

Amongst its main goals are the production of XML metadata documents that can be easily shared by the community of geographical information users and swiftly integrated in their computer systems; the production of metadata for SNIG and the National Cartography Registration (a list of certified cartographic products, their metadata and related producers).

The MIG Editor is presently available with Portuguese language menus, although there is a current effort to provide menus in other languages (at least in English). Such effort will allow it to be adapted to dataset management in the context of other international projects into which IGP currently participates.

II.2. GENERAL STRUCTURE AND GUIDELINES

In order to provide structured storage of dataset characteristics, the reference framework of ISO 19115 proposes around 400 descriptors. These descriptors are organized in a hierarchical fashion, from the main classes (termed «superclasses»), encompassing a more general set of items, down to the descriptors themselves, which document a very specific trait of the dataset. The first task in the preparation of the BACCHUS metadata structure consisted in choosing a subset of classes and descriptors adapted to the task in hand, and trying to fit this profile to specific project needs. The next step was to assemble the chosen classes and descriptors in an operational frame. The final task had to do with populating this frame with the characteristics of each dataset.

The main superclasses picked off the total framework of proposed ISO 19115 descriptors to form the desired subset were:

1. MD_Metadata
12. SpatialRepresentationInfo
13. ReferenceSystemInfo
15. IdentificationInfo
16. ContentInfo (Vector)
16. ContentInfo (Grid)
17. DistributionInfo
18. DataQualityInfo

The developed metadata structure is a multifunctional one, in the sense that it allows storage of specific characteristics for the main types of geographic datasets currently in use. One of the main questions that had to be attended to was the lack of ISO descriptors specifically aimed at remote sensing data. Due to the relevance of this kind of data in the context of BACCHUS, IGP prepared the cited structure so that it could also support it. This was done by (re) interpretation of the ISO descriptors considered necessary. All these goals were achieved by concentrating

all the relevant descriptors for each single geographic dataset in a Microsoft Excel sheet (the metadata sheet). Inside this sheet, a model based on ISO descriptors allows to cover not only the main characteristics of datasets but also their state of the art (e.g. if the dataset is the result of some kind of pre-processing performed upon a previous dataset, it was possible to gain insights on the involved processes, the used raw data, and so on). The metadata sheet is structured in a hierarchical fashion, unfolding left to right from the main classes of descriptors to the single descriptor and its value (see Tables II.1 and II.2).

Table II.1. Extract of the Metadata Hierarchical Structure; upper left part of the metadata sheet, illustrating the use of superclasses (e.g. 1.MD_metadata)

IGP - METADATA FOR LAND USE 1990 (1:25 000)		for the test site of Monção	
ISO ELEMENTS			
1. MD_Metadata	3. Metadata Language		
	8. Contact (of Person Responsible for Metadata)	KeyNum	
	9. Date Stamp		
	22. metadataMaintenance	143. maintenanceAndUpdateFrequency	
		144. dateOfNextUpdate	
145. userDefinedMaintenanceFrequency			
148. maintenanceNote			

Varying with each type of dataset, a set of descriptors is to be chosen, and the others left blank. When being filled, the only essential care has to do with maintaining its imbedded hierarchy, especially when there is a need to add more rows to the sheet (e.g. with documenting the several bands of a satellite image). Finally, one Excel workbooks gathers the several metadata sheets referring to the various datasets in use.

Table II.2. Extract of the Metadata Hierarchical Structure (upper right part of the metadata sheet; illustrating the values of descriptors)

ISO ELEMENTS / ANSWER	
210. azimuthAngle	NP
211. azimuthMeasurePointLongitude	NP
213. obliqueLineLatitude	NP
214. obliqueLineLongitude	NP
	Sheets nº 2, 3, 7, 8 of the Carta de Ocupação do Solo 1990 (COS90) Cartographic Series
394. date	1990-01-01
395. Date Type	001

The structure that was distributed comprised three files:

- One Microsoft Excel workbook, containing the organized metadata structure itself. This contained the basic metadata sheets that were filled with the dataset's characteristics.
- One Microsoft Word document containing the International Standard ISO 19115, providing a comprehensive reference to ISO metadata descriptors.
- One Microsoft Word document including the metadata structure's steering guide - the guidelines for the feeding of the metadata sheets (related to the specific arrangement of descriptors within the structure).

The cited Microsoft Excel workbook comprised three sheets. The first (according to the following sequence) was designed as a README file; the remaining two were the ones to be filled in:

- *Metadata_Glossary* - Described terms specific to the metadata structure's context.
- *General Elements (NameDataset)* – An ISO metadata structure referring to a single geographic dataset.
- *Contacts (KeyNum)* - Provided reference to a person whose contact was required in specific parts of the metadata structure of one or several datasets.

Filling in the metadata implied bearing in mind three essential guidelines:

- *General Elements (NameDataset)* was replicated as many times as needed, so that each dataset could be documented in one single metadata sheet. The sheet name (*NameDataset*) was filled accordingly to the name of the dataset to which the contents provided reference.
- *Contacts (KeyNum)* was also replicated and numbered using a unique integer number, resulting in as much contacts as those contained in the whole of the workbook's metadata sheets (Table II.3). Different metadata sheets can share the same contact, thus avoiding unnecessary redundancy of contact references inside the metadata structure. (*KeyNum*) was thus replaced by the key number of a specific contact.
- Anyone filling in the metadata sheets had to steer primarily by the ISO rules contained in ISO 19115. Each descriptor inside General Elements (*NameDataset*) pointed directly to a number in a table of ISO descriptors contained in annex B (pages 39 – 86) of above cited ISO document. It was advisable to consult these tables as many times as necessary, in order to gain as much insight as possible on the ISO structure's rationale.

Table II.3. Extract of the Contact Sheet template

Metadata Hierarchical Prototype for Bacchus Data								
Contact Sheet 1			< Empty Space >	Answer	Comments/ Doubts			
(ISO_Num). Contact (of Person Responsible for Metadata or Data)	375. individualName	Miguel André Oliveira			Miguel André Oliveira			
	376. organizationName <i>(The organization you represent)</i>				Instituto Geográfico Português (IGP)			
	377. positionName <i>(The position or role you have in the organization)</i>				NA			
	378. contactInfo <i>(Your Address)</i>	388. phone				+ 351 21 3819600 (extension 411)		
			389. address	381. deliveryPoint				Rua de Artilharia 1., 107
		382. city					Lisboa	
		383. administrative Area					Lisboa	
		384. postalCode					1099-052	
	385. country				Portugal			
	392. contactInstructions				NA			
379. role <i>(Your function in relation to the Dataset.)</i>				NA				

Some more specific guidelines also had to be accounted for:

- Because the names of ISO descriptors have a general tendency to be too abstract, their relation to a particular dataset is sometimes hard to grasp. Bearing this in mind, simplified names were sometimes presented (in red between parentheses), in addition to the original ISO names.
- Some descriptors included a level of detail that made reference to ISO documents other than ISO 19115. In the absence of some of those documents, the option was to use common sense and try to comply as much as possible with the desired contents of the descriptor.
- For several reasons, not all available descriptors were used for each dataset at once. In this sense, those that were not used received an NA (Not available) or NP (Not applicable) attribute.
- Vector Datasets presented a special case. In this context, spatial characteristics were documented inside the metadata sheet, whilst attributes (Tabular Information) were presented in a separate file (.doc), which is stored jointly with the metadata files.

BIBLIOGRAPHY

- [1] Gouveia, C., Henriques, P., Nicolau, R., Rocha, J.; Santos, M. (2001). Moving from CEN TC 287 to ISO/TC 211 - The approach of the Portuguese National Geographic Information Infrastructure. In: Proceedings on 4th AGILE Conference on Geographic Information Science „GI in Europe: Integrative, Interoperable, Interactive. Brno, Czech Republic, April 19-21, 2001.
- [2] ISO/TC-211, 2003. Geographic Information: Metadata, International Standards Organization, International Standard 19115.

