# CUT 1001: AO2 – Managing spatial variation in grapevine water requirements

This is an excerpt from the final report CUT 1001: **Optimising industry returns from existing soil and water research.**

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## Adoptable Outcome 2: Managing spatial variation in grapevine water requirements

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### 1. Background

Micro-irrigation systems offer growers a high degree of control over both the volume of water applied and the timing of irrigation events. Theoretically, growers can optimise water use efficiency by closely matching the volume of irrigation supplied with the crop water requirement (see industry adoptable outcome #1). The scale at which a grower attempts to match irrigation supply with crop water requirement, for example whole farm, block or sub-block, and the variation in irrigation supply and crop water requirement at that scale, will influence the accuracy and precision of irrigation management and subsequent yield and drainage.

In practice, large discrepancies can exist in the volume of water applied per plant compared to the expected irrigation volume (see 'Irrigation distribution uniformity mapper', GWRDC project CUT 1001). Irrigation systems are designed to deliver uniform volumes of water across an area but deterioration of systems over time, poor system design or incorrect operation of a system can lead to significant variation in emitter rates and hence poor irrigation distribution uniformity (Hornbuckle et al. 2007a, b). This limits a grower's ability to accurately control irrigation volumes.

In addition to the complication of variable emitter rates across a block, spatial variation in canopy cover creates large differences in crop water requirement. Analysis of aerial photographs of 74 grapevine blocks in the Sunraysia irrigation district to determine canopy cover of individual plants indicated that mean block canopy cover at veraison ranged from 20 to 80 % (McClymont et al. 2012a *submitted*). The four-fold range in mean canopy cover highlights the need to adjust irrigation between blocks to account for differences in crop water requirement.

Within-block variation was also substantial and, given a scenario of irrigating to meet the crop water requirement of the largest vines, there would be substantial over-watering of smaller vines. By comparison, irrigating to meet the mean crop water requirement within a block would cause a yield penalty due to under-watering of a proportion of each block.
A decision framework was built to:

- Assess the impacts of within-block variability of irrigation supply and crop water requirement, and
- Identify the need to improve irrigation system performance and/or divide a block into smaller irrigation management units (IMUs).

### 2. Modelled impacts of within-block canopy cover or irrigation variation on yield and drainage

The decision framework utilises a crop water production function model to predict water losses and yield penalties resulting from spatial variation in crop water requirement and irrigation supply, allowing growers to assess the potential benefits of improving their irrigation system performance and/or creating IMUs. The model, illustrated in Figure 1, relates yield to crop water supply such that the supply of crop water requirement results in the maximum yield being obtained with no water loss. The yield response factor ($k_y$) for grapevines (defined by Doorenbos and Kassam 1979) determines the yield penalties associated with under-watering. For the purpose of the model, it is assumed that irrigation above crop water requirement will be entirely lost via deep drainage or soil evaporation. The model does not recognise the possibility of a decrease in yield due to waterlogging.

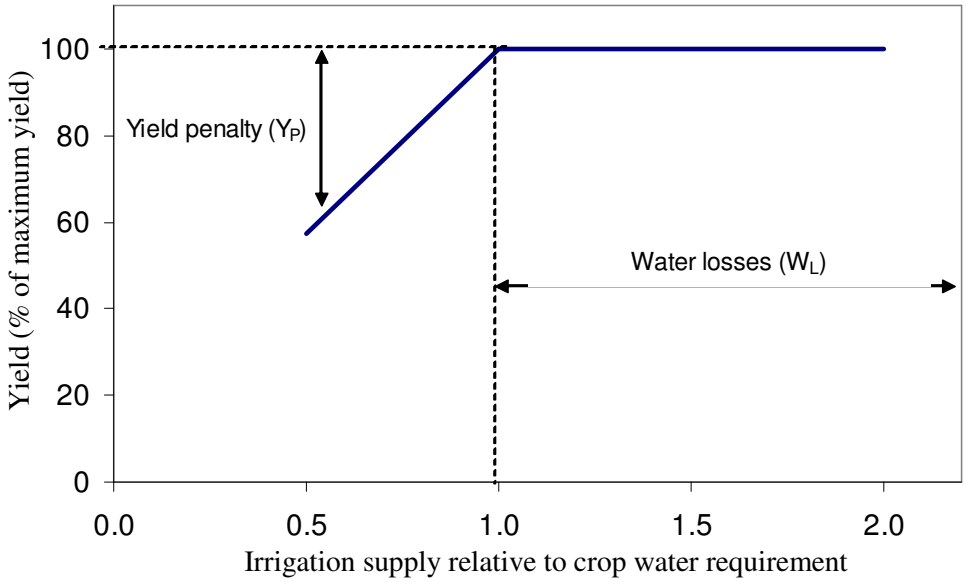



**Figure 1.** Crop water production model used to determine grapevine yield penalties and irrigation water losses associated with within-block variation in crop water requirement and/or irrigation supply.

