Using tractor mounted optical sensors to assess grapevine canopy decline

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Abstract

The Limestone Grape and Wine Council investigated the use of Greenseeker® NDVI technology to determine if this technique would assist growers in being able to accurately quantify a loss in vine productivity (assumed as a result of dieback caused by Eutypa) in their vineyards when compared to the labour intensive 'ground truthing' technique.

Part one of the project was undertaken during 2013/14 growing season on six Cabernet Sauvignon blocks located throughout the Limestone Coast. Results were variable, with some vineyards producing a higher degree of accuracy than others. A major limiting factor attributed to variable responses in the relationship between the Greenseeker© NDVI and ground truthing methods arose as a result of inconsistencies in the amount of vineyard ground truthed and the methodology associated with the ground truthing (LSCGWTC final report to GWRDC 2014).

In 2015/16 season, the project was continued however, with less blocks covered and more intensive (whole of vineyard) ground survey by 6 people in total within the week of the Greenseeker NDVI analysis.

The resultant correlation between Greenseeker NDVI and ground truthing identified that physical disease ratings (characterized by a loss in vine productivity) could be replaced with Greenseeker NDVI, or possibly even high resolution aerial or satellite imagery for larger study areas. Further to this, the analysis identified that a different method for identifying percentage of completely dead plants would be required, however, it was not outside of the scope of Greenseeker NDVI to quantify proportion of vines completely dead as a consequence of trunk disease or possibly root diseases such as Phylloxera in the future.

Introduction

Eutypa Dieback, caused by the fungus *Eutypa lata*, is a major trunk disease of grapevines (Sosnowski and Wicks 2012). Incidence of Eutypa in the Limestone Coast was recently assessed and the varieties Cabernet Sauvignon and Shiraz were observed with a mean incidence of 47% and 44% (Sosnowski et al. 2012). The authors reported disease incidence was greatest in vines 15+ years old increasing by 2% per year on average. But it needs to be noted that this is not necessarily a linear increase.

Vines infected with Eutypa often produce stunted shoots with chlorotic leaves; leaves may be cupped due to toxins produced by the fungus and produce small uneconomic amounts of fruit. Necrosis of wood results in wedge-shaped areas of stained tissue. The fungus grows slowly down through the cordon and trunk eventually discolouring and killing the wood (Moller and Kasimatis, 1981, Sosnowski and Wicks 2013) and as a result is hard to control chemically.

Ascospores infect grapevines through pruning wounds and germinate in xylem vessels. The mean rate of progression of wood staining due to Eutypa ranged between 12 and 18 mm per year in a study of eight cultivars, with a maximum of 50 mm per year recorded in individual Cabernet Sauvignon and Shiraz grapevines (Sosnowski *et al.*, 2007).

Identification of the disease has traditionally been through ground surveys during spring at critical time points of grapevine phenology (E-L stages 12-23). However, this method is laborious and time consuming, restricting on the area that can be covered.

The Greenseeker is a mobile system with an active lighting optical sensor which emits high intensity light 660 +/-10nm in red and 770+/- 15nm in NIR wavebands (Mazetto et al. 2009), operated at cordon height levels. The light is reflected by the leaves and is captured by a photo diode in front of the sensor. Greenseeker gives back the index values NDVI and Red/NIR in real time and is a measure of the vine vigour status through a measure of 'greenness' which reflects the amount of chlorophyll in the leaves. Historically this technology has been used in broadacre agricultural pursuits particularly to look at requirements for nitrogen application and spraying weeds.

One operator in the Coonawarra wine region has used this technology since 2011 to initially assess vine vigour for potential improvements in wine quality by identifying batch lots for winemaking. It was identified during this process that the technology could be used for other uses including improving irrigation uniformity, vineyard biosecurity and identifying vine decline. For example, when Greenseeker maps were analysed and compared on an annual basis, the change in vigour was identified and the information used to make a more informed decisions on the long term viability of the vineyard (Figure 1).

