

Precision Vineyard Management from Space

– From Bacchus to Eneide



ESA/ESRIN lies in the middle of the Frascati DOC wine-growing region, southeast of Rome. The right-hand image is an ERS multi-temporal satellite image of the Rome and Castelli Romani region. The second image is from an INTA aircraft multi-special-imaging overflight of the Frascati vineyard area (ESRIN entrance and surrounding vineyards) conducted in 2004, with 50 cm resolution



Simonetta Cheli & Luigi Fusco
ESA/ESRIN, Frascati, Italy

Stefano Sandrelli
Osservatorio Astronomico di Brera, Milan, Italy

In a highly competitive global market such as the wine business, consistent quality is a must, especially if Europe wants to maintain its position as world leader. It currently accounts for 55% of the world's vine-growing areas, 60% of wine production and 70% of exports.

In this very special sector of agriculture, technology and science play fundamental roles in all phases of activity, from the start of the vine-growing season, through the ripening of the grapes, to the bottling of the wine. The quality of the wine produced depends on many parameters, including the soil characteristics in the area, the weather and growth conditions during the season, the ability to monitor and control vine diseases, the degree of maturity of the grapes at harvest time, their grade, colour, organic acids, etc. during fermentation and, finally, the wine production techniques employed. In general, however, European vineyard managers still have little access to technical means or reliable systems to guide them in their decision-making.

Precision Farming in the Frascati area

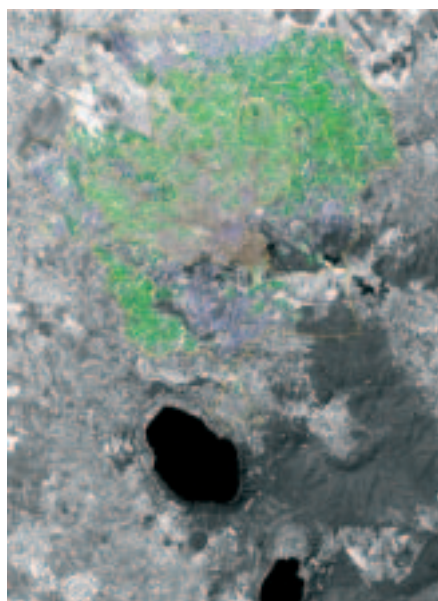
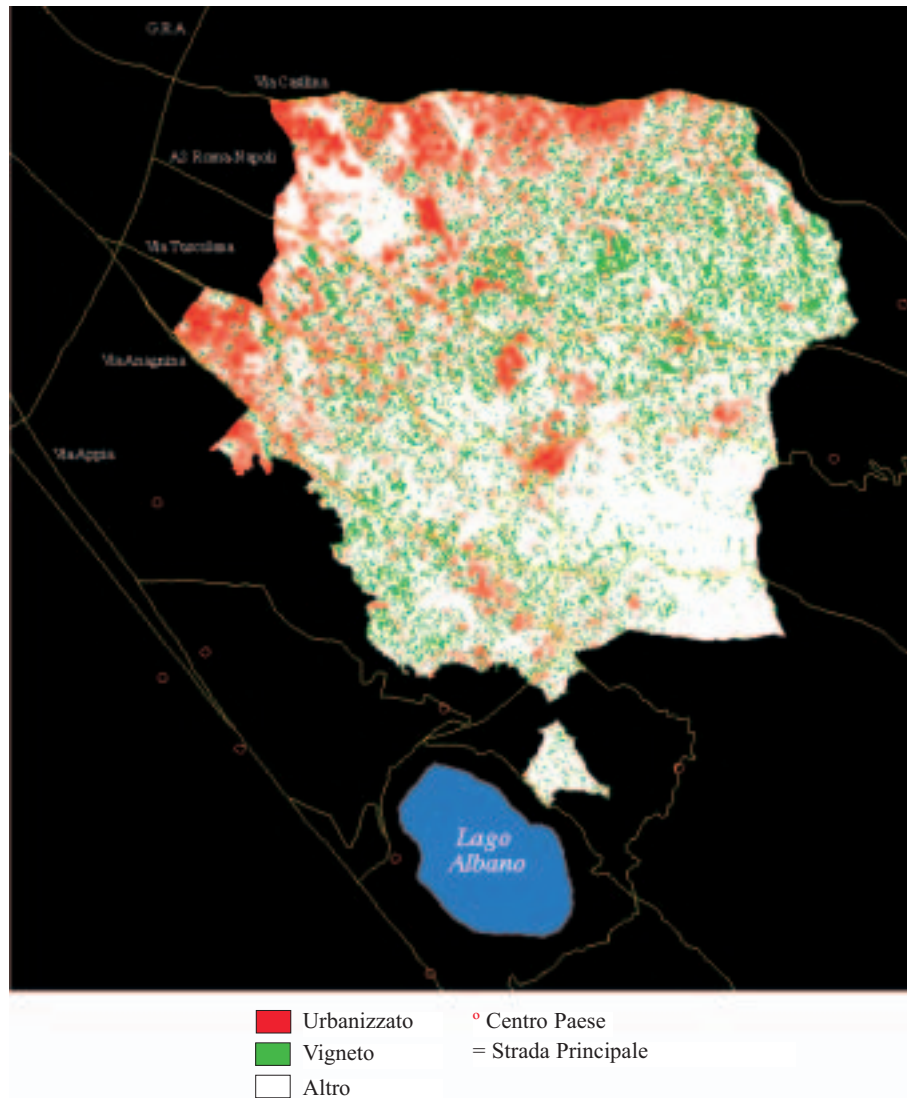
Space technologies, particularly those associated with Earth Observation (EO), can help the wine-growing community in a number of technical areas. One of several initiatives promoting the use of EO in the wine sector has been 'Bacchus', a Research and Technological Development project started in 2003 (to be completed in 2005), funded by the European Community through its Fifth Framework Programme. The project is led by a consortium representing SMEs, institutes, public agencies and regulatory organisations from the main wine-producing regions of Spain, Italy, France and Portugal (see <http://www.bacchus-project.com>).

