Applied Research into the Integration of Spatial Information Systems with Viticultural Research & Vineyard Management Systems

Lloyd Smith[1], Peter Firns[2]

Spatial Information Research Centre

University of Otago. Dunedin, New Zealand

[1]Phone: +64 3 479-8301 Fax: +64 3 479-8311

Email: alsmith@infoscience.otago.ac.nz

[2]Phone: +64 3 479-7391 Fax: +64 3 479-8311

Email: pfirns@infoscience.otago.ac.nz

Presented at the 10th Colloquium of the Spatial Information Research Centre, University of Otago, New Zealand, 16-19 November, 1998

Abstract

Applied research is being carried out into the integration of location specific data with viticulture production, management and market related data using spatial information systems, to enhance viticulture research and vineyard management information systems. It aims to investigate the needs for information systems, the options, and how spatial information technology developments would benefit the grape growing and wine making industry.

The purpose of this paper is to present the research proposals, outline the propositions that spatial information systems can be applied in viticulture, integrated with other management information systems in grape growing and winemaking, and that benefits, including improved quality and profitability, will be obtained by the industry.

***Keywords and phrases*:** spatial information, viticulture research, vineyard management, precision viticulture.

1 Introduction

The establishment and ongoing management of a vineyard requires information. Decisions made by the viticulturist call on information – in the form of personal knowledge, notebook entries, filed documents, maps & charts, spreadsheets or computer databases. The quality of available information is always an important factor determining the quality of decisions made and, therefore, the quality of results – of the grapes produced and, ultimately, profitability if the following quotation is accepted: “It is vastly more profitable for a grower to make wine of a fine quality, thus securing individuality and a reputation for himself, than to produce an inferior quality wine, although in large quantities.” (Bragato 1895)

This research is assessing ways in which information used by viticulturists can be obtained, stored, manipulated, and presented to better meet their requirements. A lot of data may be captured, analysed and applied by the viticulturist. Its usefulness for providing decision support information depends on appropriate data management. The relevance and applicability of spatially related and analysed information is the main topic of the research. It is aimed to explore potential uses and the feasibility of applying computer-based spatial information technology, similar to desktop systems commonly used in many other business applications, to viticulture and vineyard management. The reason for the emphasis on spatial (or geographic) information is that many of the variables affecting grape quality are inherently spatial in nature.

2 Spatial Information and Viticulture:

One way to visualise the nature of spatial information systems is to think of a printed map as containing a lot more information than is visible on its surface. Grape growers may refer to several kinds of maps of the vineyard, and to many categories of information. Behind every map, however, is a wealth of additional or more detailed information not included on the printed map. 'Drill down' into the map and you obtain a lot more information than what has been printed. Paper based maps are static, single theme, current only at the time they are drafted, with no underlying database and unable to be 'queried'. Computerised maps can have multiple thematic layers with extended databases, and can overcome all of these limitations of paper maps. Figures 1 & 2 illustrate these points by depicting a collection of maps comprising a 'spatial database' – the major resource of any spatial information system.

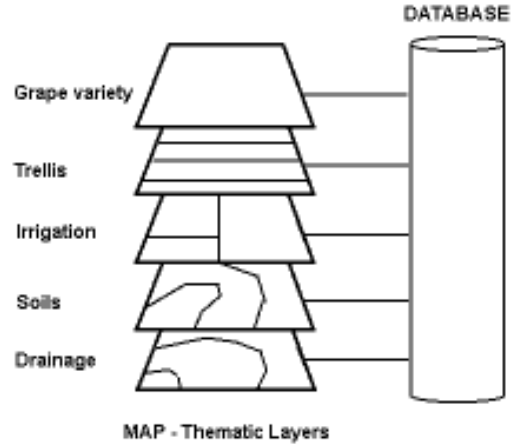

Figure 1: 'Intelligent' map, with extended entity data

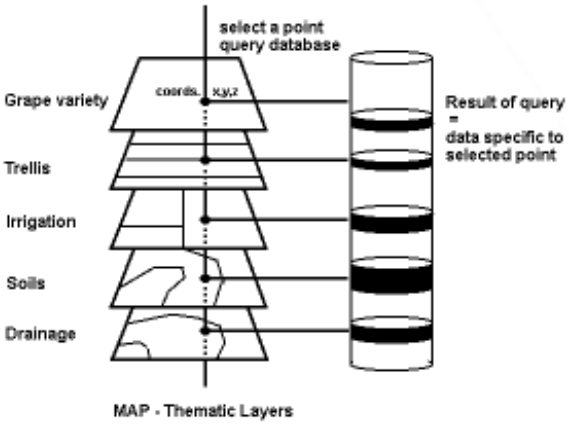

Figure 2: Map Query, of space and related data.(another query option would be – select an area)