ANNEX III. COLOUR IMAGES

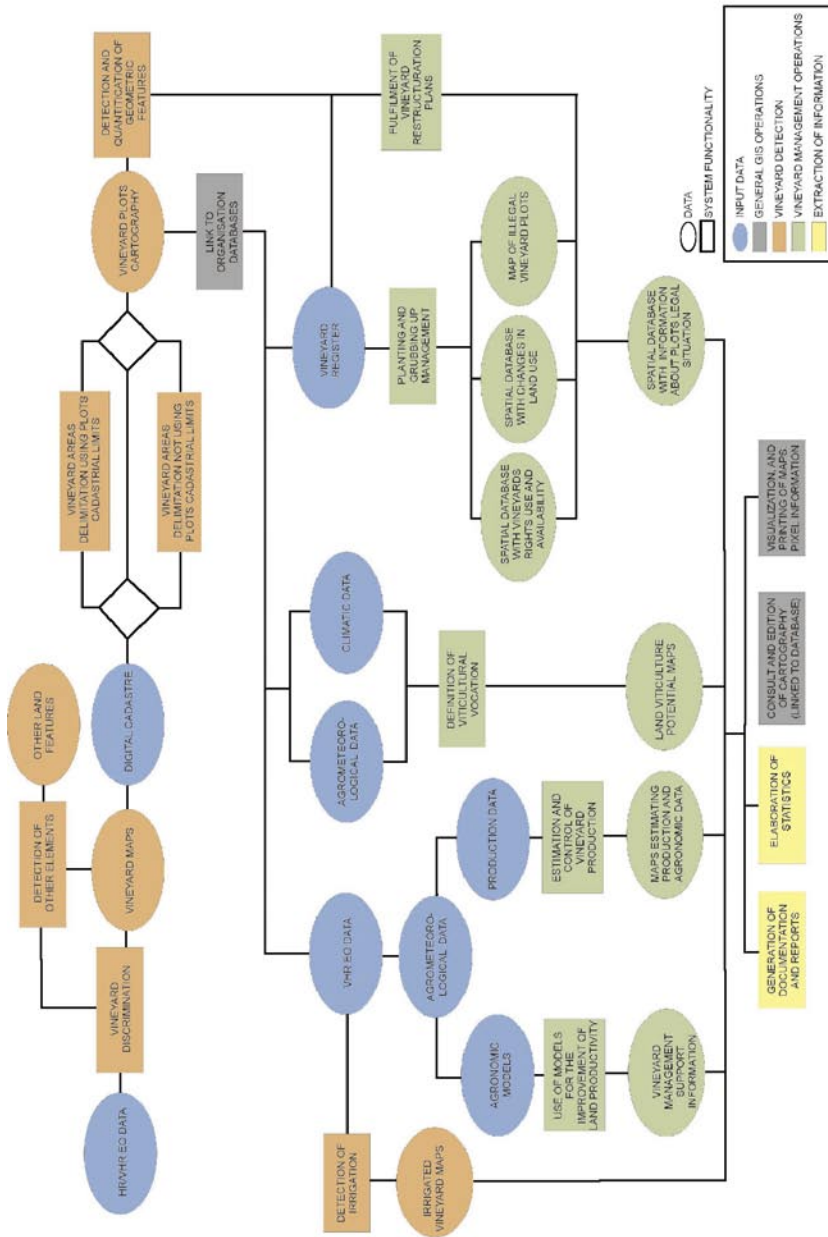


Figure 3.3. FULL SET OF THE SPECIFIC FUNCTIONAL REQUIREMENTS



FIGURE 4.1.B. ORIGINAL 50 CM RESOLUTION COLOR INFRARED IMAGE USED FOR ALGORITHM DEVELOPMENT. ROUJAN AREA, LANGUEDOC, FRANCE

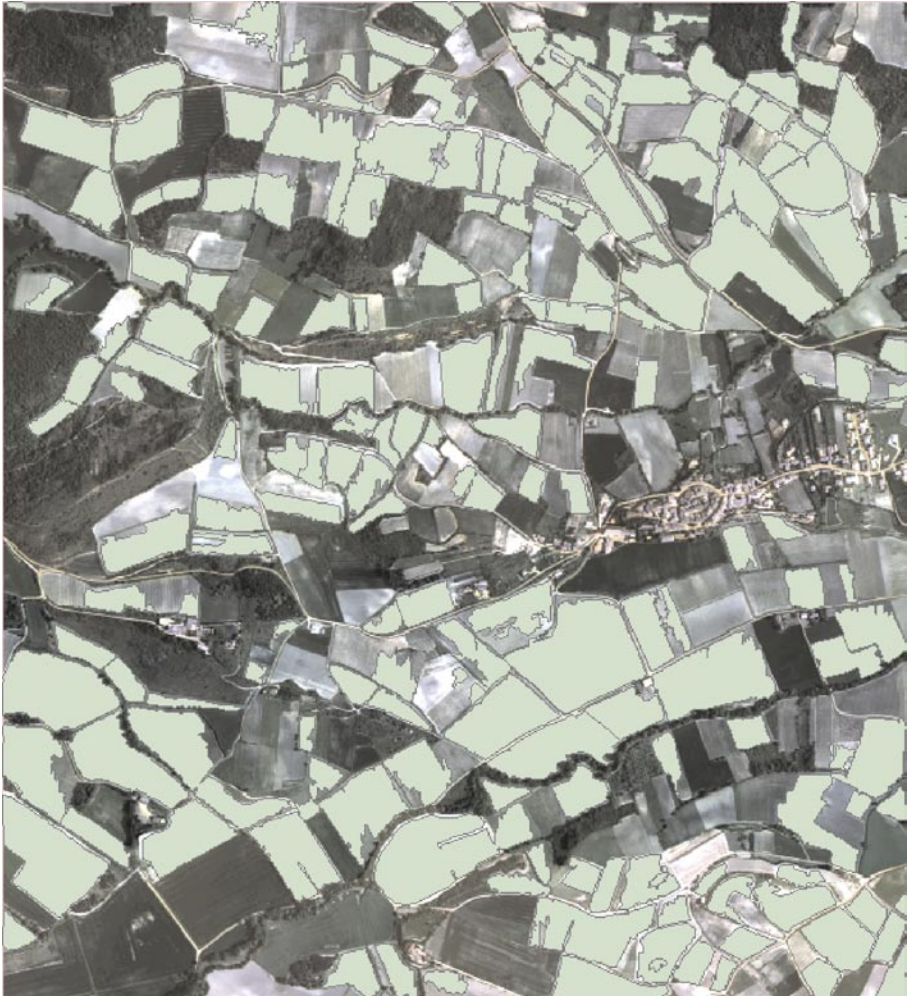


FIGURE 4.12. RESULTS OF THE SEGMENTATION ON THE RED CHANNEL OF THE INTA IMAGE, LIMOUX TEST-SITE (FRANCE)

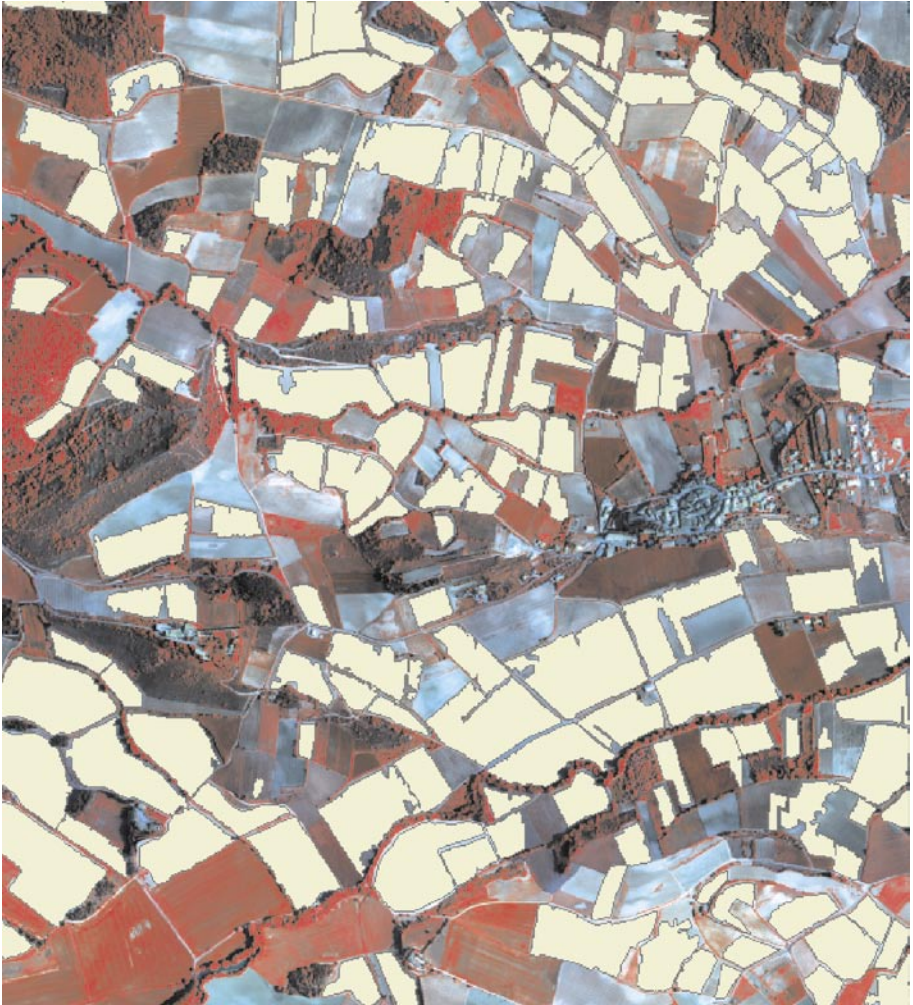
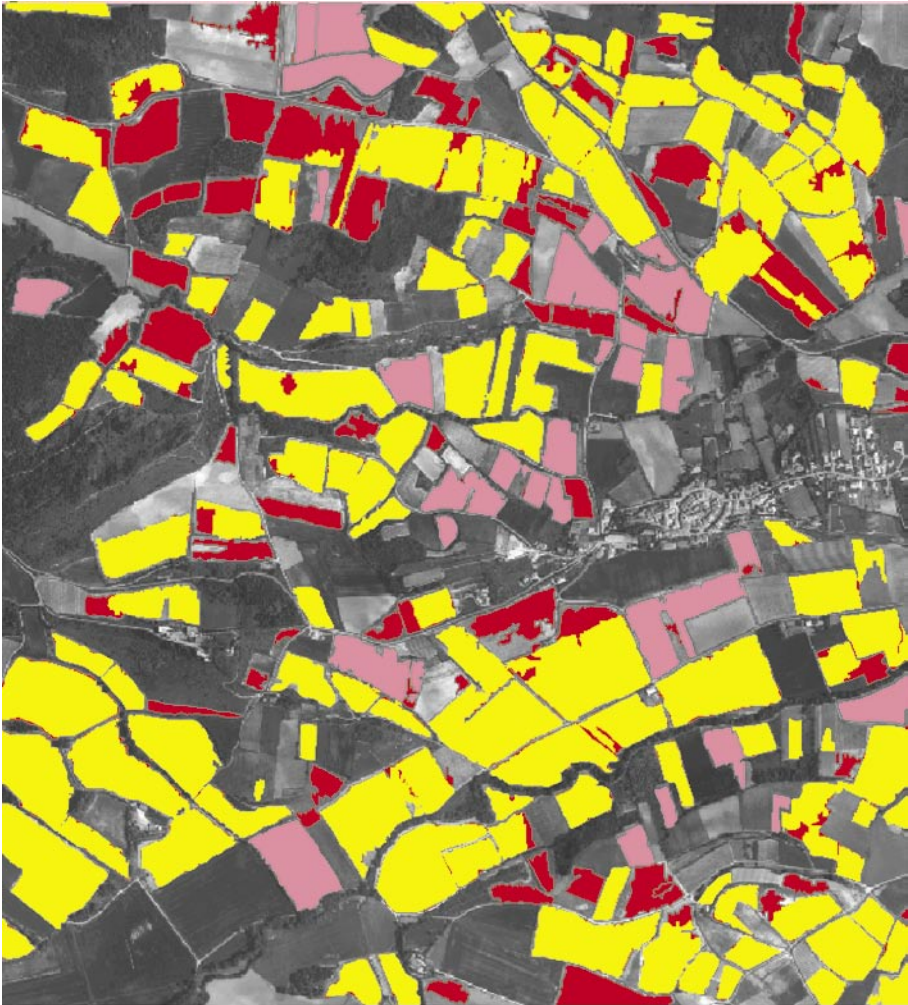