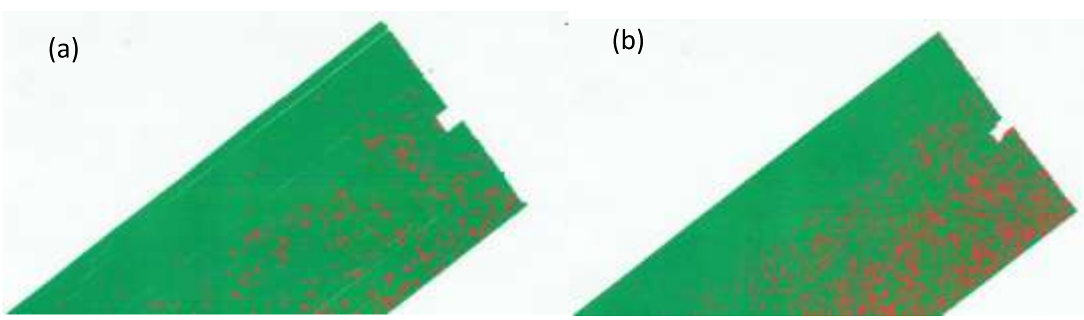

Figure 1. Comparision of the same block of grapes in January 2013 (a) and January 2014 (b) using Green seeker® NDVI imagery.

For viticulture, there is potential to use the Greenseeker NDVI as an early detection tool to measure a decline in vine productivity associated with Eutypa and trunk disease, that traditionally, have been captured by manual ground truthing techniques. Currently very few operators within the viticultural industry have utilised this technology due mainly to a lack of confidence, knowledge and skills to adopt this type of technology along with the uncertainty in the accuracy of the data produced. It was the aim of this project was evaluate blocks for vine decline by the traditional, laborious ground truthing method (scale 0-100%, where 0% is dead and 100% is full canopy) and compare against values obtained through Greenseeker NDVI (normalised index, scale 0-1, where 0 is dead and 1 is full canopy).

Materials and methods

Three vineyards located within the Limestone Coast were chosen for the analysis. The key characteristics of each vineyard are described in Table 1. Vineyards were of the red winegrape variety *Vitis vinifera* cv. Cabernet Sauvignon. Vines varied in age with an approx. age range of 16 to 22 years and were fully cropping (i.e. mature). All vineyards were subject to drip irrigation and trained to a single wire. Canopy management practices aimed at producing high quality grapes by limiting canopy growth; these practices included shoot trimming and some shoot positioning throughout the season.

Table 1. Summary of vineyards sampled during the 2015/16 growing season

Vineyard / Region	Vineyard ID	Age	Variety	Cordon Type
Limestone Coast Other	LC1	16	Cabernet Sauvignon	Single Wire
Coonawarra	LC2	18	Cabernet Sauvignon	Single Wire
Coonawarra	LC3	22	Cabernet Sauvignon	Single Wire

Ground truthing survey

Prior to ground truthing, the estimated number of vines per row and the total number of rows within each vineyard was calculated and put into an excel spreadsheet. Each vineyard was split into 3 sections, with each section being covered by a team of two surveyors. Each team was equipped with an IPad with the pre-loaded excel vineyard spreadsheet with vine numbers and rows. Vines were visually assessed from 0-100%, reflecting the proportion of healthy shoots along the cordon. For one of the vineyards (LC1) each team covered the entire vineyard (Figure 1) and this methodology allowed for investigation into human accuracy to detect vine decline.

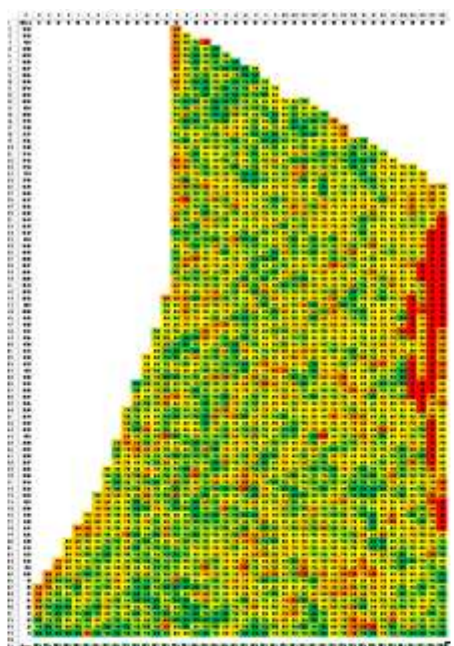

Figure 1. Example of ground truthing survey. Colours represent vine health assessments from 100% full canopy (green) to 0% dead (red).