Spatial information systems can be integrated and applied with management information systems for inventory purposes and for decision making. They assist in understanding how things act and respond to natural influences and to managed inputs and controls, in the space around them. Integration in this context is the combination of shared data and analysis systems where information used and decisions made in one area affect what happens in another, eg. financial information related to vineyard decisions.

The power of spatial information systems derives from the integration of spatial data with descriptive data pertaining to spatially distributed phenomena – whether these are naturally occurring phenomena or cultivated/manufactured resources. Data describing the management, development, yield and other characteristics of resources is typically integrated with data related to climate, soil, topography and other geographic phenomena. The availability of sophisticated spatial analysis tools provides a basis for management tools in many industries, either managing geographically distributed resources or dependent upon knowledge of geographical phenomena. In the case of wine production, both these characteristics are evident and the interaction between natural phenomena and vineyard management practices is known to have significant effect on the quality of the end product. A spatial information system for viticulture research should, therefore, support analysis which will lead to viticulturists gaining greater understanding of fruit responses to management practices under varying natural conditions. This will require the integration of data from a variety of sources within a well designed spatial database.

Spatial database design includes the specification of geometric/spatial representations of resources as well as attribute data design. A spatial data representation of a vineyard would require geometric objects corresponding to growing blocks, rows of vines and the location of individual vines as well as data representing trellis systems, irrigation networks and other infrastructure. Attribute data of interest includes characteristics of the vines, rootstock, grape quality

and yield, management practices (eg. fertilisation, pest spraying, pruning & irrigation practices) and of the final product. Natural phenomena of interest would include climatic information (temperature, rainfall, sunshine, wind – both micro-climate data monitored within the vineyard and long-term macro-climate data), topographic data & soil-type data. While much of this data may derive from paper maps, its integration within a well-designed spatial database provides a value-added resource for decision support systems in management and research.

Spatial information technology relevant to viticulture includes satellite navigation (GPS) and surveying systems; monitoring equipment and data loggers; remote sensing facilities (eg. satellite & aircraft imaging); computer systems to collate, verify, edit, store, & manipulate graphics & data; methods for analysing, especially spatial analysis; presentation of information and results of analyses.

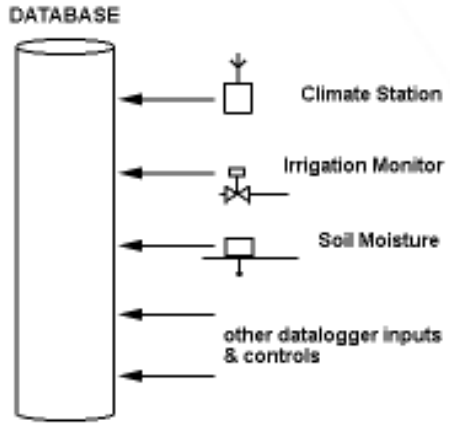

Figure 3: Data capture technology

This technology extends the capabilities of data management, long established viticulture methods, and accumulated resources of historical data.

Grape growing is governed by the annual cycle of seasons, and with the occurrence of several key viticultural events. Each new cycle begins with bud burst in spring, followed by flowering, fruit set, veraison, harvest, and finally pruning before the next cycle begins. This can be represented by a process model.

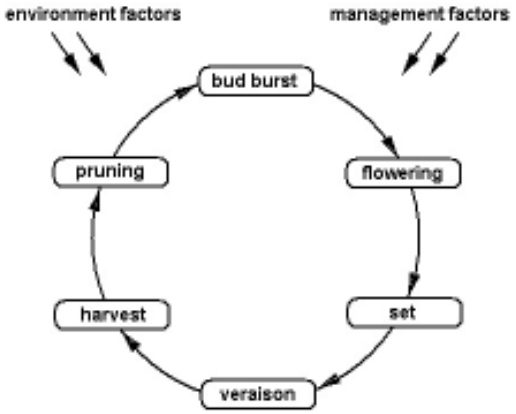

Figure 4: Process Model

A decision support system can be used and integrated with the process model to represent the use of information. Cycles of data input (eg from environmental factors and management factors), control, analyses, reports or presentations of information, decisions, actions, monitoring and further iterations.