### 3. Measurement of variability in irrigation supply

The framework utilises the 'DU Calculator' tool (www.irrigateway.net/tools/du/) to instruct growers in measurement of irrigation distribution uniformity (see 'Irrigation distribution uniformity mapper', GWRDC project CUT 1001). Growers are provided with instructions for measuring emitter rates and recording GPS coordinates of emitters and block boundaries. This data is entered in the website to generate a report that provides irrigators with a map of the emitter application rates and calculates the irrigation distribution uniformity for their field. The distribution uniformity value provides growers with an indication of whether or not improvements to irrigation system performance should be a priority. Individual emitter rates are incorporated into the framework data analysis to allow the combined impacts of variable crop water requirement and irrigation supply on yield and water losses to be calculated.

### 4. Measurement of variability in canopy cover

Canopy cover data can be obtained from on-ground measurements, aerial images and image-processing software (McClymont et al. 2009b, 2010a, 2011) or aerial spectral data (McClymont et al. 2012b, *submitted*). On-ground measurement tools include shade-sticks (Goodwin 2009), ceptometers and the Paso Panel (Battany 2010). On-ground measurements can be time-consuming although the shade-stick method in particular is cheap and simple to use. In contrast, analysis of aerial images enables relatively fast analysis of large areas. Initial image processing can be conducted using the freeware package ImageJ (Rasband 1997-2007) to identify image pixels as vine or non-vine. The data then needs to be aggregated to provide a canopy cover value for individual vines; this step is undertaken rapidly by Genstat but individuals without access to similar software will find other methods (e.g. manual identification of regions-of-interest in ImageJ) time-consuming. The aggregation step could be conducted automatically within ImageJ if a suitable plug-in were developed. Alternatively, various commercial companies provide multispectral data and associated vegetation indices (e.g. normalised difference vegetation index, NDVI) to the viticulture industry at reasonable cost.

## 5. Decision tree framework

Decisions to overhaul or replace poorly performing irrigation systems or implement site-specific irrigation should be based on an expectation of sufficient improvement in yield, fruit quality and/or water use efficiency to warrant the added infrastructure and logistical costs. The decision tree framework was designed to guide users through a process of assessing the variability in irrigation supply and crop water requirement and the potential impacts of these in terms of yield penalties and water losses and to identify the need to improve irrigation system performance and/or create IMUs.

The decision tree framework relies on measurements of emitter rates and vine-scale canopy cover. The impacts of failure to match irrigation supply with crop water requirement are based on the model described in section 2. The framework concept was developed as part of a CRC for Irrigation Futures project for use in perennial horticulture and a number of documents describe its initial format and provide case studies (McClymont et al. 2009b, 2010a,b, available from the author on request). Later versions of the framework have evolved but are currently not documented.

### 5.1 Yield penalties and water losses

The decision tree framework begins with a requirement for canopy cover and irrigation supply data (see section 3 and 4 above). The data are collated in the 'IMU Workbook', a Microsoft Excel based spreadsheet. The workbook automatically generates initial data summaries including calculations of mean and maximum crop water requirement, yield penalties and water losses, the relationship between canopy cover and emitter rate, and the coefficient of variation (CV) of canopy cover (standard deviation of canopy cover/mean canopy cover). Emitter rate data are also submitted to the 'DU Calculator' website (www.irrigateway.net/tools/du/) and this calculates irrigation distribution uniformity (section 3). Alternatively, students with access to Genstat (VSN International Ltd, Hertfordshire, UK) could use a version of the Whitfield program (McClymont et al. 2010a) to calculate water losses and yield penalties assuming uniform irrigation inputs.

Yield penalties and water losses are calculated for different irrigation strategies: crop water supply matches maximum crop water requirement of the block, and crop water supply matches mean crop water requirement of the block. Calculation of yield penalties and water losses are based on either an assumption of uniform water application (Table 1 in the 'IMU workbook') or on actual emitter rates (Table 2 in the 'IMU workbook'). A practical assumption is made, that no alternative water is available (i.e. plants are not able to access groundwater or water from nearby creeks, dams or channels).