Greenseeker NDVI assessment

The Greenseeker was mounted horizontally onto a tractor and readings were taken approximately 0.5 metre apart as the tractor passed the vines. Data was logged on a screen in the cab (Figure 2), and exported for further processing using Farmworks© software. The NDVI data was interpolated using kriging so that the point data from the disease ratings could be assigned. The outputs were exported to excel where they were analysed.

Figure 2. Greenseeker data capture in the cab of the tractor

As there was no geographical reference for the manual readings, the data from the Greenseeker/NDVI and the disease rating had to be aligned so that they can be directly compared. Each vine was mapped and given a unique identifier, which enabled both datasets to be combined. The map below shows the raw disease rating data after it had been geographically represented. Lower ratings equate to higher disease impact.

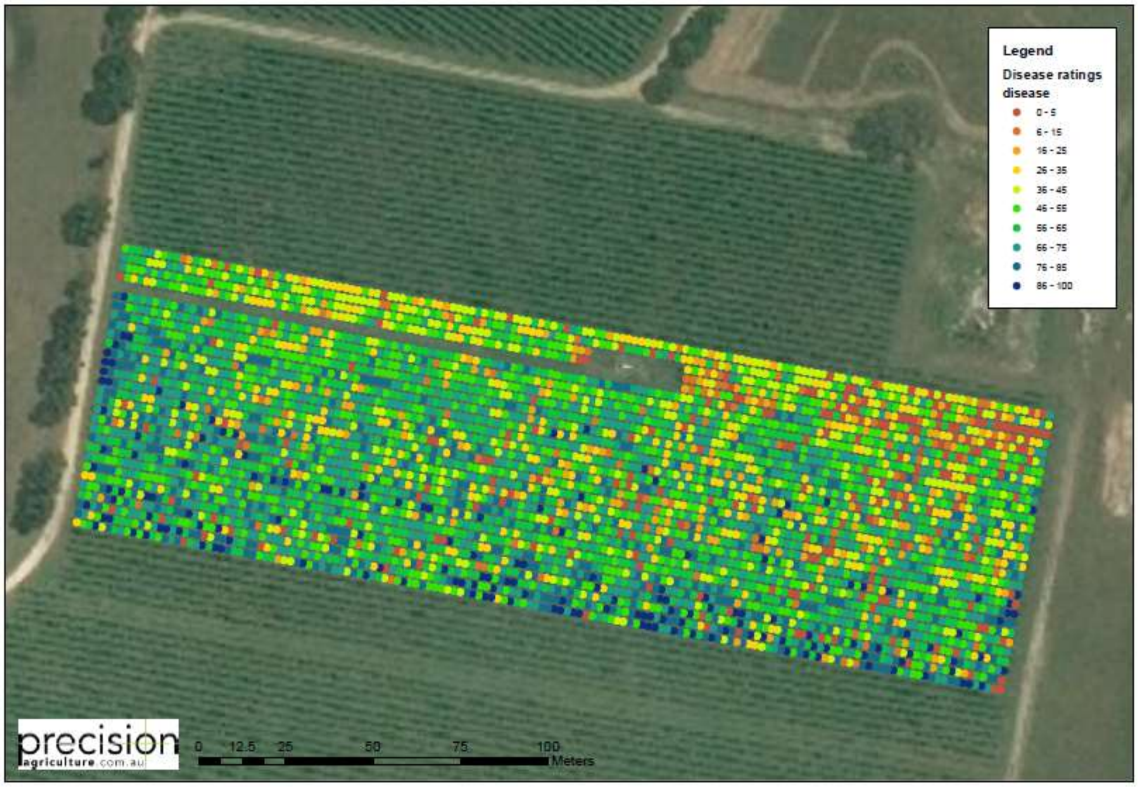

Figure 3. Raw disease rating data after geographical represention. Lower ratings equate to higher disease impact.