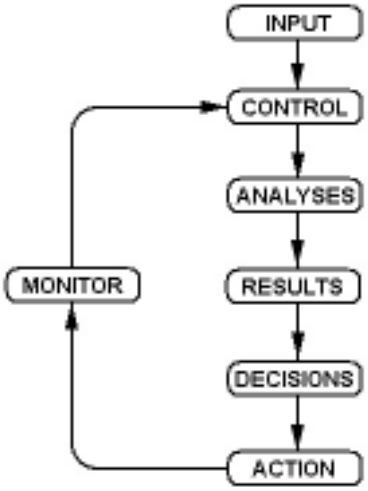

Figure 5: Decision Support System

3 Applications of Spatial Information Technology:

Spatial information systems are being applied in other agriculture and horticulture industries, to support management decision making. They enable spatial analysis, in addition to data integration. In agriculture, for example, Schulmann (1997) points out that “GIS (Geographic Information Systems) allow farm operators to successfully manage and fine-tune specific sites. The data being collected enable them to see what is occurring in smaller sections of the field.

With this knowledge, farmers can control water, fertilizer, crop selection, planting density, and pest-disease control programs".

Some parallel examples in viticulture include:

- Select and highlight on the map all areas of a vineyard that are of poor drainage and heavy clay soil and slope less than 2 degrees and are planted with pinot noir on their own roots.
- Pick any point in the vineyard and have the information system display all recorded soil, climate and vine characteristics relevant to that point.
- Data related to points, zones or blocks of vineyards could be analysed by selected criteria to produce answers on causes and effects, and what might happen if particular actions were taken, eg. mark areas of the vineyard on the map where powdery mildew is severe (effect) and find predominant climatic conditions (causes) occurring in those areas.

Emerging systems, incorporating methods that are being put into everyday practice, are based on standard personal computer systems and accessible software, with costs and benefits relevant to commercial businesses. They integrate the use of maps, aerial images, ground base monitors (climate, soil moisture, etc), yield recorders and other data sources. (Anderson 1997)

4 Purpose, aims and objectives of the research project:

The aim of this research will be to explore and evaluate potential applications of spatial information systems in viticulture research and vineyard management, and their integration with other management information systems. It is also intended to compare spatial information system-based processes with systems and methods currently used, analyse the pros & cons, assess economic and technical feasibility, and to report on these issues to the New Zealand wine industry.

The wine industry in New Zealand has developed dramatically in the last two decades. Vineyard area has increased more than 50% in 10 years and growing regions have spread throughout the country. The emphasis has shifted from bulk or fortified wine varieties to quality premium wine grapes, with an international reputation and success. Fundamental to this is our ability and willingness to adopt new technologies, for example stainless steel transferred from the dairy industry, agriculture techniques and skills, trellising systems transferred from the fencing industry. We explore and question things, find and implement answers. This project will emulate these precedents.

Strategies for progress into the next millenium include improvements to quality of grape growing and wine making (Wine Institute 1992). To achieve this, the right decisions must be made in viticulture, based on reliable and relevant information.

An often quoted fundamental in the quality of wine is the quality of the grapes. This is determined by their environmental and growing conditions, referred to as 'terroir' by the French (Robinson 1996). Terroir is a combination of vineyard location, soils, climate, and other environmental factors, as well as choice of grape varieties, viticulture practices, and the strategies or philosophies of the producers. Location or spatial references are important to many of these factors.

Growing grapes and producing wine are natural processes, manipulated by the grape grower and wine maker. Environmental influences affect the grape crop, as well as the decisions and actions of the grape grower and winemaker.

Grape growers take advantage of natural factors – soils, climate, drainage, etc – by selecting suitable sites for particular grape varieties. They control or manipulate other factors – irrigation, pruning, vine training, spraying, etc – through management procedures. These factors may be spatially variable through the vineyard, and it is assumed that management procedures could also be varied. With the assistance of a spatial information system, it may be possible to analyse the factor variations and apply a variable approach to each vineyard block, rather than managing it homogeneously (average approach).

Wine makers achieve greater control over the product by selecting, fermenting and blending batches of grapes with suitable ripeness and flavours. It may be possible to give them more choice, by defining sub-blocks within the vineyard. Batch selection could be decided with the assistance of spatial analysis of data related to grapes in the vineyard and environmental factors affecting their development, instead of picking whole blocks as single batches. Wine makers would have access to specific information about the origin of each batch when making blending decisions and when assessing the blended product.