In addition to yield penalties caused by failure to match within-season irrigation with crop water requirement, yield penalties may occur due to impaired canopy development. The framework addresses the yield penalty caused by poor irrigation supply uniformity, such that while some plants have received adequate water to achieve optimum growth others within the same block have had canopy development impaired (Table 3 in the 'IMU workbook'). Theoretical determination of this yield penalty is only undertaken if there is a significant relationship between irrigation supply and canopy cover (i.e. there is a yield penalty caused by low canopy cover due to under-irrigation of vines). This assumes that the yield penalty can be overcome by fixing irrigation supply (i.e. vines will grow to a similar canopy cover).

### 5.2 Decision tree design

To start the framework process, users are asked whether or not crop water requirement and irrigation supply are uniform. This determines which of four main pathways (**YY**, **YN**, **NN** or **NY**)

the user will follow (see Appendix A). Crop water requirement and irrigation supply are considered to be spatially uniform if the CV of canopy cover is less than 10 % (or the spread is less than 50 %, ((maximum-minimum)/mean)*100) and irrigation distribution uniformity is greater than 90 %. These values do not reflect industry standards of irrigation system design or spatial analysis of canopy cover data. Rather, they provide a starting point for users of the decision framework and have been set for the following reasons:

- there is unlikely to be much scope for further improving irrigation distribution uniformity that is already greater than 90 % (and little measurable benefit from doing so), and
- any benefit from sub-dividing blocks with a CV of canopy cover less than 10 % will be small.

Furthermore, analysis of 74 aerial photographs of grape blocks in the Sunraysia indicated that CVs of canopy cover ranged from 5 to 36 % and 15 % of blocks had a canopy cover CV of 10 % or less. Thus a CV of 10 % was considered to provide a reasonable initial benchmark for the industry.

A canopy cover CV greater than 10 % or an irrigation distribution uniformity less than 90 % will not in itself define a need to alter irrigation system design or management, these values simply help direct a grower to one of four pathways for further analysis of their system.

The four pathways guide the user through the decision-making process with regard to whether or not system modifications are desirable and address the types of modifications that may be suitable for the user's situation. Each of the pathways concludes with a recommendation of actions including to reassess at a later date. This highlights the ongoing nature of the process and the need to evaluate the success of any system modifications or management changes that have been undertaken. It is noted that plant health issues, unrelated to irrigation, or basic system maintenance problems can contribute to non-uniformity in crop water requirement and irrigation supply and that these problems should be dealt with prior to undertaking the framework process. The pathways are briefly described below in sections 5.3.1 – 5.3.4.

A simple design has been adopted for the decision tree (Appendix A). Oval nodes represent data acquisition or analysis steps and decision processes. Rectangular nodes represent decisions and recommendations. Thought bubbles are used when users are required to make either objective or subjective judgements based on data and personal priorities.

### 5.2.1 Crop water requirement uniform, irrigation supply uniform (YY)

**YY** is the simplest pathway, both crop water requirement and irrigation supply are considered to be uniform. A recommendation is given to assess if actual irrigation is closely matching the crop water requirement, to adjust irrigation volumes if necessary, and reassess at a later date.

### 5.2.2 Crop water requirement uniform, irrigation supply not uniform (YN)

The **YN** pathway is followed when crop water requirement is considered to be uniform but irrigation supply is not uniform.

The **YN** pathway assumes benefits of site-specific irrigation will be minimal and focuses on potential benefits of improving the uniformity in irrigation supply (evaluated by comparing Table 1 and Table 2 in the 'IMU Workbook'). If the grower decides an improvement in irrigation supply is necessary, the framework makes suggestions regarding possible causes of poor irrigation uniformity and appropriate actions.

### 5.2.3 Crop water requirement not uniform, irrigation supply not uniform (NN)

For **NN**, neither crop water requirement nor irrigation supply are considered to be uniform.

The **NN** pathway essentially directs growers to address irrigation supply problems and then to consider if subdivision to create smaller IMUs and allow site-specific irrigation is beneficial.

This pathway initially questions whether there is a relationship between emitter rates and canopy cover. A good relationship between emitter rates and canopy cover would result in minimal drainage and yield penalty, however, block yield will be less than potential because of the small vines associated with low emitter rates. In other words, fix the irrigation system and small vines will grow into big vines and block yield will increase. It is anticipated that this scenario will be unusual in perennial horticulture crops due to routine system inspection and repair of damaged emitters.

### 5.2.4 Crop water requirement not uniform, irrigation supply uniform (NY)

The **NY** pathway is followed when crop water requirement is not considered to be uniform but irrigation supply is uniform.