Results and Discussion

Ground truthing surveyor accuracy

An analysis of variance (ANOVA) was performed on the individual datasets to determine surveyor accuracy for two out of the three vineyards (Table 2).

No significant differences in the assessment for vine health was detected for LC1 vineyard, however a significant difference in sampling was detected for LC3.

On the day LC3 was surveyed, the ground survey group experienced technical difficulties with equipment, namely IPads overheating in the +33°C weather. In addition, the survey teams were visibly affected by this heat and it is likely to have contributed to erroneous readings resulting in discrepancies between survey groups.

Table 2. ANOVA was performed on the survey groups to detect differences in ability to identify vine decline

Vineyard ID	Category	Mean	Groups	Pr>F	LSD
LSC1	Group 1	81.090	A	0.489	3.745
	Group 2	79.782	A		
LSC2	Group 1	90.360	A	<0.0001	1.635
	Group 2	86.190	B		

Amount of vine decline according to ground truthing survey:

The ground truthing results identified varying levels of vine decline (i.e. had reduced productivity and canopy growth or foliar symptoms of Eutypa) and the amount of dead vines with "0" recorded also varied depending on site. The following chart describes the variance between vineyards:

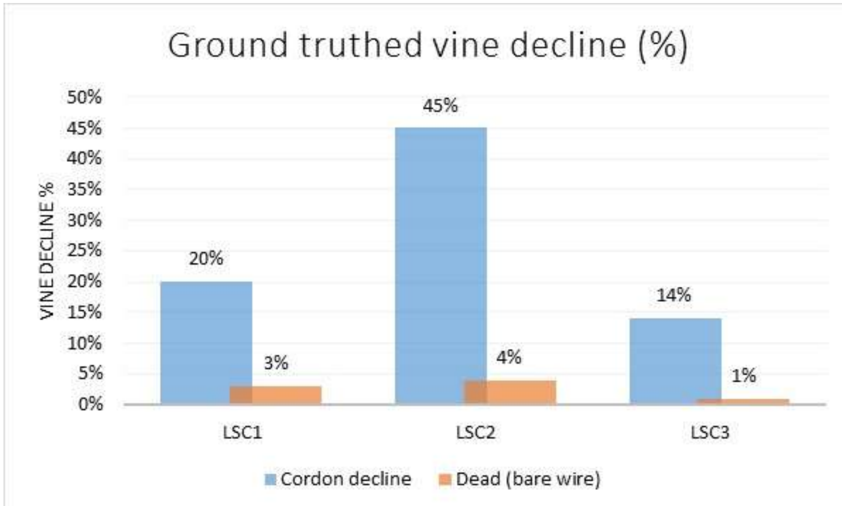

Figure 4. Ground truth vine decline assessments in the three surveyed vineyards.

Greenseeker NDVI results:

As there was no geographical reference for the ground truthed readings, the data from the Greenseeker/NDVI and the disease rating had to be aligned so that they can be directly compared. Each vine was mapped and given a unique identifier, which enabled both datasets to be combined. The map below shows the raw disease rating data after it had been geographically represented. Lower ratings equate to higher disease impact.

The NDVI data was interpolated using kriging so that the point data from the disease ratings could be assigned. The outputs were exported to excel where they were analysed. The following map shows the raw (left) and interpolated NDVI values from the Greenseeker mounted on the tractor.