Assessment of the urban pressure exerted by Rome's growth on the Frascati DOC area: red = anthropic areas, green = potential vineyard area, as classified using a Landsat-4 TM dataset in 1986

Bacchus's goal has been to demonstrate to regional vineyard regulatory bodies, vine quality-control bodies and wine producers how a comprehensive space-based solution can meet their information needs. Such a solution relies on the integration of very-high-resolution remote-sensing data gathered from space with other more traditional information available, for instance, in Geographical Information Systems (GISs). This Bacchus project environment has been used as a reference infrastructure for:

- defining new data-handling methods for improving current methodologies for vine area location, land parcel identification, and vineyard inventory making
- generating new land-management reference maps and experimenting with dedicated models for vineyard management.

Test sites in the participating countries have been selected for the trialing of pilot system(s) and for demonstrating the potential of this integrated approach to several interested parties in the wine business. In particular, the Frascati DOC



(Denomination of Controlled Origin) wine region was selected as one of the two Italian Bacchus test sites.

ESA's ESRIN establishment happens to lie right in the middle of this important wine region southeast of Rome, which is partially in the volcanic Castelli Romani area. Since the start of the Earthnet Programme at the end of the 1970s, the Earth Observation team at ESRIN has had routine access to imagery from Landsat, ERS, Envisat and several other high-

Composite of IRS (5 m resolution) and Quick Bird (0.61 m panchromatic, 2.4 m multi-spectral) satellite imagery covering the Frascati area. The yellow line identifies the boundaries of the community participating in the Frascati DOC region; the green lines delineate the Frascati DOC vineyards, and the blue lines the built-up areas in the region

resolution EO missions. It has therefore accumulated a large archive of EO data and related information on the Frascati area, mainly to verify the quality of the ESRIN-generated EO products. Such data include a high-quality digital elevation model, for documenting the changes in local land use and environmental parameters over time. By using historical Landsat Thematic Mapper datasets, for example, it was possible in 1996 to assess the urban pressure of the city of Rome on the Frascati DOC area over the previous 10 years.