The NY pathway directs growers to consider the benefits of subdivision to create smaller IMUs. IMUs can be identified by visual assessment of the block/aerial photograph or by cluster analysis using downloadable software such as FUZme (Minasny and McBratney 2002; version 3.0, Australian Centre for Precision Agriculture, The University of Sydney, Australia) or Management Zone Analyst (Frigden et al. 2004; MZA, version 1.0.1, University of Missouri-Columbia and Agricultural Research Service, Columbia, MO, USA;). The effectiveness of sub-divisions in reducing yield penalties and water losses will be determined by the uniformity of new IMUs. Practicality and cost must be considered.

## 6. Addressing irrigation system performance

Micro-irrigation aims to evenly deliver water to each vine in a block. However, system performance can deteriorate over time. Poor maintenance (emitter and filter blockages), wear and tear (malfunctioning pumps, emitters or valves) and incorrect operating pressures all potentially contribute to low uniformity of water delivery. Poorly designed irrigation systems will also have low uniformity.

Spatial patterns of emitter rates revealed in the maps created by ‘DU Calculator’ are of particular value in determining possible causes of poor system performance. Once problems causing low distribution uniformities have been identified then mitigation measures can be undertaken to improve the system performance. Possible interventions include thorough flushing and cleaning of the system, running the system at higher/lower operating pressures, general maintenance and repair of the system or redesigning parts of the system to overcome limitations. Redesign of an irrigation system may involve sub-division of blocks to ensure that uniform irrigation within a management unit can be achieved.

## 7. Site-specific irrigation

Site-specific irrigation has previously been suggested as a management tool to improve the match between irrigation supply and crop water requirement by dividing a block into smaller irrigation management units (IMUs) based on canopy cover.
Site-specific irrigation (also referred to as variable rate irrigation) aims to apply irrigation to defined management units within a field based on need and thus to ensure optimal use of available water (Feinerman and Voet 2000, King et al. 2006). Potential benefits of site-specific irrigation include increased yield and fruit quality by avoidance of water stress, and decreased drainage by avoidance of over-watering. Water saving will not always occur as the aim of site-specific

irrigation is to maximise yield (or crop value) and minimise drainage, rather than reduce application (Feinerman and Voet, 2000).

Historically, the basis for delineating IMUs has been the water-holding characteristics of the soil (King et al. 2006, Evans et al. 2007, Hedley et al. 2009). However, King et al. (2006) suggested that available water-holding capacity (or surrogates of it) may not be the most appropriate defining parameter. More recently, delineating zones based on canopy cover has been suggested as an effective method of determining IMUs (Boshoff 2010, Taylor et al. 2010).

**Research note: Correlations between canopy cover and grapevine yield, fruit composition and wine quality**

Multispectral aerial imagery is routinely utilised by the Australian viticulture industry and commercial companies provide vineyard maps of canopy cover. This provides growers with easy access to high density canopy cover data during growing seasons. By comparison, collection of high density fruit composition data would be costly and yield and wine quality data can only be captured retrospectively.

Bramley et al. (2003), Lamb et al. (2004) and Hall et al. (2011) have observed correlations between canopy cover, measured from aerial imagery, and yield or fruit composition. In general, mid- to late-season measures of canopy cover are positively correlated with yield and negatively correlated with fruit composition. Within the recent GWRDC 'Five sites' project, Zerihun et al. (2010) showed that berry composition parameters were significantly correlated with canopy cover of a Langhorne Creek Shiraz block at veraison. Phenolics, anthocyanins and tannins were negatively correlated with canopy cover while titratable acidity was positively correlated. Furthermore, Lanyon et al. (2008, 2010) observed generally negative correlations between canopy cover at veraison and wine properties (colour, phenolics, anthocyanins and tannins) and, to a lesser extent, wine sensory attributes during the 'Five sites' project. The main exception to these observations was the Tatura site where vines were grown in a narrow hedgerow (VSP trellis system).

The effectiveness of site-specific irrigation in reducing within block variability in yield, water use efficiency and fruit composition has been investigated using data from the GWRDC funded projects 'Managing soil and water to target quality and reduce environmental impact' (GWRDC project DPI 04/04) and 'Viticultural management of grape tannin and anthocyanin levels to achieve desired wine quality specifications' (GWRDC project DPI 05/01) (McClymont et al. 2012b, *submitted* – see case study below).

Multivariate cluster analysis has been used to reveal IMUs with persistently high or low canopy cover and hence high or low potential transpiration (McClymont et al. 2012b, *submitted*). Cluster analysis software is freely available for download from the web. However, precision agriculture consultants will likely be needed to manage the data analysis. New methods for delineating management zones are evolving (Pedroso et al. 2010) and should also be considered. Additional spatial information (e.g. canopy temperature) could be included in the multivariate cluster analysis or used to inform irrigation management decisions.