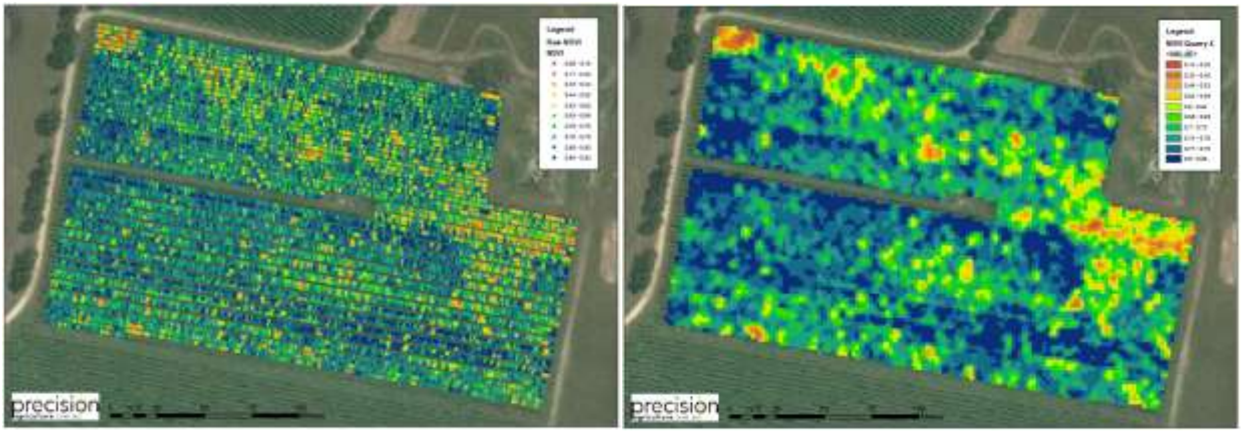

Figure 5. Raw (left) and interpolated (right) NDVI values (vineyard LSC2) from the Greenseeker mounted on the tractor

With such large point datasets, it is often difficult to obtain clear outputs on a point by point basis. To alleviate this, the NDVI was averaged for each vine health rating per vineyard, using pivot tables in excel (Table 3). There are other techniques to do this, however this method gave a good and simplified result.

Table 3. Example of average NDVI (0-1) for each % vine health and canopy cover (0-100)

Average NDVI	% vine health and canopy cover (0 unhealthy-100 healthy)
0.152212	10
0.730317	30
0.754485	40
0.760458	50
0.776855	60
0.795112	65
0.79762	70
0.808745	75
0.806936	80
0.819923	85
0.811707	90
0.811468	95
0.8118	100

Correlation analysis

The following charts show the relationship between the averaged Greenseeker NDVI and vine health rating for each of the surveyed vineyards:

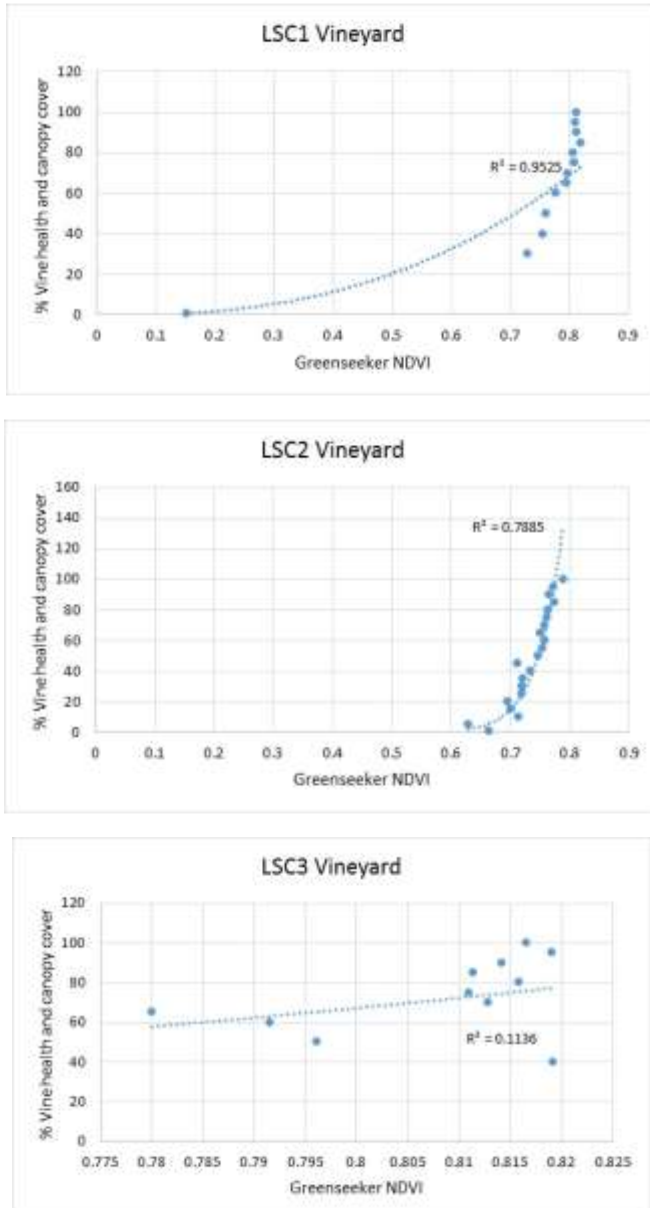

Figure 5. Relationship between ground truth vine health rating and Greenseeker NDVI for each of the vineyards surveyed.

Power correlation curves were used as they represent NDVI data the best. As NDVI approaches 1.0, the differentiation becomes less as the crop 'saturates', which is similar in other crops. Good correlations were observed in LSC1 and LSC2 vineyards (R^2>0.75), but not LSC3.

LSC3 data was found to be erroneous due to a number of reasons, namely technical and human sampling errors on the day of ground truthing, coupled with the vineyard having fewer ranges of vine health and canopy cover and NDVI values and it is because of this that the data from this vineyard has been excluded from the rest of the analysis.

Nonetheless, the combined dataset (LSC1 and LSC2) show a good correlation between ground truthing and Greenseeker NDVI

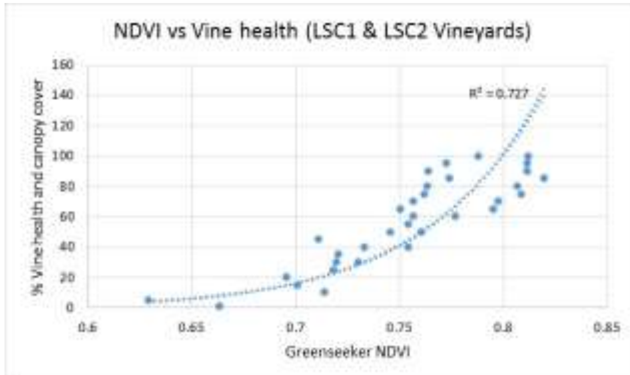

Figure 6. Relationship between ground truth vine health rating and Greenseeker NDVI for the combined dataset (LSC1 and LSC2).

One of the concerns of the methodology used in the analysis, is that it hasn't adequately picked up the higher disease incident areas (lower vine health scores). This is due to the interpolation of the NDVI as well as the averaging of the NDVI values from each vine health rating category. Even at the very low vine health rating (high disease incidence), the NDVI values are quite high (0.6 to 0.7). In one of the three vineyards tested, there were some data values which appeared to more accurately represent the low vine health ratings, with one data point showing the NDVI value at 0.15 (Figure 6). NDVI numbers at that level would normally represent dead plant material.

A different method for identifying percentage of completely dead plants would be required. This should be a simple matter of pointing the Greenseeker at a dead vine, obtaining the reading, and then filtering all the data from the paddock to determine percentage of the vineyard completely dead.

Once the algorithm has been determined, and using GIS mapping software, it can then be used to predict levels of disease (low vine health ratings) across the vineyard (Figure 7).

