Phylloxera and Grape Industry Board of South Australia

PROCEEDINGS OF THE WORKSHOP, 12 AUGUST 2002:

'PHYLLOXERA EARLY DETECTION: REVIEW OF CURRENT METHODOLOGIES'

FINAL REPORT to
Grape and Wine Research and Development Corporation

Project No: **GWR 02/02b**

Principal Investigator: **Peter Hackworth**

Research Organisation: **Phylloxera & Grape Industry Board of South Australia**

Date: **27 September 2002**

PHYLLOXERA & GRAPE INDUSTRY BOARD OF SOUTH AUSTRALIA

REMOTE SENSING REVIEW WORKSHOP

National Wine Centre
12 August 2002

Executive Summary

A workshop was held to review the Phylloxera & Grape Industry Board of South Australia's existing phylloxera early detection program. Attendees included key phylloxera, remote sensing and pvv researchers and interstate industry representatives.

The Phylloxera & Grape Industry Board of South Australia is currently using remote sensing technologies as the basis for its early detection program. This involves:

- collection of remote sening imagery at 1metre resolution, two weeks prior to harvest
- processing the imagery using a Normailised Difference Vegetation Index
- identification of vines showing low vigour relative to surrounding vines
- identifying the owners of the low vigour vines using the Board's GIS database
- inspection of the identified vines to determine the cause of the low vigour

Imagery is also delivered to grapegrowers.

Related research:
A project lead by Dr Alex Held will attempt to determine if a phylloxera infestation results in chemical changes in the plant, if these changes are expressed spectorally through the leaf and how early these can be detected.

Dr David Lamb has proposed complimentary research to investigate whether a phylloxera infestation results in detectable changes in the chemical composition of leaves. This may lead to the identification of a chemical marker that provides an early warning of phylloxera.

Key Issues:

- participants from the other states are keen to see the remote sensing program be extended nationally. However, their priority is not disease detection but the development of highly accurate regional vineyard databases;
- the current system of using remote sensing to identify low vigour sites for ground inspection can be further improved;
- additional resources should be directed to ground truthing the identified sites;
- the early detection program increases awareness and should encourage growers to report possible infestations;
- remote sensing is seen as an important tool for improving grower knowledge of the level of variation in plant growth in their vineyard
- there is reasonable confidence that researchers will identify a phylloxera 'spectral fingerprint';

- until the spectral fingerprint work is completed, and the wavelengths have been confirmed, the current system for site detection can probably be achieved using (cheaper) aerial photography;
- using change detection as a method for identifying sites where vigour has reduced between flights, requires further work to address seasonal climate variation and how to line-up pixels accurately;
- while early detection is important to minimise damage, it also is an aid to maintaining international quarantine barriers that restrict the import of grapevines

Background

The Phylloxera & Grape Industry Board of South Australia (PGIBSA) commenced a program for the early detection of phylloxera in 2001. At the time a project steering committee determined that remote sensing technologies would provide a cost-effective method for determining the presence of phylloxera on South Australia's vineyards.

In 2002 the Board resolved to review the program and invited researchers in related fields to participate (refer Appendix One, Meeting Agenda). To also enable industry representatives from other regions interstate to attend, the Board successfully applied to GWRDC for funds to cover travel to the workshop (refer Appendix Two, Workshop Attendees).

Welcome

Jim Caddy, Chairman of the PGIBSA's Outbreak Management and Early Detection Committee welcomed participants and explained that the Board had invested over $200,000 into the early detection program. He explained that the goals of the workshop were to:

- Outline the PGIBSA program;
- Improve industry understanding of GIS & remote sensing tools;
- Examine current and proposed research; and
- Develop industry guidelines that:
    - Enhance phylloxera survey protocols
    - Maximise value-adding (eg to Precision Agriculture, industry bodies)

Presentations

Overview of the South Australian Early Detection Program

Peter Hackworth, Executive Officer, Phylloxera & Grape Industry Board of South Australia explained that while Phylloxera had never been detected in SA a number of factors made early detection a priority:

- The high density and broad scale nature of viticulture in SA meant that an outbreak would result in rapid spread of the insect and high damage to production
- Compensation would not be available to growers affected by an outbreak
- Ongoing pressure from interstate groups for SA to justify its PEZ status

The Board had considered a number of options including ground inspection (ie root surveys as per the NVHSC survey protocols), insect trapping and a heightened awareness campaign targeted at grapegrowers. All were significantly more expensive than a program based on collecting remote sensing images and processing the data to identify low vigour sites for ground inspection.

Remote sensing also offered other potential benefits including the ability to locate unregistered vineyards[1] and to provide grapegrowers with a tool that was an aid to precision viticulture. The Board's program aimed to use and build on the experience of work undertaken by John Whiting in Victoria and Lee Johnson in California.

[1] In SA all vineyards 0.5 ha and greater are required to be registered with the PGIBSA

The Board established a project reference group[2] to advise it on technical aspects of the program including determining which data collection system to use (DMSV vs Hyper Spectral vs Aerial Photography), image resolution and timing of the flights.

On the advice of the reference group the Board appointed SpecTerra Services to undertake the remote sensing using Digital Multi-Spectral Video (DMSV), taken at 1 metre resolution and approximately 2 weeks before harvest.

The Limestone Coast was flown in 2001 and McLaren Vale in 2002. The cost was $106,000 and $34,000 respectively. One immediate problem had been to accurately determine the flight boundaries. There was also the related need to identify the owners of the properties that the Board was collecting remote sensing images of. This was necessary for ground truthing and because the Board had committed to delivering copies of the images to growers. While the Board had a Vineyard Register of 3,000+ growers it was not compatible with a Geographical Information System (GIS). To convert the database to GIS took 18 months and cost approximately $65,000.

With a GIS database the Board now has the capacity to:

- more accurately define flight areas which reduces costs[3];
- identify vineyard owners for ground truthing;
- deliver vineyard images to growers;
- identify unregistered vineyards;
- produce maps of GI's showing the location of vineyards;
- produce outbreak quarantine maps; and
- produce maps for researchers and industry (eg for AGY a map showing the location of all Chardonnay)

The remote sensing program has brought a number of additional benefits:

- a permanent record of the vineyard areas and their relative health for a given period of time;
- growers clearly appreciate receiving their aerial images, a tangible return for their levy;
- grower awareness of phylloxera is increased;
- PGIBSA is able to take a stronger stance in national forums;
- PGIBSA is perceived by the broader industry as taking a lead role in the adoption of new technology;
- PGIBSA is developing considerable expertise and intellectual property which may be realised at a later date; and
- it encourages the adoption of precision viticulture practices

[2] Don Lester, David Cartwright, Peter Stephens, Rob Bramley, Russell Flavel, David Lamb, Bill Wilden, John Whiting, Peter Hackworth

[3] In the Limestone Coast, the total area for which remote sensing data was collected was 173,327 ha. Of that 13,100ha were vineyards and the cost was $96,636 (ex GST) or $7.37/ha. If the GIS database had been fully established the flight area could have been reduced to 60,000 ha.

The Board recognised that it faced a number of challenges including lowering the cost of the program by:

- finding co-investors in the remote sensing
- on-selling the data
- refining the technology for higher automation
- value adding

Jane Edwards, GIS and Remote Sensing Technical Officer, Phylloxera & Grape Industry Board of South Australia outlined the technical aspects of the existing program, describing the current four step process (applied to Limestone Coast imagery):

STEP 1: Imagery Acquisition.

- Collection of 1m resolution, Digital Multi Spectral Video (DMSV) images, approximately 2 weeks before harvest
- Processing of imagery to remove non-vineyard areas, 'seamless' joining of images and georeferencing (latitude/longitude reference points)

STEP 2: Creation of True Colour and Normalised Difference Vegetation Index (NDVI) images.