While canopy cover provides an effective means of defining IMUs, the management of these requires an understanding of the environment within each IMU and the production and quality goals. Irrigation frequencies and depths need to be determined with consideration of rooting volumes and soil types. Similarly, while irrigation volumes will be influenced by canopy cover, alternative water sources (e.g. high water-tables) need to be taken into account. With regard to

production goals, deficit irrigation is commonly applied to control vegetative growth and/or manipulate berry size and fruit quality. Estimates of crop water requirement are commonly based on well-watered conditions and irrigation supply therefore needs to be reduced to impose a deficit. Soil moisture monitoring is currently used to aid irrigation scheduling decisions in vineyards (Goodwin 1995). Placement of soil moisture sensors within different IMUs will assist growers to fine-tune irrigation of these zones. In the future, thermal imaging of blocks could be used to provide greater understanding of spatial responses to irrigation management and to trigger irrigation events. For example, at the Deakin Estate site (see case study below), canopy temperature ($T_c$) relative to air temperature ($T_a$) was measured at 100 locations across the block at veraison in 2008 (McClymont et al. 2012b, *submitted*). The data showed that $T_c$-$T_a$ varied across the site and the spatial pattern supported the belief that large vines were accessing water in addition to irrigation (the South zone) and that water availability was limited for some vines (the West zone), possibly due to soil type or root development. Consequently, initiation of irrigation was delayed for the South zone (historically characterised by vigorous vines with low $T_c$-$T_a$) and more frequent irrigations were applied to the West zone (characterised by small vines with higher $T_c$-$T_a$) to improve temporal water availability.

## 7.1 Case study: Site-specific irrigation in a Shiraz vineyard

The DPI 04/04 project documented high variability in canopy cover, yield and fruit composition at the Sunraysia site (Goodwin et al. 2009). The vineyard manager implemented site-specific irrigation management to attempt to improve yield of poor performing areas and reduce overall variability in yield and quality. Three IMUs were operated. Multivariate cluster analysis of NDVI measured over three seasons indicated a close match between clusters and the IMUs (Figure 2).

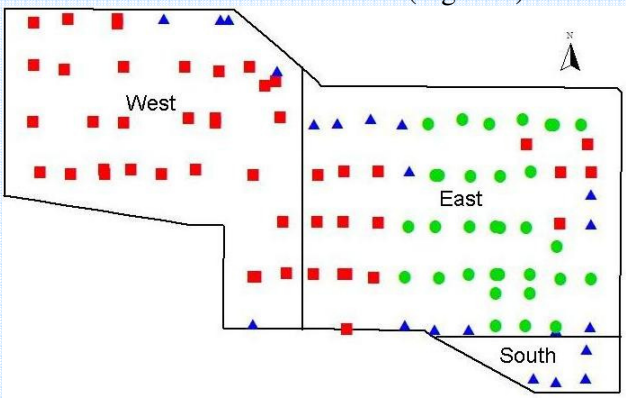



**Figure 2.** Site-specific irrigation management units (East, West and South) within the study block. Points indicate the target vines used for the measurement of yield and fruit composition. The results of the multivariate cluster analysis of normalized difference vegetation index (NDVI) are indicated by red, green, or blue points showing classification to three clusters.

Yield and fruit composition parameters at the site were monitored for two seasons (2005/06 and 2006/07) prior to implementation of site-specific irrigation (in 2009/10). Water stress and low vine vigour and yield were common in the West zone. Excessive vine vigour existed within the South zone; yield and berry weight were high and quality parameters within this area were generally poor compared to the East and West zones. The East zone produced moderate yields with intermediate quality parameters.

The aims of improving production and reducing yield and fruit composition variability were partially achieved by site-specific irrigation management when irrigation frequency in the West zone was increased and initiation of irrigation delayed in the South zone. Site-specific irrigation increased yield in the West management zone relative to the East and South zones. Furthermore, despite the withholding of irrigation to the South zone until December, the yield in this zone relative to the East zone did not decrease in comparison to previous years (Table 1). Additionally, variation in yield across the site decreased (data not shown). Fruit composition results were varied; pH and titratable acidity showed increased similarity between zones but other parameters maintained differences between zones (Table 1).