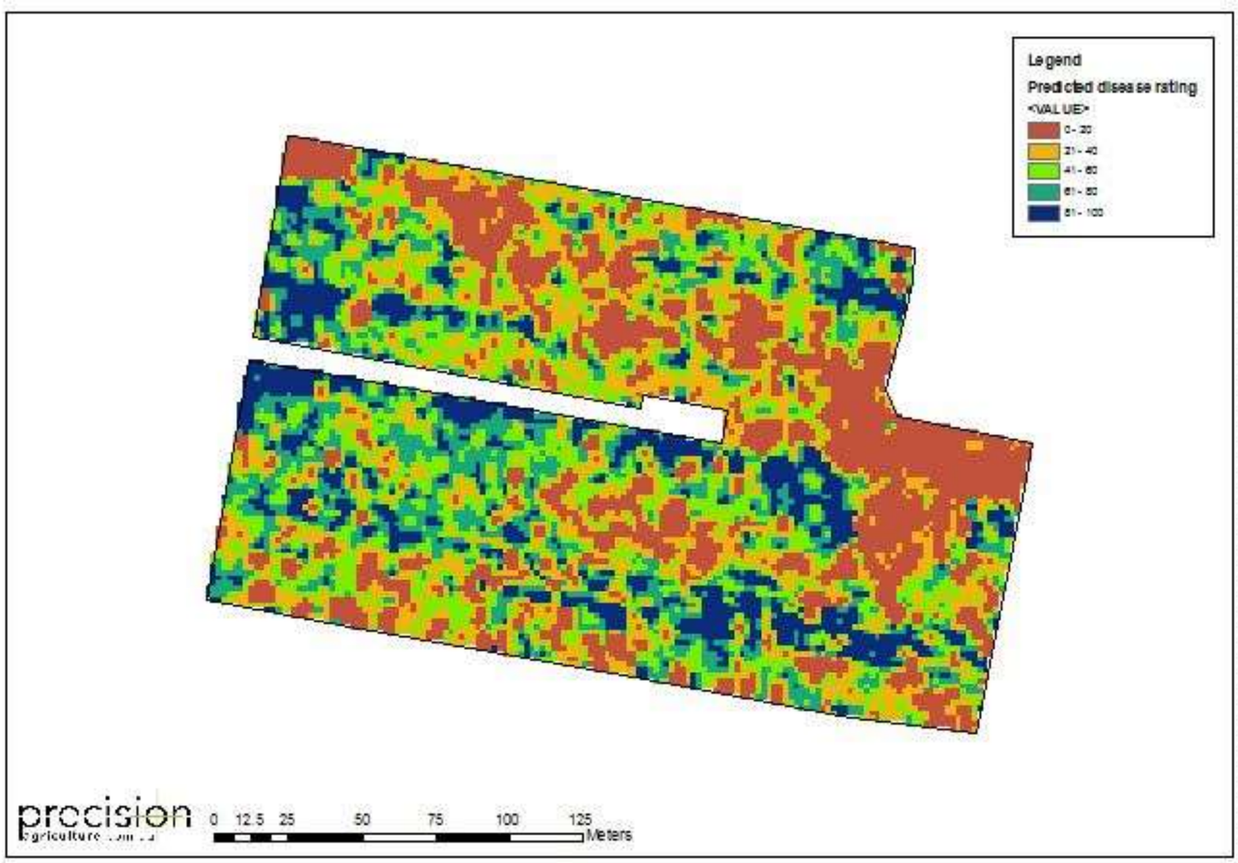

Figure 7. Predicted level of infection (LSC2) due to vine decline within a vineyard

Economical costs associated with the two methodologies

The laborious, traditional identification of the disease through ground surveys during spring at critical time points of grapevine phenology (E-L stages 12-23) requires a specific skillset and as such is time restrictive on the area available to survey on a given day. From the results present above, there is also a "human error" component if surveys are performed on hot days or if using unskilled surveyors. The cost of performing a traditional ground survey is estimated at \$48/ha per person (\$96/ha for two people surveying) and there are limitations as to the number of vines able to be surveyed within a vineyard due to fatigue. In contrast, hire of the Greenseeker with NDVI would cost in the order of \$56/ha (however this cost is considerably cheaper (\$17/ha) if other vineyard operations were being undertaken by the contractor for example slashing or spraying at the same time) and would cover between 2.4ha and 3.1ha per hour (depending on length of vineyard rows). Furthermore, the machine is objective and therefore has no bias towards quantifying incidence and is not as affected by the surrounding environment (i.e. climate).