- These images developed to highlight variation in canopy vigour

STEP 3: Identification of sites requiring inspection.

- Visual scanning of imagery to identify sites that could be infested by phylloxera (low vigour, surrounded by vines of relative high vigour)
- Imagery of infested vineyards in King Valley was used as a guideline

STEP 4: Ground truthing.

- Contact growers and inspect vine's feeder roots for the unique fleshy galls produced by phylloxera

All vineyard images were printed and delivered to growers, with a recommendation that they inspect sites of low vigour within their vineyard. This was a very long process, especially considering surrounding vineyard imagery needed to be removed to maintain confidentiality.

Significant improvements are in the process of being developed:

- removal of inter-row material from the imagery (which could potentially mask infestations);
- automation of printing vineyard images for growers;
- development of an ER Mapper program to save a True Colour and an NDVI image of each vineyard, with all surrounding vineyards removed;
- development of a program to print all the vineyard images from a region in a single process. The printed images include the Grower's name and number, GI and vineyard number. The title states "True Colour" or "NDVI" (depending on the image type) and the page orientation is portrait or landscape (depending on the dimensions of the image).

Jane identified two priority technical issues requiring further investigation. The first relates to imagery specification. Infrared aerial photography provides a cheaper imagery type at higher spatial resolution, but only provides three spectral bands of data (compared with four provided by DMSV). Can aerial photography be used to detect phylloxera as efficiently or more efficiently than DMSV imagery? The second priority is to develop an automated technique to detect sites requiring inspection. This would greatly improve the cost effectiveness of the program.

Remote Sensing Overview

Dr Stuart Phinn, Senior Lecturer, Biophysical Remote Sensing Group, School of Geography, Planning & Architecture, University of Queensland provided an overview of the different technologies available for remote sensing.

He emphasised that successful remote sensing projects begin with a clear understanding of what information is required from the data, and thus detailed specifications of required information, ie:

- Type of information for management/monitoring;
- Scale of mapped products required (smallest feature, extent);
- Required frequency of information;
- Required accuracy levels; and
- Cost restrictions

This set of information enables constraints to be defined for the type of remote sensing data and processing techniques to use. Available data types, including airborne and satellite data, vary greatly in spatial, spectral, temporal and radiometric resolutions, and cost. Many processing techniques are available to extract required information. For example, image classification can determine the composition of the target area, while image indices can measure levels of biophysical traits, either through empirical calibration or physical models. Effectiveness of indices will depend upon the choice of wavelengths (bands) to capture. Change detection can also be a valuable technique, as long as images from different dates are accurately geo-registered and radiometrically calibrated. Stuart provided examples of processing remote sensing data for environmental monitoring. Classification of land cover types in the Maroochy River catchment from imagery collected in 1988 and 1997 determine changes that had occurred between the two dates.

Precision Viticulture

Dr David Lamb, Associate Professor & Convenor (Physics & Electronics), School of Biological, Biomedical & Molecular Sciences, University of New England discussed the opportunities provided by remote sensing to improve grape production.

Research conducted over the past three years has demonstrated the link between remotely-sensed images of vine vigour (biomass) and basic measures of fruit quality like phenolics and Brix. He then presented an example of how remote sensing had been used to identify wine quality variation in a block of Shiraz vines on Stanbridge Estate (Griffith).

Multispectral Imagery had been collected and processed into an NDVI image. A representative range of spectral sites was identified and bunches collected from these sites in the vineyard. Brix measurements were taken and the data applied to produce a new map of the block showing

variation in Brix. Data could be coarsened to show two district zones therefore grape quality providing the vineyard manager with the option of harvesting separately.

David emphasized that this work had been undertaken over 2 days (imaging on day 1 and 1-hour field visitation/map production on day 2). This was perceived as important if it was to be a useful tool for industry.