**Table 1.** Mean yield and fruit composition within West, East and South irrigation management units under uniform irrigation (2006 and 2007 vintages) and site-specific irrigation (2010 vintage).

| Attribute | Irrigation | West | East | South |
|---|---|---|---|---|
| Yield (kg/m2) | Uniform | 0.86 – 2.43 | 3.07 – 3.60 | 4.09 – 4.44 |
| | Site-specific | 2.80 | 2.96 | 3.98 |
| Berry weight (g) | Uniform | 1.10 – 1.19 | 1.24 - 1.31 | 1.76 - 1.79 |
| | Site-specific | 1.09 | 1.04 | 1.46 |
| Juice pH | Uniform | 3.84 - 3.95 | 3.63 - 3.87 | 3.37 - 3.59 |
| | Site-specific | 3.98 | 4.00 | 3.89 |
| TA (g/L) | Uniform | 3.78 – 3.85 | 4.37 – 5.04 | 6.00 -7.56 |
| | Site-specific | 3.94 | 3.93 | 5.19 |
| Anthocyanins (mg/g) | Uniform | 1.481 -1.966 | 1.231 - 1.326 | 0.848 - 0.852 |
| | Site-specific | 1.541 | 1.306 | 0.725 |
| Phenolics (mg./g) | Uniform | 4.374 - 6.747 | 4.614 – 5.339 | 4.367 - 4.681 |
| | Site-specific | 5.385 | 4.764 | 3.565 |
| TSS ( o brix) | Uniform | 24.11 – 25.48 | 23.74 - 24.21 | 21.10 – 21.45 |
| | Site-specific | 24.90 | 23.77 | 21.74 |
| Tannins (mg/g) | Uniform | 1.646 – 3.390 | 1.644 – 2.490 | 1.564 – 1.998 |
| | Site-specific | 2.896 | 2.404 | 1.583 |

Note: the irrigation management for the East zone remained essentially unchanged, thus the apparent yield decrease in this zone under site-specific irrigation is more likely the result of seasonal conditions than site-specific irrigation management.

## 8. Future directions

### 8.1 Verification of benefits of site-specific irrigation

While modelling has indicated that site-specific irrigation can offer economic and environmental benefits (Hedley et al. 2009), including reduced irrigation inputs and water losses in perennial horticulture systems (McClymont et al. 2011), field work is necessary to verify that modelled impacts are realistic. To date, experimental investigation of the impacts of site-specific irrigation on perennial horticulture has been limited. Site-specific irrigation has been described in industry articles (Leonard 2008) and was suggested by Boshoff (2010) as a means to manipulate grapevines and either increase or decrease differences between zones within a block. Further work is required to determine long-term impacts of site-specific irrigation, particularly on fruit quality.

### 8.2 Improved irrigation scheduling decisions

The range in mean block canopy cover and, subsequently, crop water requirement across the Sunraysia region highlights the need to tailor irrigation inputs to match crop water requirement based on site-specific canopy characteristics rather than generic crop coefficients. Irrigation scheduling guidelines should be updated to reflect current knowledge regarding calculation of potential vine water use based on canopy cover and evaporative demand.

Intense spatial measurement of canopy temperature (either by remotely-sensed thermal images or 'on-the-go' logging with infrared temperature sensors) helps to understand water status patterns across blocks and would aid irrigation management decisions. Canopy temperature has traditionally been studied based on point measurements with the aim of defining crop water stress indices for irrigation scheduling. The '5 sites' project has demonstrated spatial collection of canopy temperature data to inform general scheduling practices. Further investigation of the use of thermal images to prioritise and trigger irrigation events could encourage development of irrigation management services based on temperature data. Such services are currently being trialled in Spain (pers. comm. Pablo Zarco-Tejada, 2011).

### 8.3 Software development

The model described in this work has provided a basic assessment of the yield penalties and water losses associated with spatial variation in crop water requirement (McClymont and Goodwin 2011, McClymont et al 2011, 2012a *submitted*). The model allows users to evaluate the impacts of different irrigation strategies (e.g. to meet maximum or mean vine water requirement) and choose the strategy that best suits their yield and water use priorities. To date, analysis of yield penalties and water losses has been conducted using a Genstat-based program assuming uniform irrigation application or the 'IMU Workbook' which allows integration of emitter rate data. However, calculation of yield penalties and water losses by growers remains difficult. A user-friendly interface is needed to allow growers to derive yield penalty and water loss predictions from emitter rate and canopy cover data. The 'DU Calculator' in Irrigateway (www.irrigateway.net/tools/du/) provides growers with a simple interface for compiling and mapping irrigation supply information. This software could be expanded to incorporate canopy cover data and automatically calculate yield penalties and water losses associated with a grower's individual irrigation practices and identify IMUs. Such software would enable growers to explore various irrigation management options.