FIGURE.4.13. RESULTS OF THE SEGMENTATION ON THE NEAR INFRARED CHANNEL OF THE INTA IMAGE, LIMOUX TEST-SITE (FRANCE)






-  Plots detected with both bands
-  Plots detected with the red band only
-  Plots detected with the NIR band only

FIGURE.4.14. COMPLEMENTARITY OF DETECTION WITH THE RED AND NEAR INFRARED CHANNELS OF INTA DATA, LIMOUX TEST-SITE (FRANCE)

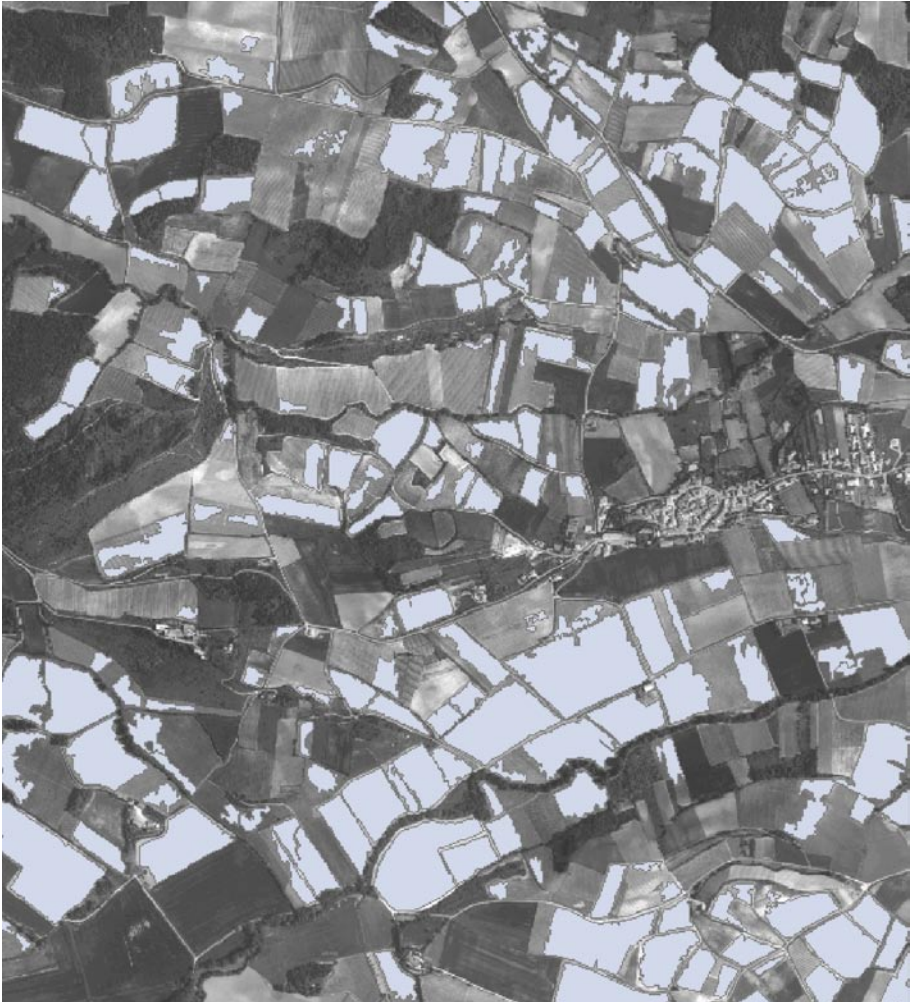


FIGURE.4.15. RESULT OF THE SEGMENTATION ON THE PANCHROMATIC CHANNEL OF THE INTA IMAGE, LIMOUX TEST-SITE (FRANCE)



FIGURE.4.16. RESULT OF THE SEGMENTATION ON THE PANCHROMATIC CHANNEL OF THE QUICKBIRD IMAGE, LIMOUX TEST-SITE (FRANCE)