Other issues include:

- Use of water resources, minimising consumption by allocating water only where it is necessary during the growing phases: This could be based on mapping of soils, moisture measurements, vineyard and vine factors (NZ WineGrower, Autumn 1998).
- Managing the use of chemical sprays to minimise costs and environmental effects, by selective timing, targeting and variable application rates & demonstrating to planning and regulatory authorities that growers are using environmentally responsible techniques. Besides assisting management decisions, spatial information systems could produce reports for presentation to these authorities.

The research project aims to explore these kinds of possibilities.

5 Speculations / Hypotheses / Assumptions:

In defining this research project, the following assumptions have been made:

- that decisions in the vineyard (about establishment, production standards, viticulture practice, etc) are only as good as the information available;
- that information can be referenced to spatial location;
- that relevant information can be analysed and correlated by spatial reference;
- and, hence, that spatial information systems can be used effectively.

This research intends to establish the validity of these assumptions and, in particular, to examine potential costs and benefits related to the last assumption. Improvements in grape production and quality are discovered by formal viticulture research, trial and error, and chance discovery. It is assumed that these will be understood better if monitored, and the information and results are examined, decided on and applied.

6 Applied Research Project:

The applied component of the proposed research will involve the development of a prototype spatial information system for a particular vineyard or vineyards. A spatial database will be developed by capturing digital/spatial representations of the blocks, rows and possibly individual vines within the study area, and integrating this with topographic data, climate data and soil data, along with data from the monitoring of vine management, berry development, yield and product characteristics. Spatial analysis and reporting functions (which are components of the software package to be used in the development of the database) will then be applied to demonstrate and assess the feasibility of using this database to provide information useful to vineyard management and viticulture research and development.

Clearly, the success of this approach is dependent upon the availability of a study area and access to appropriate data for the study area. It is planned to carry out the research mainly in New Zealand and Australia. It will explore specific vineyard locations as models, hopefully some in Central Otago, as that is the 'local' area close to the research base at the University of Otago. Another possible area is in Marlborough, where large size vineyards would be more suitable for a full scale prototype.

The main aims are:

- To assess the use of spatial information systems for viticulture research, and vineyard management, including data collection & management, manipulation, analyses, decision support, reporting, and integration with other information systems used by the wine industry. (eg. pest & disease

management systems, wine production systems, marketing & management systems, etc). To compare systems used in other crop production industries, in research projects, or in production/management systems.

- To design a model/prototype system and database and set it up and test it against hypotheses/ assumptions. The prototype would be based on the results of an analysis of requirements, from discussions with and a questionnaire of industry people. Explore the prototype, or model vineyard management system, for strengths, weaknesses and the unexpected. Explore alternative designs particularly in sampling, data capture and database management. Identify and discuss potential outputs and uses and possible specifications for a commercial system setup. Refine the model with feedback from participants.
- To estimate the feasibilities & costs of implementing spatial information systems (GIS, or computer mapping systems) at the vineyard level, using standard personal computer systems and software, including initial establishment, ongoing support and management of systems.
- To prepare and present a research report. To analyse and present results and conclusions, including costs, benefits, advantages and disadvantages.

7 Findings & Discussion (Progress so far):

So far, from preliminary enquiries, no direct applications of spatial information systems in New Zealand vineyards have yet been identified. There are computer based management or decision support systems, for example spray and pest management programmes, and winery production systems are being used by some companies.

In the USA there is increasing interest in adopting 'precision farming' techniques in viticulture and some systems in practice. For example, Harvell (1996) states that "Geographic Information Systems increasingly are being used to combine data gathering and modern technology to create a unified system of information gathering for vineyard owners in the wine industry".

Use of aerial images to analyse vineyard growth, vigour, vine health and spread of phylloxera have been trialled in California where at least one grower has been using both satellite imagery and aerial photography for the past five years (Cunningham, 1998) and, according to Cunningham, "..the company is getting more precise information about grape quality on a sub-block level than was ever possible before, and that is translating into more high quality grapes, better wine, and improved profits.

Use of airborne thermal scanner imagery has been reported in Australia, to detect irrigation deficiencies, by linking colour patterns to vine stress. Multi-spectral imaging used in New Zealand to determine the spread of noxious weeds may have some relevance to monitoring vineyard vegetation problems.