### 8.4 Determine yield-canopy cover relationships

At present, crop water requirement can be calculated based on canopy cover and evaporative demand (Williams and Ayars 2005), thus water losses associated with over-irrigation can be expressed in absolute terms. However, expression of yield penalties in absolute terms (i.e. t/ha)

remains difficult. Studies have indicated positive relationships between grapevine yield and canopy cover (Sommer et al. 2007); however, insufficient information is available to provide robust estimates of yield potentials. This limits modelling capabilities.

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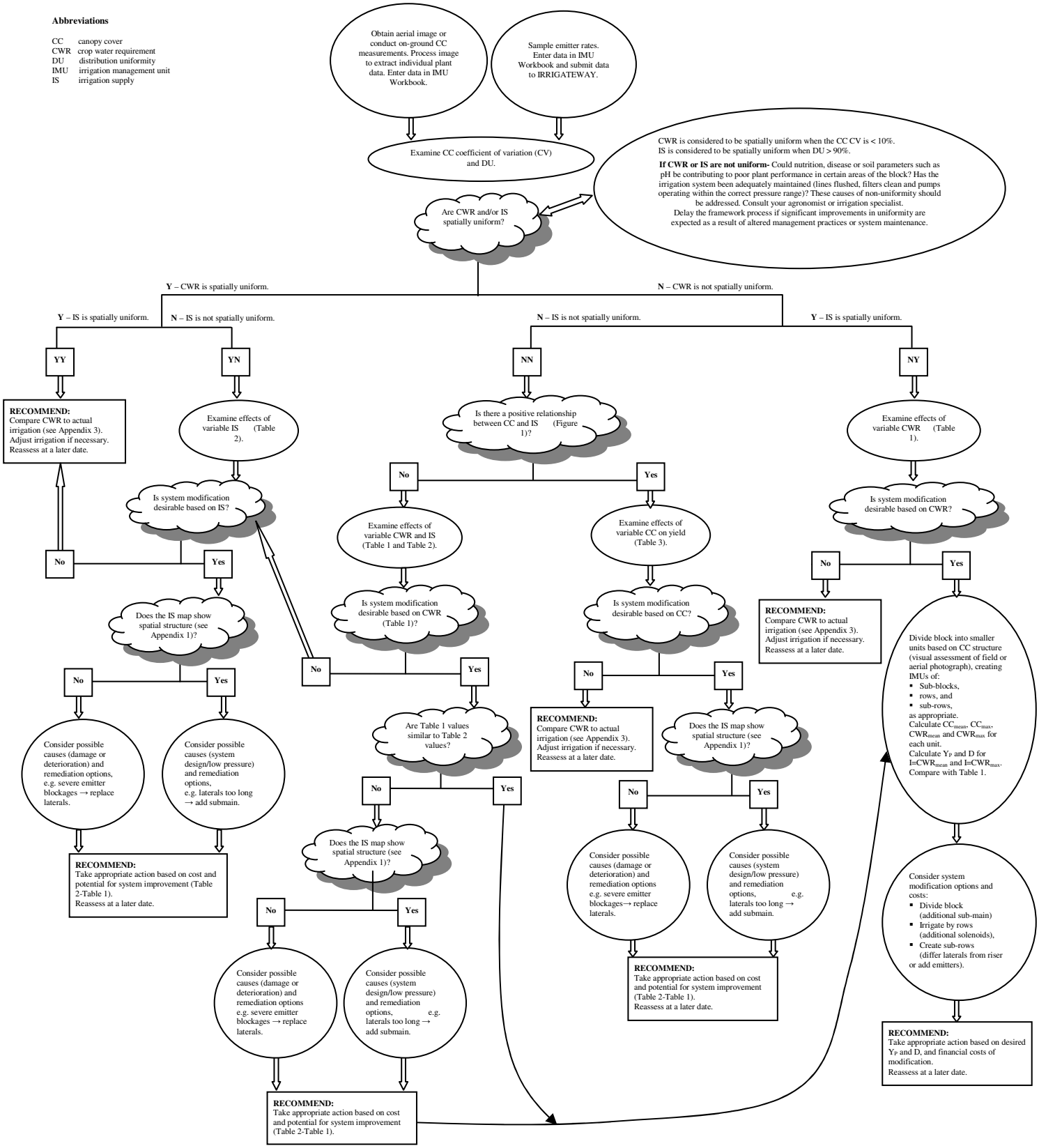
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# Appendix A. Irrigation Management Units – Decision Tree



**Adoptable Outcome 2: Managing spatial variation in grapevine water requirements**

**Authors:** Lexie McClymont, Ian Goodwin, Mark O'Connell and Des Whitfield

# Managing spatial variation in grapevine water requirements

Presenter(s)

## On-farm water management

1. What is the aim?
2. Can the aim be achieved?
3. How can we quantify the cost?
4. When and how should we improve water management?