FIGURE 5.8. LANDSAT TM (LEFT) AND QUICKBIRD IMAGE OF SPANISH BACCHUS TEST SITE. BOTH IMAGES ARE FROM 2003-07-31

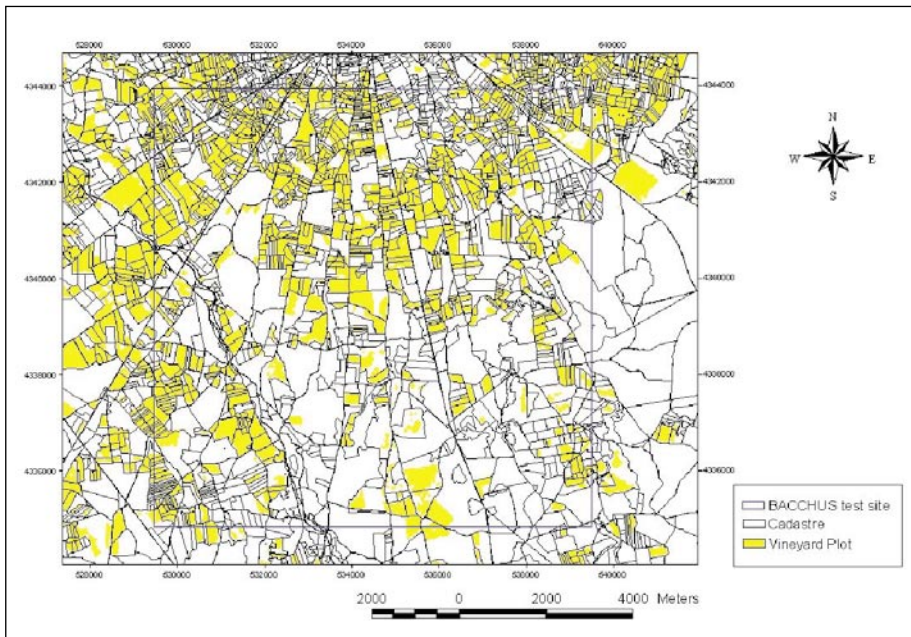


FIGURE 5.9. VINEYARD MAP OF TARAZONA DE LA MANCHA (SPAIN) TEST SITE. MULTISPECTRAL/MULTITEMPORAL APPROACH

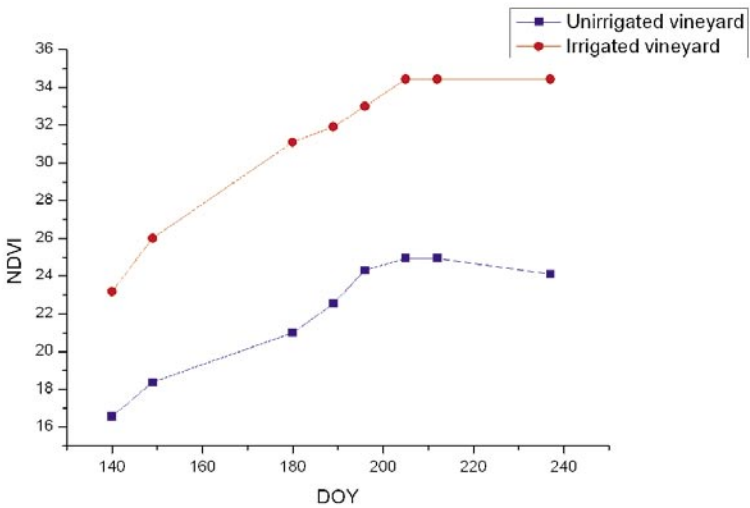
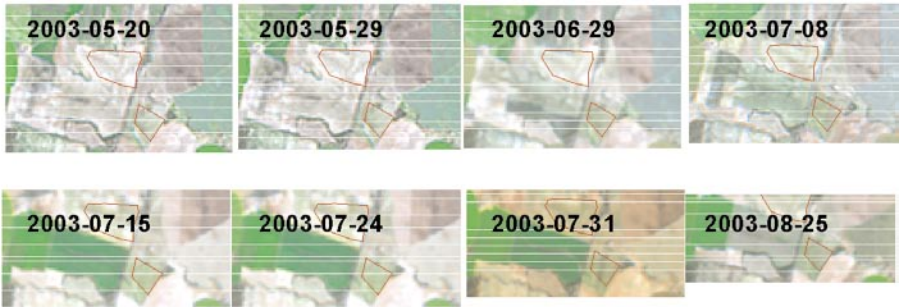


FIGURE 5.10. NDVI TEMPORAL EVOLUTION OF IRRIGATED/UNIRRIGATED VINEYARD PLOTS OVERTARAZONA TEST SITE. EACH POINT OF THE GRAPHIC IS THE AVERAGE VALUE OF NDVI FROM THE PLOTS DELIMITED BY RED LINE FOR EACH IMAGE, WHICH RGB543 IS SHOWED

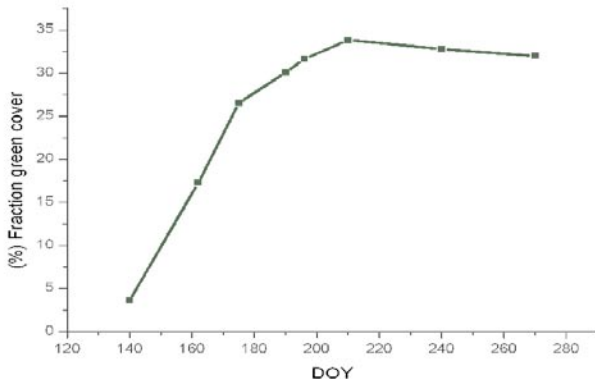
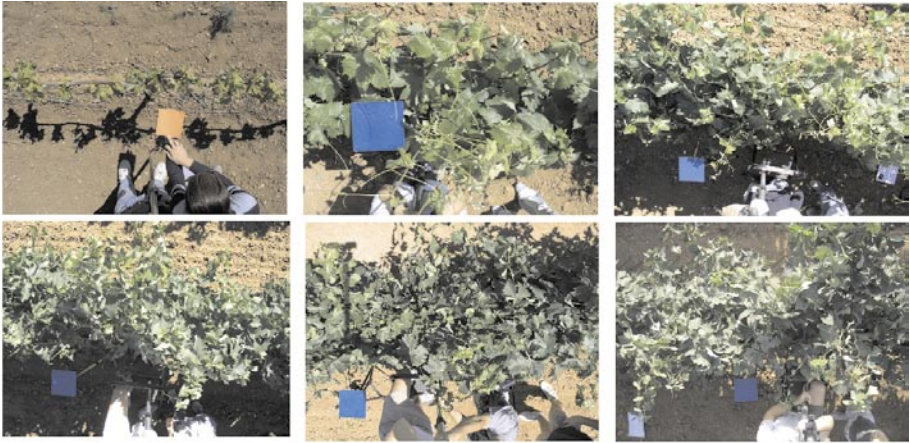


FIGURE 5.11. MONITORING OF FRACTION COVER OVER TARAZONA DE LA MACHA VINEYARD PLOT



FIGURE 5.12. QUICKBIRD IMAGE AND VINEYARD CLASSIFICATION MAP OF SPANISH TEST SITE (VILLARROBEDO)