Comparison with the classification performed using images taken in 1996 shows that:

Urban	in '86: 14.59%	in '96: 15.70%	delta: +1.11%
Vineyard	in '86: 38.00%	in '96: 35.45%	delta: -2.55%
Other:	in '86: 47.40%	in '96: 48.85%	delta: +1.45%

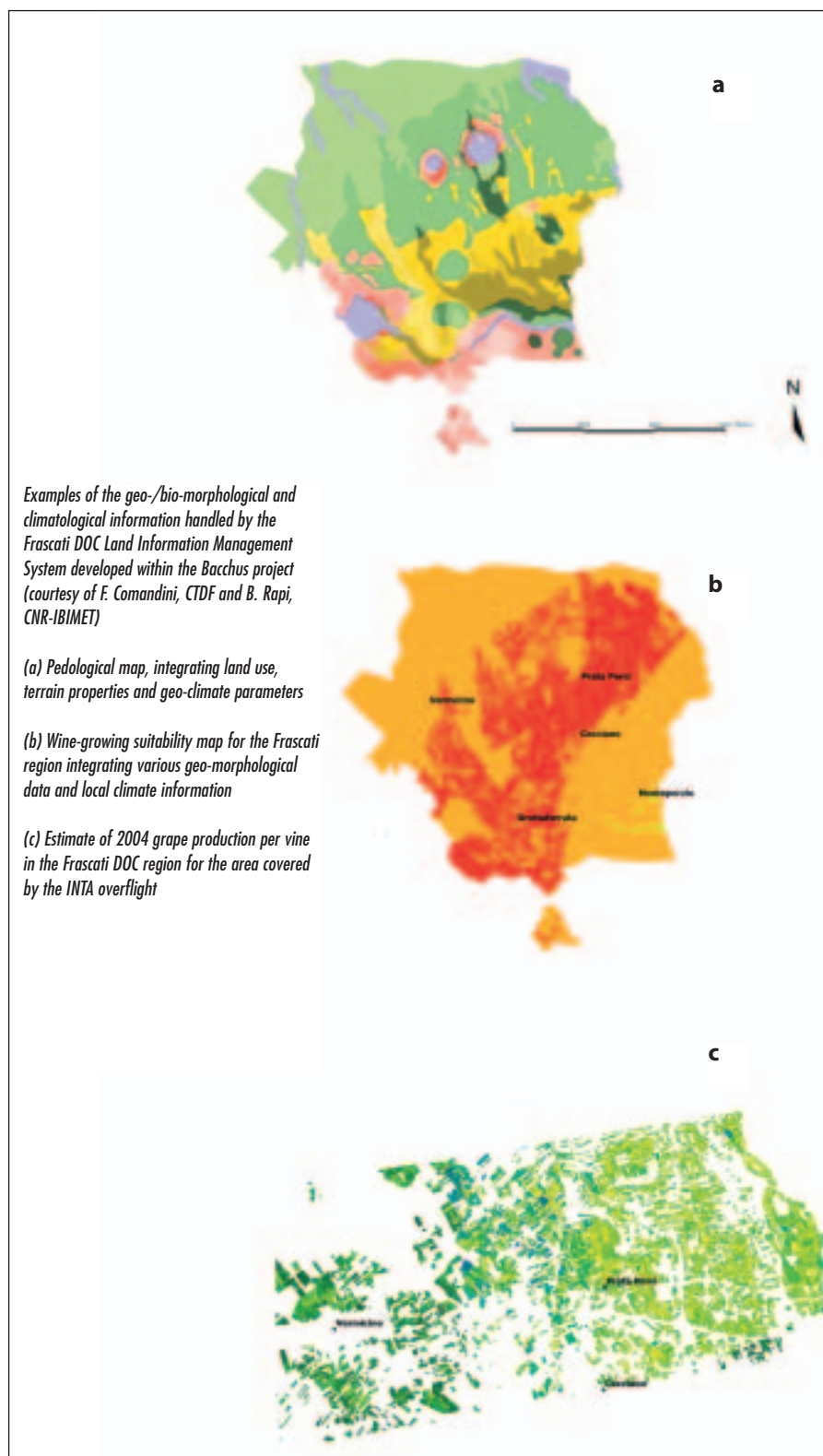
This space-based assessment is in line with the changes defined in the land register for the Frascati DOC production.