David also reported on another (unfunded) preliminary investigation of the potential of field radiometery as a means for identifying phylloxera-infested vines based only on leaf spectral signature. In this project, conducted in collaboration with the Phylloxera Research team (DNRE Rutherglen), spectral reflectances of leaves from vines with and without phylloxera (50 samples of each) were measured.

Preliminary results suggested:

- it may be possible to positively identify phylloxera infested vines based on the leaf spectral signature, but
- it may not be possible to exclude phylloxera-free vines on the basis of leaf spectral signature.

To advance this work there is a need to investigate whether a phylloxera-infestation results in detectable changes in the chemical composition of leaves. This may lead to the identification of a chemical marker that provides an early warning of phylloxera. He has prepared a research proposal that complements the spectral signature project led by Alex Held.

Reflectance Spectrometry

Dr. Alex Held, Leader, Environmental Remote Sensing Group, CSIRO Land and Water gave an overview of the research project, *Early Detection with Reflectance Spectrometry* commencing in the second semester of 2002. The project is being carried out in close collaboration with Kevin Powell (DNRE - RRI), and intends to use detailed glasshouse experiments, as well as targeted field sampling in Rutherglen (Upton and King Valley), to identify optical and chemical changes caused by Phylloxera on selected varieties.

Project will seek to determine:

- How early in the growth cycle can Phylloxera be detected using reflectance spectrometry?
- What chemical changes, if any, are caused by the pest?
- How do other stresses (e.g. water, nutrients, diseases) differ, if at all, from Phylloxera symptoms in their spectral response?
- Are observed differences caused by leaf spectral changes or by canopy architecture factors?
- Are simple carotenoid/chlorophyll indexes good indicators of crop condition?
- Can this information be used to customise an imaging system (ie spectral sensitivity, spatial resolution)?

Projected Outcomes

- Better understanding about spectral 'separability' between *Phylloxera* and other plant stresses
- Information on timing for earliest-possible detection of the pest.
- Specialised spectral indices potentially customized for *Phylloxera* stress detection
- Protocols for field sampling with hand-held spectrometers:
  - Seasonal aspects
- Proposed spectral positions for customised imaging sensors

Discussion

A number of key issues emerged from the workshop.

- Participants from the other states are keen to see the remote sensing program be extended nationally. However, their priority is not disease detection but the development of highly accurate regional vineyard databases. It was agreed that such databases would be of major benefit to industry; improved accuracy for future production, collection of levies, irrigation and other infrastructure planning.
- The current system of using remote sensing to identify low vigour sites for ground inspection can be further improved. Concurrent collection of remote sensing images and ground GPS points of phylloxera-infested vines in Upton and the King Valley could achieve this. This research would also help resolve the issue of image resolution
- Additional resources should be directed to ground truthing the identified sites; this is necessary to ensure no phylloxera are present, to build knowledge for future programs and to reinforce the awareness message to growers
- There is agreement that the early detection program increases awareness and should encourage growers to report possible infestations (if I don't report it, the Board will find it anyway)
- Remote sensing is seen as an important tool for improving grower knowledge of the level of variation in plant growth in their vineyard
- There is reasonable confidence that researchers will identify a phylloxera 'spectral fingerprint' within 2-3 years. However, it's likely that the required light wavelength combinations will not be the same as those currently collected by the Board.
- Until the spectral fingerprint work is completed, and the wavelengths have been confirmed, the current system for site detection can probably be achieved using aerial photography rather than DMSV, if the suppliers can meet the quality standards required (eg for ortho-rectification, solar reflectance correction, seamless mosaicking of the images, etc)
- Using change detection as a method for identifying sites where vigour has reduced between flights, requires further work to address seasonal climate variation and how to line-up pixels accurately. Also, the time between flights (eg 3-4years) is probably too long, ie phylloxera may be widespread by the time it is detected
- While early detection is important to minimise damage, it also is an aid to maintaining international quarantine barriers that restrict the import of grapevines

The only alternative to remote sensing is intensive ground truthing, ie physical inspection of vines in every fifth panel of every third row, with surveying being conducted over 3 concurrent years. The cost (around $30 per hectare per annum compared to $10 per hectare for remote sensing) makes it impractical except for regions seeking to move from PIZ or PRZ status to PEZ status.