GENERAL FLOW

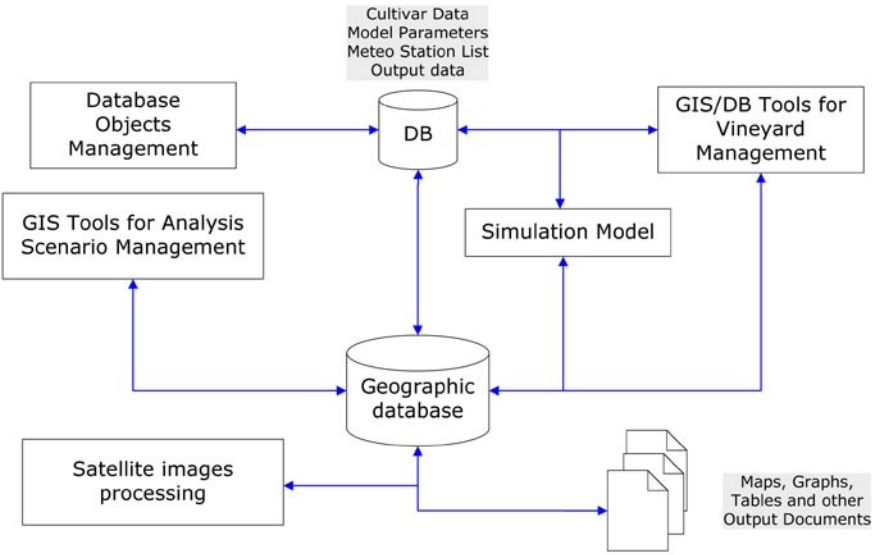


FIGURE 6.1. GENERAL DATAFLOW

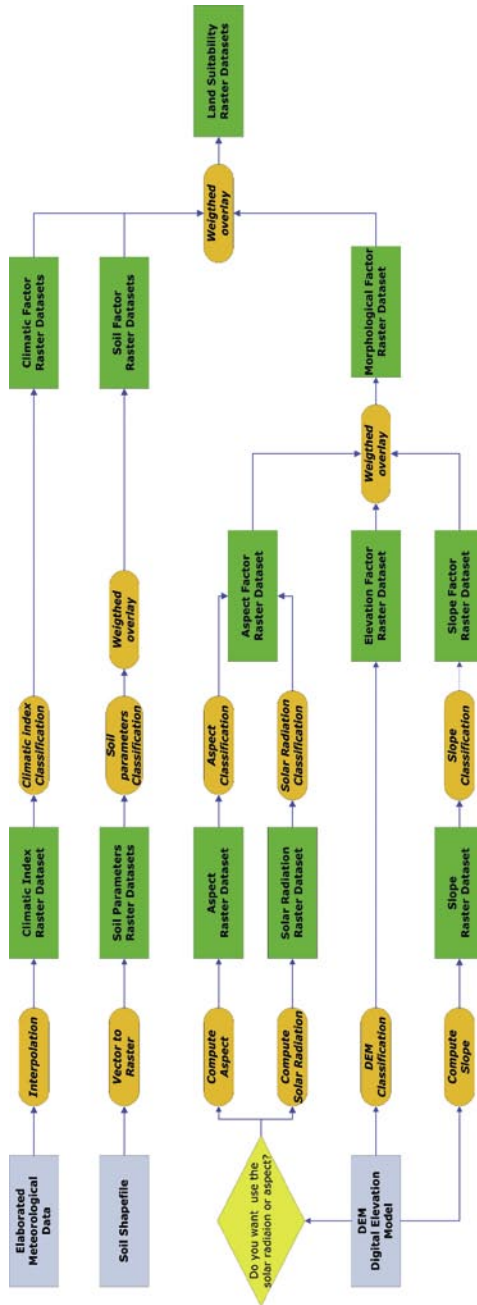


FIGURE 6.3. FLOWCHART OF THE LAND ANALYSIS MODULE

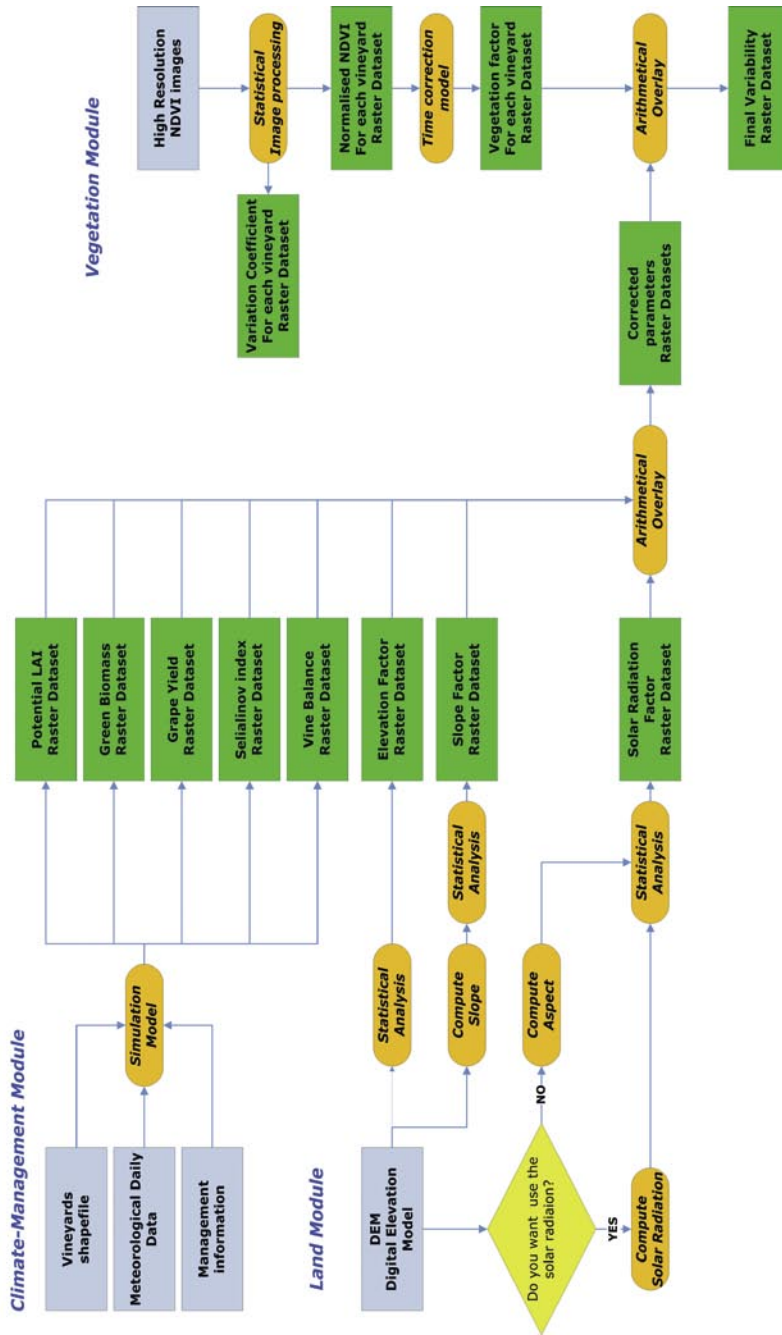


FIGURE 6.5. FLOWCHART OF THE VARIABILITY ANALYSIS MODULES

**FRASCATI
MALVASIA**

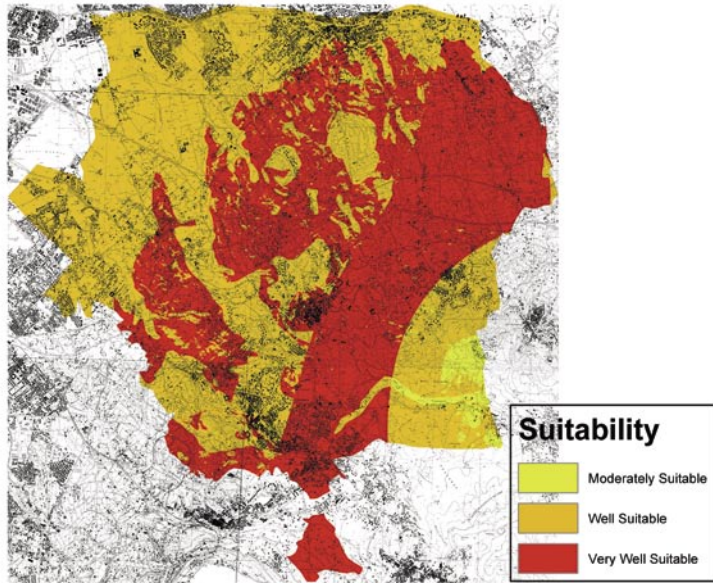


FIGURE 6.7. LAND SUITABILITY FOR THE MALVASIA DEL LAZIO IN THE FRASCATI DOC AREA

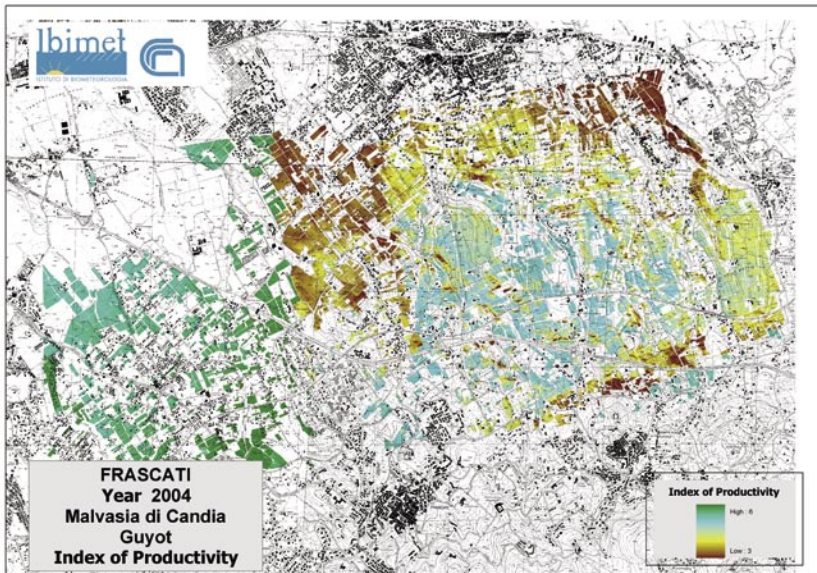


FIGURE 6.8. INDEX OF PRODUCTIVITY FOR THE FRASCATI DOC AREA

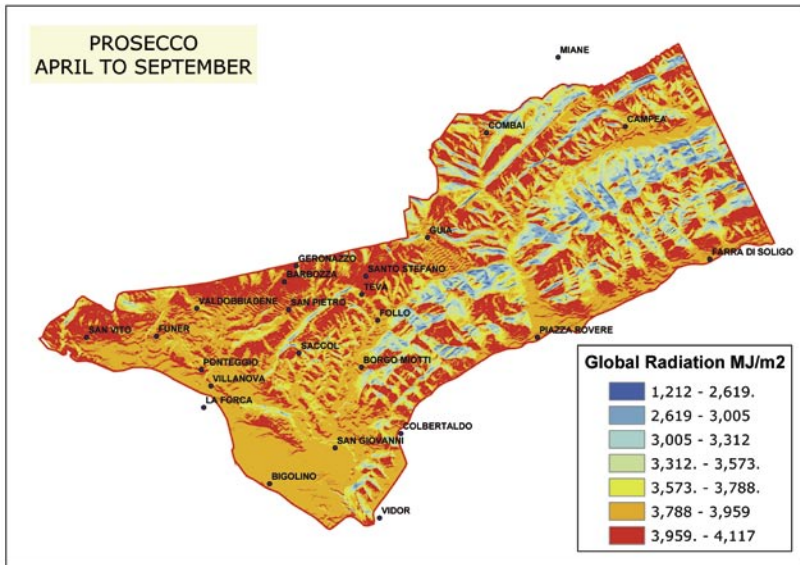


FIGURE 6.9. CLASSIFICATION OF THE PROSECCO DOC AREA ON THE BASE OF THE GLOBAL SOLAR RADIATION, COMPUTED BETWEEN APRIL TO SEPTEMBER.

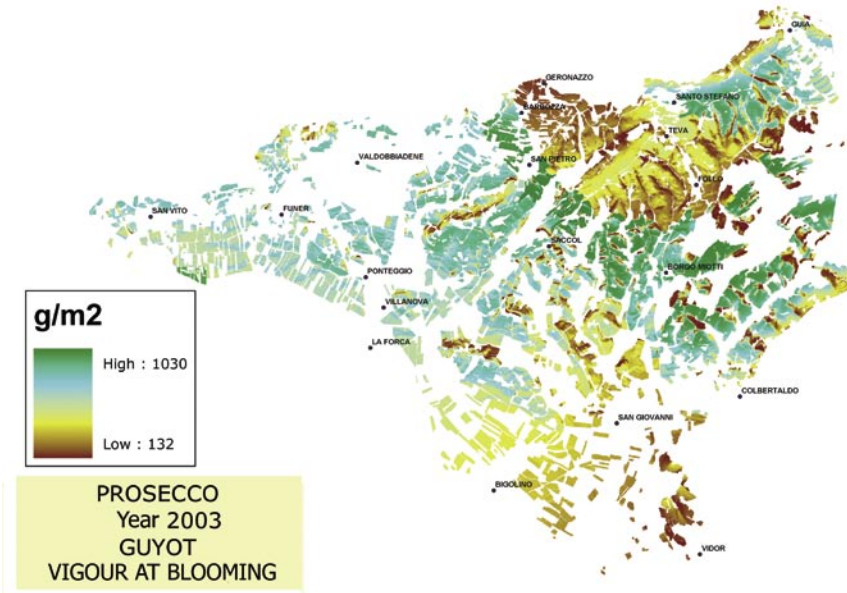


FIGURE 6.10. ESTIMATION OF THE SPATIAL VARIATION OF PLANT VIGOUR AT THE PHENOLOGICAL PHASE OF BLOOMING.