Future directions for Growers wanting to use the Green seeker for vine productivity

This work has demonstrated the potential, wide spread use of this type of sensor within the grape growing industry. For grapegrowers, this represents a practice change in the way vine decline is accurately quantified within a vineyard. A clear advantage to this technology is that it is not limited by the environment (i.e. cloud cover or wind) and as Greenseeker is equipped with its own light source (hence not limited by the environment), information gathered both within a season and between seasons is relevant. Therefore accurate rate of whole vineyard decline overtime is now easily measurable and enable a more proactive reaction of vine decline by the grower, in particular yield responses as a direct quantification of amount of bare cordon or non-productive vine. Although outside of the scope of this project, there are other potential benefits to this data capture which may include measures of vine water status and irrigation uniformity and biosecurity (i.e. vine decline as a consequence of a biosecurity breach).

There exists an opportunity to develop an excel protocol that will take the Greenseeker NDVI file and export as a .csv file into excel. From there a grower may be able to sort the data into ranges (for example, based on data generated from this report) to identify target indices of vine productivity (or trunk disease incidence). However, it is clear more work in this area is required to develop such protocols.

Conclusions

The study has identified that changes in vine productivity (for example as a result of trunk disease) could be assessed with Greenseeker NDVI. However, for greater accuracy, vineyard specific algorithms should be developed to obtain the best representation of the field and also to remove timing of capture issues (NDVI changes during the growing season) (This may only need to be 10-20 sites per vineyard?). It may also need to be done in different regions depending on soil effects of NDVI

The current methodology for detecting productivity variance with NDVI requires more work to detect higher disease incident areas. It would appear from the analysis that this is possible, based on data values which appeared to more accurately represent the low disease ratings, with one data point showing the NDVI value at 0.15 which, would represent dead or missing cordon. However, as the scope of the project was to assess changes in productivity rather than quantify “dead arms” it is clear further development of this method would be required. For example, obtaining the Greenseeker NDVI reading of a dead vine, and then filtering all the data from the paddock to determine percentage of the vineyard completely dead. Further research is also required to optimise the timing of Greenseeker assessment and the evaluation of high-resolution aerial or satellite imagery compared with greenseeker NDVI, for larger study areas.

Given the incidence of trunk disease in Limestone Coast and elsewhere in many grape growing regions of Australia, the ability to rapidly assess changes in vine productivity (as a consequence of trunk disease) and potentially quantify the degree of “dead arm” would enable strategic management decisions for trunk disease for grapegrowers.

Acknowledgements

The authors on behalf of Limestone Coast Grape and Wine Technical Council (LSCGWTC) would like to acknowledge Westmere wines, Kidman wines and Balnaves Coonawarra for access to their vineyards and in kind support. In particular, we would like to thank Balnaves Coonawarra for the use of their Greenseeker machinery to conduct analysis on these vineyards. Finally, we wish to acknowledge SARDI through the support of Dr Mark Sosnowski and Matt Ayers. We would also like to acknowledge the support of Tim Neale of Precision Agriculture PTY, LTD for undertaking data analysis and interpretation of the data sets.

We thank Wine Australia for their financial support for this project through their "grassroots" funding program of the LSCGWTC

Literature Cited

Sosnowski, M., Ayers, M., Kidman, C., and Newson, D (2012) Impact of eutypa dieback in the Limestone Coast. Stage 1. GWRDC report

Sosnowski, M.R., Shtienberg, D., Creaser, M.L., Wicks, T.J., Lardner, R., and Scott, E.S. (2007a). The influence of climate on foliar symptoms of eutypa dieback in grapevines. Phytopathology 97,1284-1289.

Sosnowski M and Wicks T (2012) Current status of grapevine trunk diseases in Australia. Wine & Viticulture Journal 27(2), 21.

Moller, W. J., and A. N. Kasimatis. Further evidence that Eutypa armeniacae-not Phomopsis viticola-incites dead arm symptoms on grape. Plant Disease 65.5 (1981): 429-431.

Mazzetto, Fabrizio, Aldo Calcante, and Aira Mena. Comparing commercial optical sensors for crop monitoring tasks in precision viticulture. Journal of Agricultural Engineering 40.1 (2009): 11-18.