The friendly spirit of cooperation between ESA/ESRIN, the local scientific institutions (in particular the University of Tor Vergata and the Consiglio Nazionale della Ricerca, Istituto Scienze Atmosfera e Clima) and the local authorities (in particular the Municipality of Frascati), all of whom have an interest in understanding and monitoring the evolution of the environment in this part of the world, has allowed a unique multidisciplinary knowledge base concerning farming in the Frascati area to be established. Integration of this knowledge into the enlarged Bacchus project partnership has led to the generation of very high-quality land-management information systems specifically tailored for the Frascati DOC area.

Results for the Frascati Test Site

The Bacchus project has taken advantage of recent progress in EO and ICT technologies, including:

- The availability of very-high-resolution imagery from space: IKONOS (since 2000) and QuickBird (since 2002) have been providing data with 80 cm and 60 cm resolution, respectively. European missions with similar capabilities, also at radar frequencies, will soon become available (e.g. Pleiades and Cosmo Skymed) and be able to support wine management applications.
- Good progress in web technology, especially for the handling of mapping services as part of the Open GIS consortium standardisation effort and the European INSPIRE initiative: the availability of web-GIS technology will make the dedicated geomatic services accessible via the Internet.
- Wireless communication: Significant progress has been made in the integration of wireless communication, for example to collect ground measurements or provide information





A Proba CHRIS image frame covering the Frascati DOC test area, supporting study of the phenology of the grape in the region by the University of Tor Vergata, CNR-ISAC and ESA/ESRIN). The black areas are all the vineyard parcels belonging to the Frascati DOC region

via portable devices. Vineyard managers view this technology with interest for supporting the wine traceability chain.

During the Bacchus project a number of dedicated tools have also been developed for:

- EO image data and GIS management, by the Spanish partner GEOSYS, to provide a friendly PC-based, end-user environment
- specific vineyard area high-resolution image classification and feature extraction, by the French partner CEMAGREF
- vineyard land analysis and management, by the Italian partner CNR-IBIMET. It provides models for vineyard area management and land-use potential for single vineyard parcels in terms of vine vigour, production potential and potential product quality.

Accurate knowledge of the local weather and climatic characteristics are of major importance for top wine-producing areas. The climate can have positive effects in

that, for example, less frost may increase wine production, but also dramatic impacts in that it may also affect the annual timing of the main stages in grapevine development (bud break, flowering, veraison, maturation) or change the relationship between the vines and their parasites.

The hyperspectral view (18 bands and 18 m resolution) provided by the CHRIS instrument on ESA's Proba satellite, launched in October 2001, has the potential to yield additional information on vineyard 'phenology' - the link between grape health and ripening and local climate. This information can help significantly in adjusting viticulture and wine production to the potential climate changes that are believed to be on the way.

A few CHRIS images have already been acquired over the Frascati area for the Bacchus project. Co-registration of the images to a common geometry has proved to work satisfactorily and the new imagery has already been integrated into the Bacchus system.

ERS and Envisat radar imagery allows the ready retrieval of key information about observed vineyards, such as grape quality and surface parameters. The chronology of the cultivation practices in each vineyard can also be derived, which is a basis for gathering precise information about conditions within the land parcels in question.

In a side-study to Bacchus, carried out for a final-year dissertation at the University Tor Vergata, ERS-Envisat synthetic-aperture-radar (SAR) imagery was correlated with very-high-resolution QuickBird optical images to survey the approximately 1800 hectares of the Frascati DOC area. The integration of the SAR data into Bacchus has allowed the retrieval of radar scattering information for individual vineyard parcels. The study has shown that SAR data may also be useful for monitoring the development and ripening of the grapes, with a consistently sharp increase in backscattering detected during ploughing and harrowing in March and April. Strong correlations have also been observed between SAR backscattering and the quantity of the grapes produced in a number of the parcels monitored.

The Eneide Mission and the VINO Experiment

Given that wine production can be studied from space, Valfredo Zolesi, Chairman of Kayser Italia SpA, began to think about the possibility of studying the behaviour of grapes directly in space. After all, he thought, the vine has been regarded historically as a companion to man, with archaeologists believing that wine-making can be traced all the way back to 5600 BC, and it would therefore be fascinating to think of vines now accompanying men and women on their space exploration travels too.