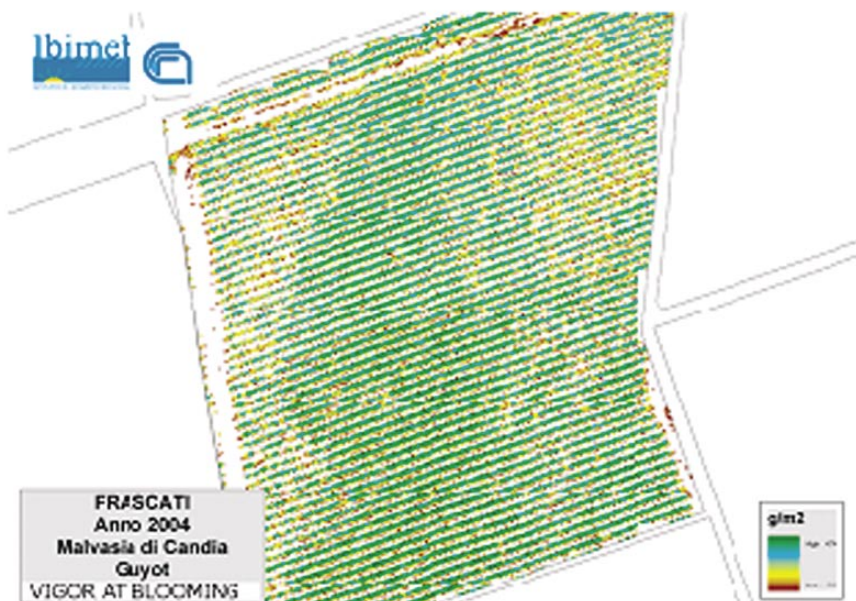


FIGURE 6.11. PLANT VIGOUR AT BLOOMING FOR A SINGLE VINEYARD

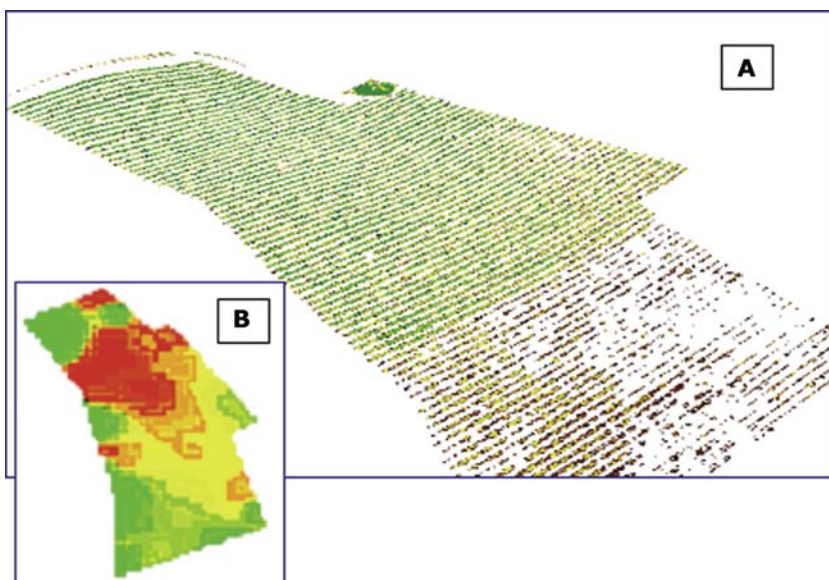


FIGURE 6.12. DETAILED REPRESENTATION OF YIELD QUALITY FORECASTING OUTPUTS: A) CONTINUOUS VALUES; B) CLASSIFICATION



FIGURE I.1. AIRBORNE MULTISPECTRAL DIGITAL CAMERA AMDC



FIGURE I.2. INS/GPS MODULE APPLANIX POS/AV 410

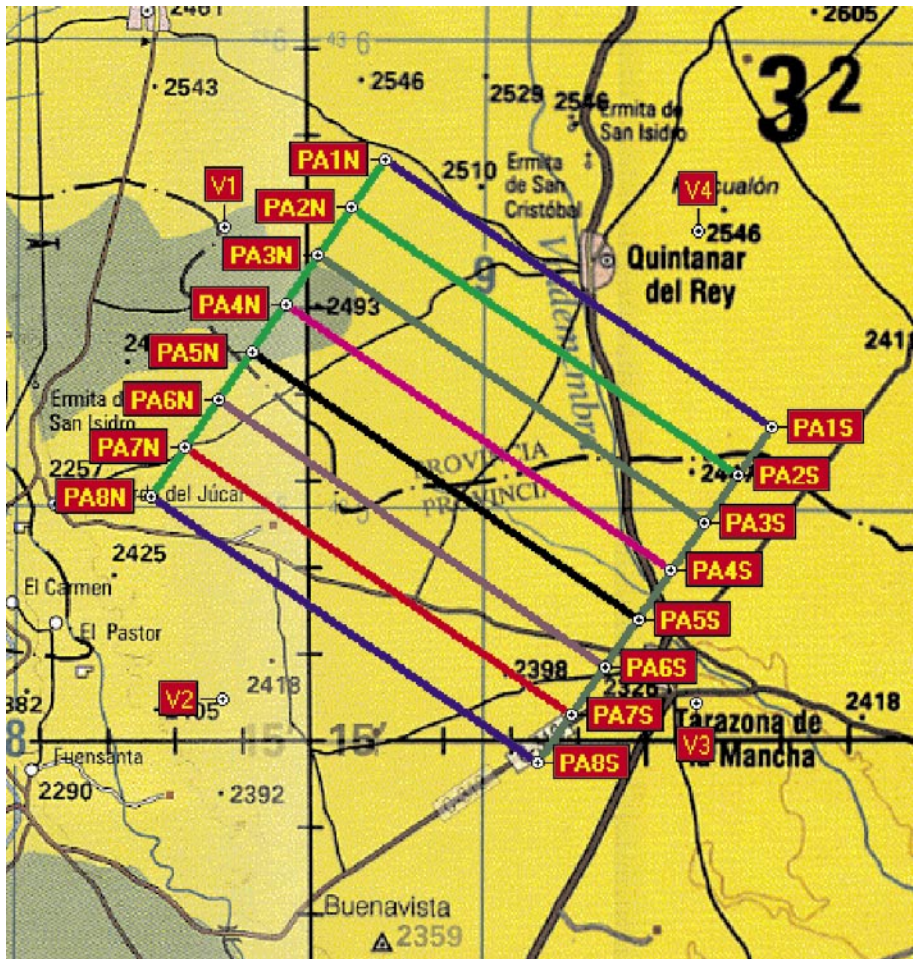


FIGURE I.3. SKETCH OF 2003 TARAZONA FLIGHT TRACK PATTERN

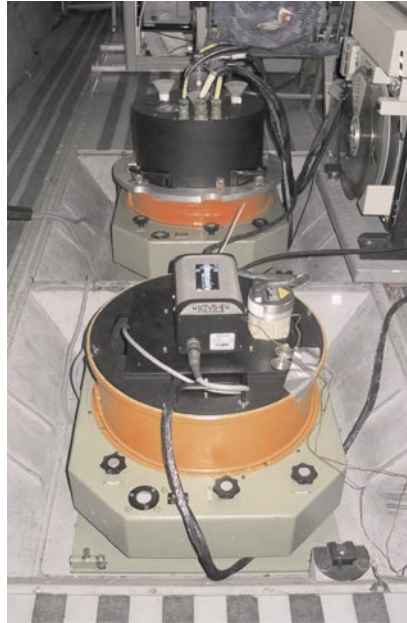


FIGURE I.4. AIRCRAFT + SENSORS CONFIGURATION FOR 2003 BACCHUS SURVEYS. (ATM+AMDC)