The idea of 'segmentation' or sub-division of vineyard blocks is being explored to provide the grape grower with more control and the winemaker with more blending options (Johnson 1998). The dynamic representation of alternative sub-divisions based on different criteria is possible with spatial information systems technology.

Control of irrigation is being linked with soil moisture measurement systems and the use of soil maps (Smart 1997). Again, spatial information systems can assist with understanding and managing these processes.

Some comments received from New Zealand viticulturists so far indicate an interest in precision viticulture and some useful points have been made about what might benefit, especially where gains could be made in quality and profitability. One example was regarding decisions on work programmes in the vineyard, and instructions (including maps) to work teams, eg. to pruners where pruning variations are required in different parts of the vineyard.

Researchers in New Zealand, as well as in Australia and the USA, are interested in the use of GIS and aerial imaging to plot potential disease problems in vineyards and the use of spatial analyses to plan management and spray programmes. The targeting of

problem areas would increase efficiencies and reduce costs of spraying as well as reduce environmental impacts and risks of spray residues.

8 Ongoing proposals:

Variations to the research plans and investigations will be determined by feedback from industry; constructive analysis and critique; and tests on model or trial systems to prove, disprove or qualify assumptions made, and initial conclusions reached. Advice and recommendations are particularly important in keeping the research relevant to the needs of the industry, and to balance the information systems expertise with viticulture expertise.

9 Conclusions:

In preparing the proposal for this research project, some potential benefits of spatial information systems to the wine industry have already been identified. How well these benefits will be realised will depend in part on results of the research and participation of the industry. Any interim conclusions reached by later this year and in ongoing stages, will be used to review the research aims, programme, way ahead, hypotheses, etc.

Possible benefits of this project, that have been identified so far, include:

- An opportunity for participants to gain further understanding of the potential applications of spatial information systems and evaluate a prototype that is specifically relevant to the needs of the industry;
- ability to record and analyse key quality attributes in grapes and relate these to viticulture practice and environmental conditions;
- learn more about the business operations and information needs of growers;
- learn more about computing and its applications in general, and transfer of information technology into the industry; focus the industry on its data capture and data management methods;
- potential to take the results of the research onwards to explore further possibilities and develop production systems;
- help to prepare a broader cost benefit analysis for implementation of spatial information systems in grape production;

Acknowledgements:

Nature, Bacchus, viticulturists, winemakers and appreciative wine drinkers.

References

Anderson, Curt AP farm writer (1997) 'Satellites, computers mean new precision for farmers'. Associated Press December 1, 1997

Bragato, Romeo (1895) 'Report on the Prospects of Viticulture in New Zealand Together With Instructions For Planting and Pruning' NZ Department of Agriculture

Buick, R D (1997) 'Precision Agriculture: An Integration of Information Technologies With Farming'. NZ Plant Protection Society

Cooper, Michael & John McDermott (1996) 'The Wines and Vineyards of New Zealand'

Cunningham, C J (1998) 'Mapping Mondavi Vineyards' FarmTech On-Line, July 1998 *California Grower* & *California Vegetable* Journals

Glyde, Scott & Frank Vanclay & Brian Freeman (1994) 'Computers, DSS and Viticulture' *The Australian Grapegrower & Winemaker* April1994

Harvell, Erik (1996) 'Pinpointing Information in Your Vineyard. Geographic Information Systems Tie Data to Specific Vines' *Wine Business Monthly*, August 1996 <http://smartwine.com/wbm/1996/9608/bm089645.htm> accessed 5 June 1998

Johnson, L & others (1998) 'Of Pixels and Palates: Can Geospatial Technologies Help Produce a Better Wine?' Proceedings, *1st International Conference on Geospatial Technology in Agriculture & Forestry*

New Zealand WineGrower Journal, vol.1 No.4, Autumn (1998) 'New Technology Detects and Signals Vines' Water Needs'

Robinson, Jancis (1996) 'Guide to Wine Grapes'

Schulmann, Richard D (1997) 'Modern Technology Meets Traditional Farm Practices'. *Geo Info Systems* Feb 1997

Smart, Dr Richard (1997) 'Soil Mapping. The Key to Wine Quality' *Practical Winery & Vineyard*, March/April 1997

Wine Institute of New Zealand Inc (1992) 'New Zealand Wine 1993 – 2000 A Working Paper'