One major advantage of remote sensing is that all vines can be examined, compared to only 6% in a 3-year ground truthing program.

There is reason for optimism that research currently being undertaken will result in the identification of a phylloxera 'spectral fingerprint'. This would significantly reduce the cost of remote sensing (mainly because less sites need to be inspected). Results are not expected until 2005.

BUSINESS ARISING SINCE THE WORKSHOP

The Outbreak Management and Early Detection Committee of the PGIBSA met after the workshop to determine its priorities and strategies for progressing early detection. The Committee has recommended the following:

1. That the Board maintains the current early detection program
2. In the 2002/2003 financial year the Board:
    a. purchase aerial photography of the Riverland (collected in February 2002 by the Central Irrigation Trust)
    b. undertake ground truthing programs in McLaren Vale and the Limestone Coast
    c. undertake further research to enhance the effectiveness of the early detection program

The research proposal is included as Appendix Three.

The Board will present the outcomes of the research to the National Vine Health Steering Committee in approximately August 2003 with any recommendations for changes to the Phylloxera Survey Protocols.

APPENDIX ONE

Phylloxera and Grape Industry Board of South Australia

REMOTE SENSING AND EARLY DETECTION OF PHYLLOXERA: WHERE ARE WE NOW, WHERE ARE WE GOING?

National Wine Centre of Australia
Hackney Rd, Adelaide

9.30am-3pm Monday 12 August 2002

Early detection of phylloxera and other major pests and diseases is emerging as a priority for the winegrape industry. The Phylloxera & Grape Industry Board of South Australia (PGIBSA) has been using remote sensing technologies to target vines with phylloxera-like symptoms for inspection by ground teams. Precision viticulture technologies are also emerging, some of which will be aided by remote sensing data. Research into the spectral response of grapevines to phylloxera has the potential to significantly aid early detection. Remote sensing is also an important tool for locating vineyards (eg for industry databases) and for environmental monitoring. We and other state and industry groups need to know which technology (eg, analogue, digital video, hyper spectral) and methodology (early detection, change detection etc) to invest in that will meet current needs and be an asset for other applications in the future.

AGENDA

1. Welcome — Jim Caddy, Chairman, Outbreak Management Committee, PGIBSA
2. SA Early Detection Program — Peter Hackworth & Jane Edwards PGIBSA
3. Data Collection and Application — Dr Stuart Phinn, Queensland University
   An analysis of remote sensing technologies and how they are applied (eg change detection, instant detection)
4. Remote Sensing and Precision Viticulture — Dr David Lamb, University of new England
5. Early Detection Research
   a. Spectrometry Trials; CRCV supplementary proposal — Dr David Lamb
   b. Reflectance spectrometry (commencing 2002) — Dr Alex Held (CSIRO Land & Water) Dr Kevin Powell (DNRE, Rutherglen)
6. Lunch
7. Discussion:

   'Remote sensing and GIS are important tools for early detection of disease, in precision viticulture and in locating vineyards. Taking into account emerging research and potential applications, in which technologies and methodologies should industry bodies be investing?'
8. Resolutions, industry communiqué, research gaps and cooperative links

Grape and Wine Research and Development Corporation

APPENDIX TWO

WORKSHOP ATTENDEES

Phylloxera & Grape Industry Board of South Australia:
Peter Stephens, Richard Hamilton, David Lloyd, Jim Hardie, Bill Brand, Jim Caddy, Ross Heinze, Peter Hackworth, Jane Edwards, Chris Ridley

Invited Guests:

Russell Flavel
Planning & Strategic Development
Sustainable Resources

Rob Bramley
Precision Agriculture Research Group
CSIRO Land and Water

Mike Stone
Victorian & Murray Valley Winegrape Growers' Council

Brian Englefield
Victorian & Murray Valley Winegrape Growers' Council

DeAnn Glenn
GWRDC

Kevin Powell
Dept. of Natural Resources & Environment

Alex Held
CSIRO Land and Water

Megan Lewis
University of Adelaide

Stuart Phinn
School of Geography, Planning & Architecture University of Queensland

Grant Telford
Queensland Dept of Primary Industries

David Lamb
School of Biological, Biomedical & Molecular Sciences University of New England

Russell Johnstone
Orlando Wyndham Group

Jim Campbell-Clause
Wine Industry Association Western Australia

Terry Coates
Agriculture NSW

APPENDIX THREE

RESEARCH PROPOSAL

AIM:

To develop a protocol for using remote sensing for the early detection of phylloxera

OBJECTIVES:

To determine

- which image collection system is the most efficient for identifying phylloxera infestations
- which spatial resolution is optimal for identifying infestations
- which image processing techniques best identifies infestations
- the ability of change detection to identify infestations

BRIEF DESCRIPTION OF RESEARCH METHODS:

The study will involve the collection of airborne imagery of five phylloxera-infested vineyards in Upton and King Valley, Victoria, approximately 2 weeks after veraison. The imagery will be analysed to identify sites of low vigour (with phylloxera like symptoms), and the results compared with ground surveys conducted at the same time as image collection.

Timing of Imagery Acquisition:

To assess the optimal timing of image acquisition, infrared aerial photography will be collected on two dates prior to harvest: veraison and 2 weeks harvest.

Collection System:

To assess the most cost effective image collection system, infrared aerial photography and Digital Multispectral Video (DMSV) imagery will be collected for all vineyards.

Spatial Resolution:

The infrared aerial photography will be provided with 0.3m, 0.5m, 1m spatial (pixel) resolutions. The DMSV imagery will be provided with resolutions of 0.5m, 0.75m and 1m. The 1m DMSV imagery will also be upgraded to 0.5m using software techniques and compared with imagery actually acquired at 0.5m resolution.

Processing Techniques:

The study will compare NDVI with other vegetation indices. A range of colour contrasting, filter, and pixel neighbourhood techniques will be assessed. Each processing techniques will be assessed for imagery collected with both collection systems at all spatial resolutions.

Ground Surveys:

The five vineyards will be surveyed by staff from the Victorian Department of Natural Resources and Environment (DNRE). Each site will be recorded as either infested or not infested, and the location determined with a DGPS to achieve sub-metre accuracy. DGPS data will also be utilized to achieve required spatial accuracy in the imagery.

Change Detection:

The ability to use change detection to detect phylloxera will be assessed by comparing the King Valley 1m resolution DMSV imagery to the imagery collected in 2001. The infrared aerial photography will also be co-registered to photography previously collected by DNRE. Assessment will particularly include the accuracy of geo-registering and radiometrical calibration.

Potential collaborators:

Dr. Megan Lewis, Department of Soil and Water, The University of Adelaide (provision of image processing advice)

Dr. Kevin Powell, DNRE Rutherglen (co-ordination of ground surveys in Upton and King Valley)

Dr. David Lamb, School of Biological, Biomedical and Molecular Sciences, University of New England (assistance with aerial photography change detection, project liaison)

Project Timeline

Activity		**Date completed**
Image Acquisition	Aerial photography – approx 2 weeks after veraison	March 2003
	DMSV imagery – approx 2 weeks after veraison	March 2003
Ground surveys	King Valley and Upton	March 2003
Image Processing and Analysis	Imagery received	June 2003
	Processing of vegetation indices, contrast stretches, filters, neighbourhood statistics (for images collected by both collection systems, with all resolutions).	July 2003
	Identification of low vigour sites in all processed images	July 2003
	Comparison with ground surveys	July 2003
	Image calibration for change detection	August 2003
Protocol	Development of protocol	September 2003