FIGURE I.5 FLIGHT CREW PARTICIPATING IN 2004 SURVEYS

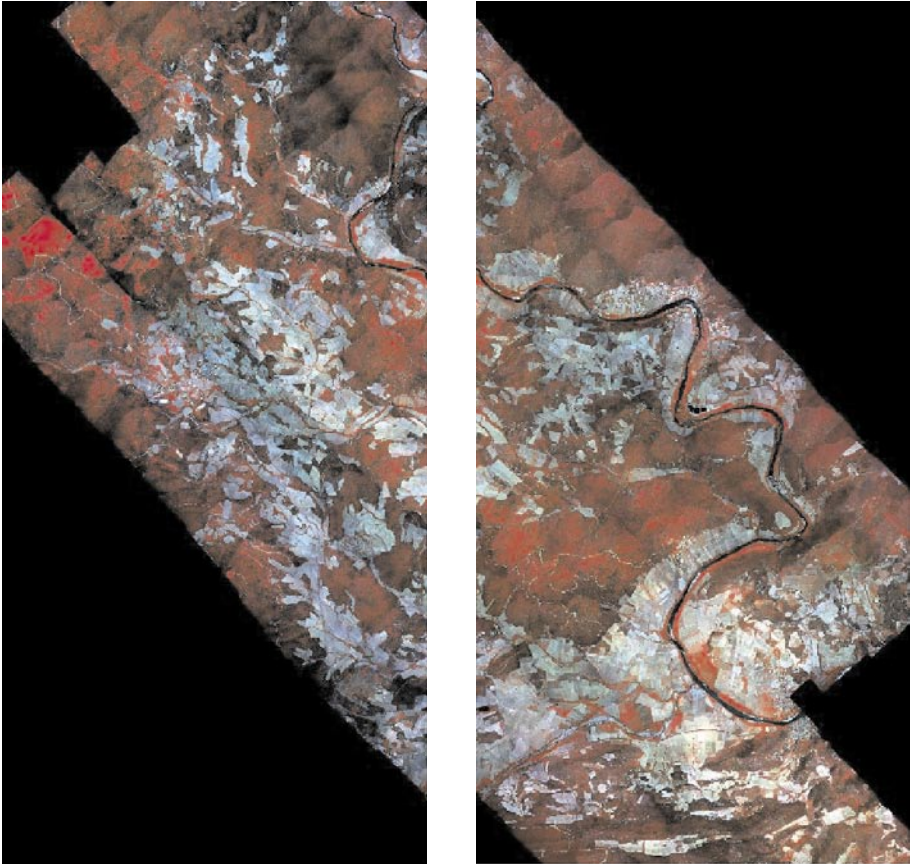


FIGURE I.6 AMDC SAINT CHINIAN MULTISPECTRAL IMAGE

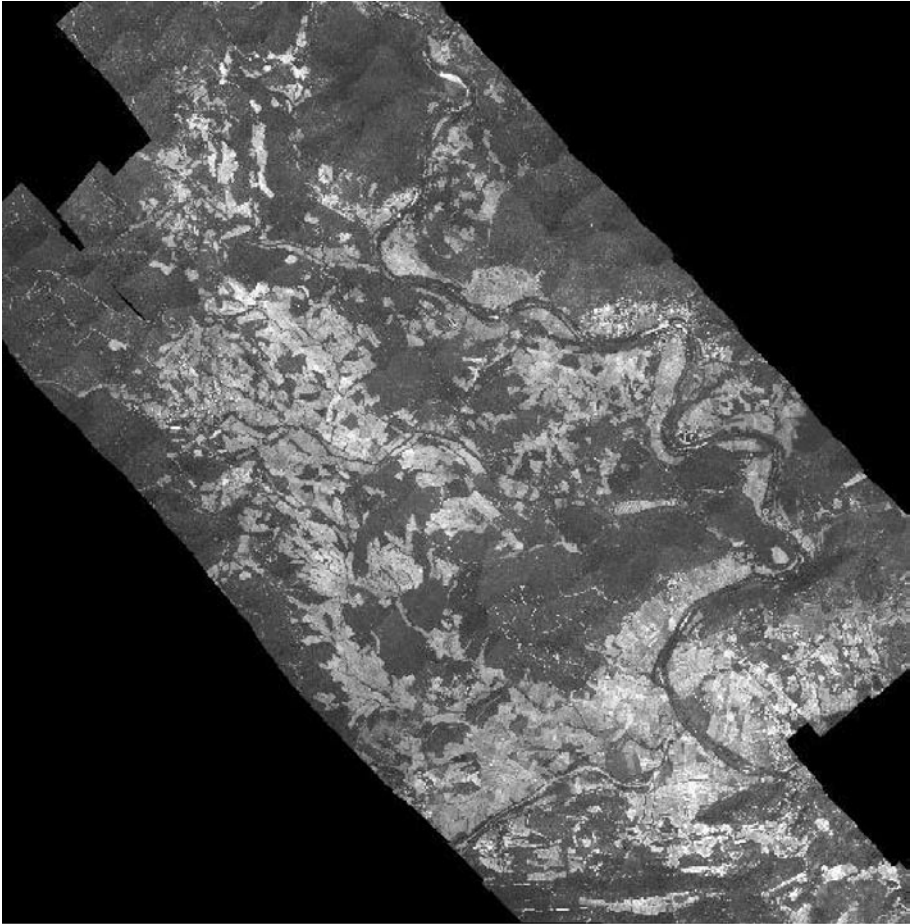


FIGURE I.7 AMDC SAINT CHINIAN PANCHROMATIC IMAGE

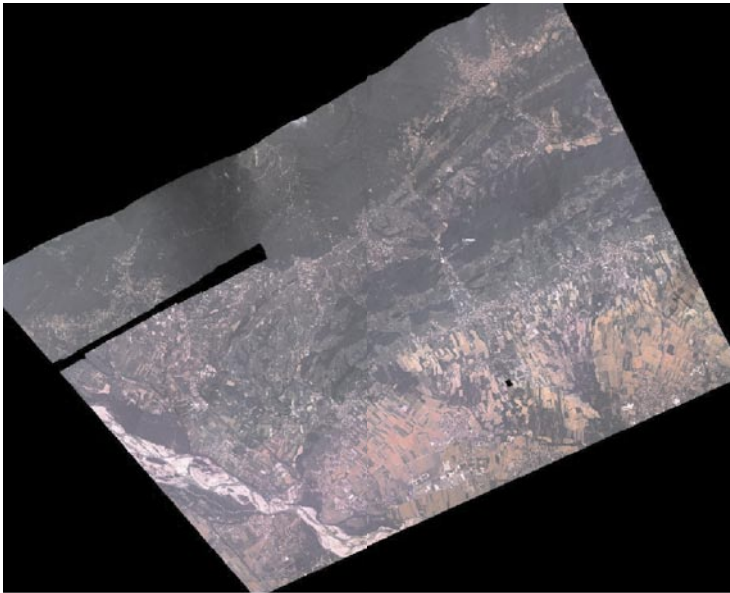


FIGURE I.8 AMDC PROSECCO MULTISPECTRAL IMAGE

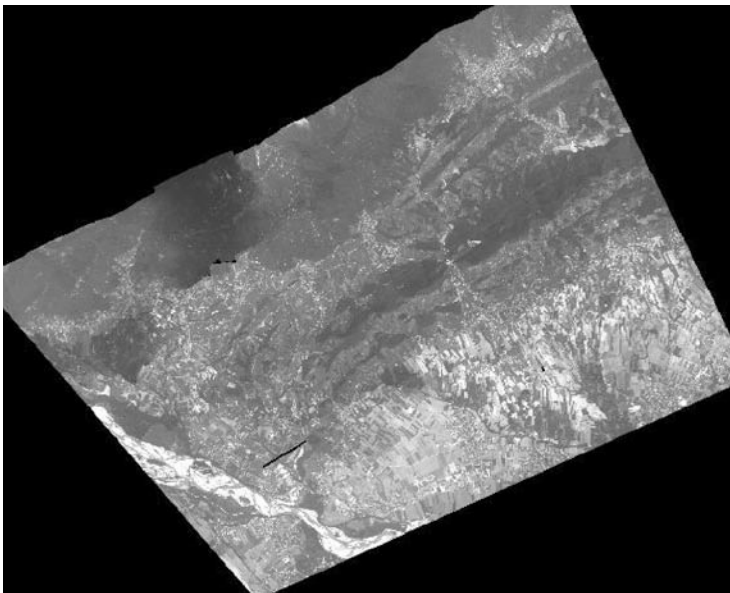


FIGURE I.9 AMDC PROSECCO PANCHROMATIC IMAGE

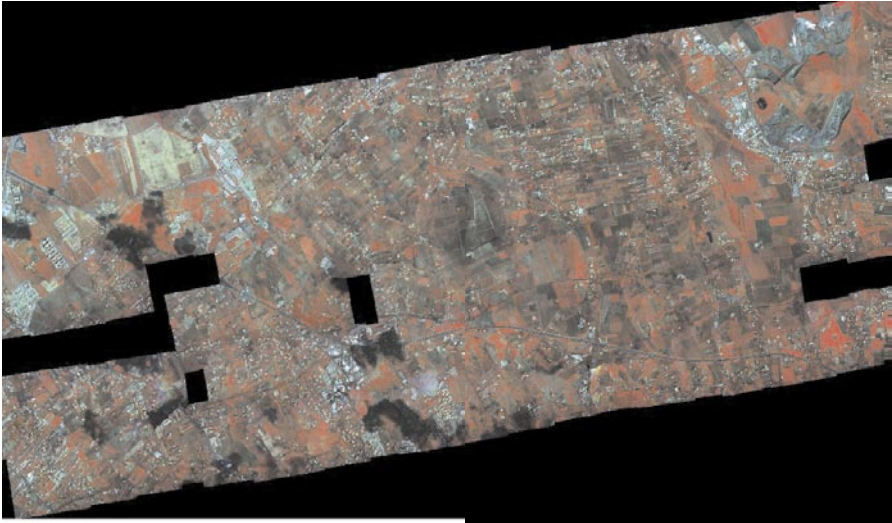