Such an opportunity was provided by the Soyuz 10S flight to the International Space Station (ISS), which included the Italian



The box that housed the vines for the VINO experiment on the ENEIDE mission

ESA astronaut Roberto Vittori. An experiment known as VINO (Vines in Near Orbits) was therefore rapidly prepared and financed by Kayser Italia, the vineyard associations of Tuscany, and the provincial authorities of Livorno. The Soyuz mission, named ENEIDE, was launched on 15 April 2005 from the Baikonur Cosmodrome and during his eight-day stay on the ISS Roberto Vittori conducted a programme of 21 experiments, including VINO.

VINO was the first attempt to study the growth and development of grape-vine cuttings in space. A few samples of rooted cuttings of Sassicaia, a high-quality grape variety grown at Tenuta San Guido in Bolgheri, in the Livorno area, were grafted and taken up to the Space Station. It was the first time that such a complex plant had been studied in space. Whilst in orbit, the samples were left to grow at ambient temperature inside a sealed container, to prevent possible bacterial contamination. Once back on Earth, the rooted Sassicaia cuttings were analysed to gauge what kinds of stresses they had undergone.

Fluid circulation was one of the most interesting aspects of the analyses, since the rooted cuttings were grafted and the nutrient fluids therefore had to deal with two different types of wood. The vines have since been replanted and in the coming weeks we will see how healthy they are and start to evaluate the effect of their trip into space on their reproduction and growth capabilities. When the plants are ready to bear grapes next season, more analyses will be performed ...

The Wine Community Meets Space Technology

During his stay in space, Roberto Vittori participated by audio link in a novel workshop titled 'Space for Wine', organised by ESA/ESRIN in collaboration with the municipality of Frascati, the Strada dei Vini dei Castelli Romani (Wine Itinerary of the Roman Castles) and the Consorzio di Tutela Denominazione Frascati (Consortium for the protection of the Frascati designation of origin). The workshop was open to local, regional and national institutions and those involved in the wine business. The goal was to explain how the application of space technology and associated sciences could help the wine-growing community, and the ESA astronaut gave the participants a brief overview of the VINO experiment and its aims. The workshop presentations are available at:

http://www.esa.int/esaCP/SEMxD7NQ57E_Italy_0.html

The Effect of Global Change on Wine-Growing Regions

As already noted, climate change in the form of global warming can have negative as well as positive effects on vine-growing areas, with the most damaging impacts expected to occur in today's top wine-producing regions. A new WWF study echoes several other recent reports in suggesting that the Earth will warm by 2 degC (3.6 degF) above pre-industrial levels between 2026 and 2060, unless major steps are taken to reduce greenhouse-gas emissions. The need to change cultivars to cope with such climate changes could spell economic disaster for the Chianti or Chardonnay vineyards, but also for the Frascati DOC area.

On the other hand, two of the 'Space for Wine' presentations highlighted potential benefits:

- A. Castagnoli discussed how the influence of global change could represent an opportunity for some wine regions to use presently marginal areas for the production of higher quality wines in the future.

- M. Severini discussed how the vintage ratings of the Frascati DOC wine have increased over the last 20 years, showing how this may be correlated with a decrease in the number of frosts experienced per year in the Frascati region.

Another related issue is the earlier maturation of the grape crops in the years to come. On the basis of local long-term meteorological measurements, it is estimated that in 2050 the Frascati grapes will ripen about three weeks earlier than today. As regards the effect of a temperature increase on the evolution of insects, which may in turn affect quality grape production, the conclusion from modelling is that, fortunately, it will be minor, since the estimated warming is not sufficient to enable these insects to complete the fourth reproduction cycle before grape maturity.

The Future of Vineyard Management

The various vineyard-management applications of Earth Observation data gathered from space which were presented at the 'Space for Wine' workshop clearly demonstrate the potential of space monitoring solutions for this highly specialised agricultural domain, at the local, regional, national and European level. This view was strongly confirmed by the representatives of the various institutions - Ministry of Agriculture, Regione Lazio and the wine sector - who participated in this unique workshop. The wine sector has clearly-identified operational requirements, and can definitely benefit from the recent and future environmental initiatives at European level, such as the GMES (Global Monitoring for Environment and Security) programme.

Acknowledgement

The authors wish to thank all of the participants in the 'Space for Wine' workshop, and especially those whose data have been used in the preparation of this article.