FIGURE I.10 AMDC FRASCATI MULTISPECTRAL IMAGE

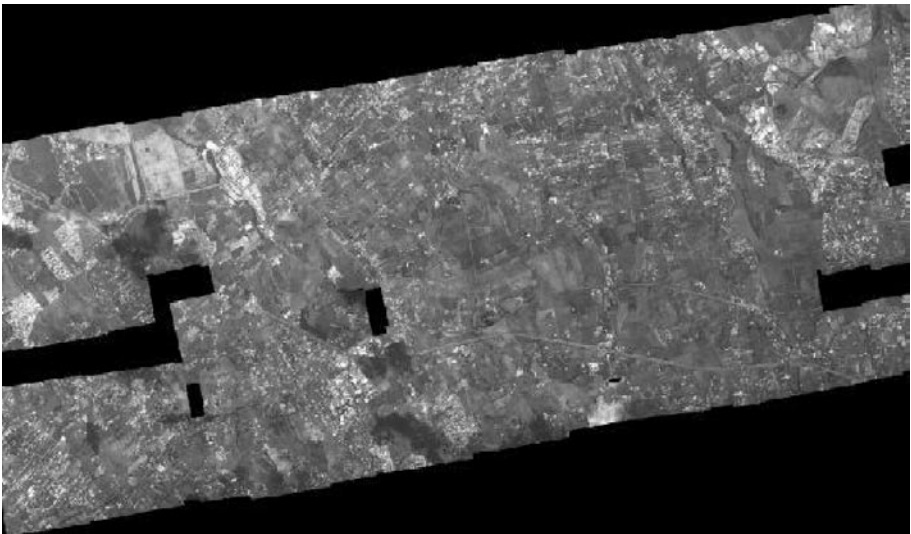


FIGURE I.11 AMDC FRASCATI PANCHROMATIC IMAGE



FIGURE I.12 AMDC BAIRRADA MULTISPECTRAL IMAGE



FIGURE I.13 AMDC BAIRRADA PANCHROMATIC IMAGE

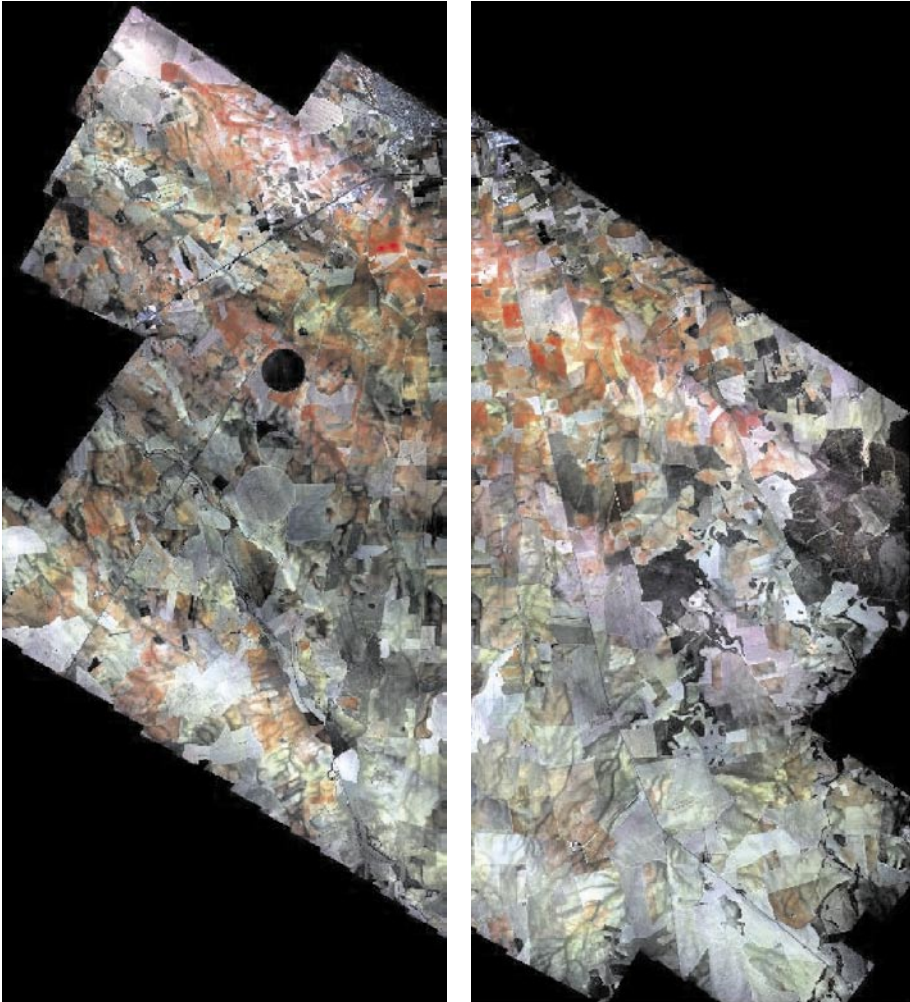


FIGURE I.14 AMDC VILLAROBLEDO MULTISPECTRAL IMAGE

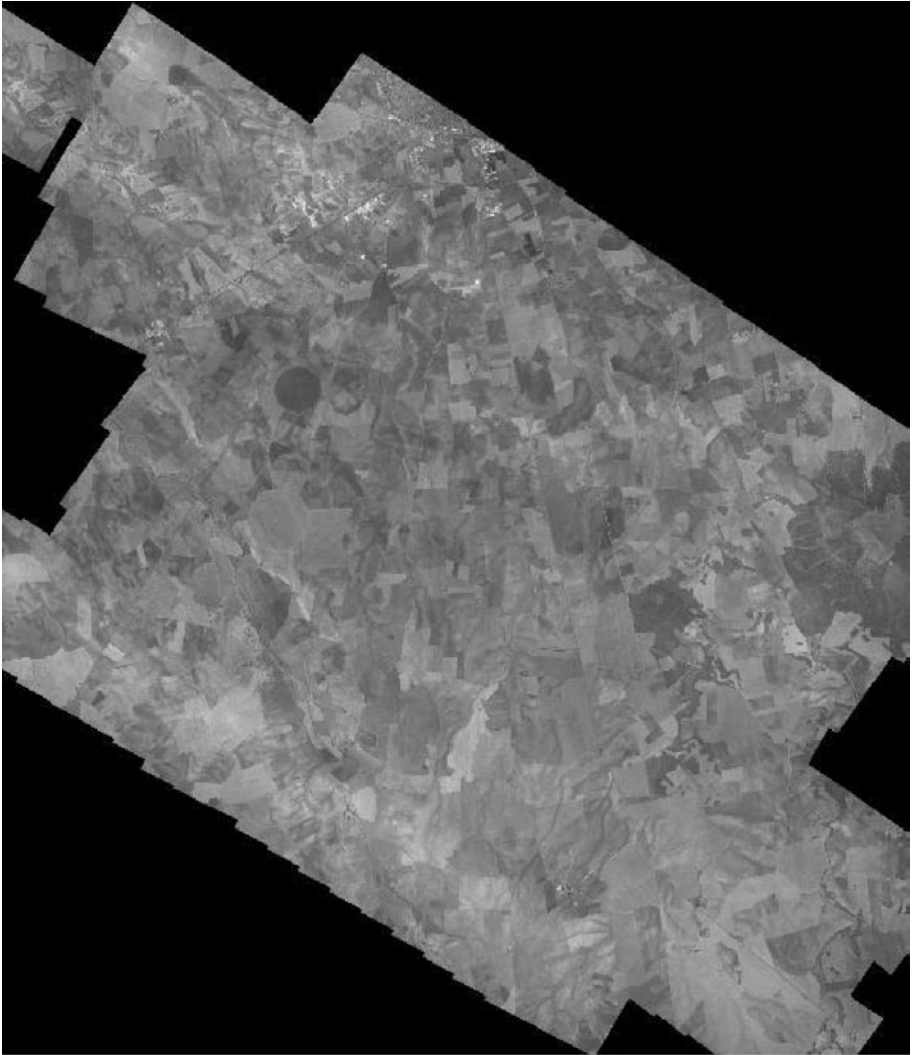


FIGURE I.15 AMDC VILLAROBLEDO PANCHROMATIC IMAGE