## 1. What is the aim?

- I + R = Crop Water Requirement (CWR)
- $ET_c = k.CC.ET_o$

$ET_o$ = reference crop evapotranspiration
CC = canopy cover (plant size)

(Allen et al. 1998; Williams and Ayars 2005; McClymont et al. 2009; Campos et al. 2010; Selles et al. 2011)

## 2. Can the aim be achieved?

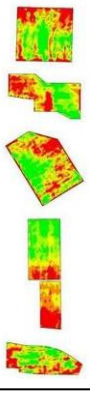
What prevents I = CWR?

- Irrigation supply is not uniform
  - Poor distribution uniformity
- CWR is not uniform
  - $CC_{vine\ 1} \neq CC_{vine\ n}$





## Within-block variation - canopy cover



| Range | CV |
|---|---|
| 0.13 - 0.20 | 12 % |
| 0.34 - 0.62 | 15 % |
| 0.28 - 0.44 | 9 % |
| 0.11 - 0.29 | 25 % |
| 0.14 - 0.32 | 29 % |

$I = CWR_{mean}$

OR

$I = CWR_{max}$ ?

Goodwin et al. (2009)

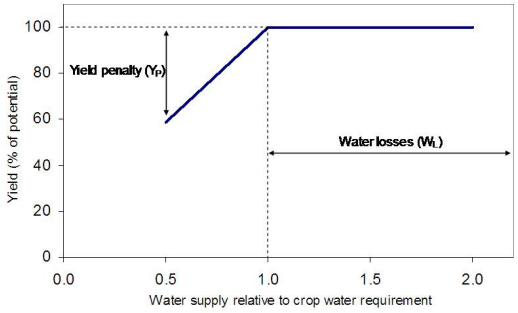
## 3. Quantifying the cost - canopy cover

Aim

- Evaluate the potential yield penalties and water losses due to within-block variation in canopy cover, and hence, crop water requirement.

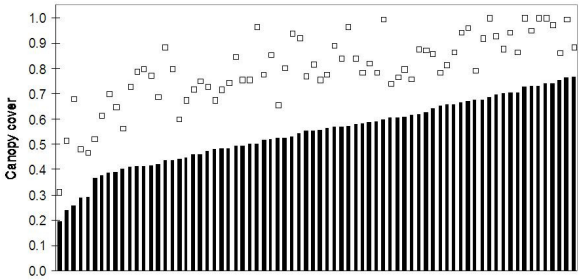
## 3. Quantifying the cost - method

Crop water production function




## 3. Quantifying the cost - results

Grapevines – Sunraysia irrigation region




n = 74 vineyard blocks; bars = mean canopy cover, open squares = maximum canopy cover

## 3. Quantifying the cost - results

Grapevines – Sunraysia irrigation region

| | I+R = $CWR_{mean}$ | I+R = $CWR_{max}$ |
|---|---|---|
| Yield penalty (%) | 5 (1 – 9) | 0 |
| Water losses (%) | 3 (2 – 8) | 25 (11 – 46) |

Yield penalty = % of potential yield

Water losses = % of applied water

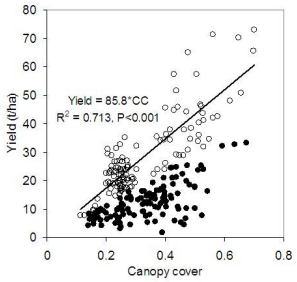
## 3. Quantifying the cost - real terms

Water supply

I + R = 1.7*CC*ETo (Williams and Ayars 2005)

Potential yield

Y = *f* Intercepted radiation (Monteith 1977)




Circles = vine yield and canopy cover,

open circles = upper 50 percentile of data

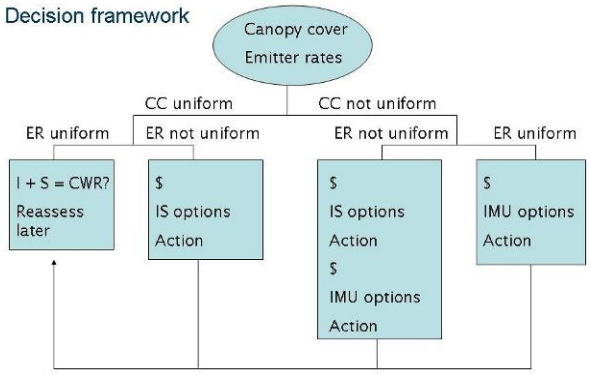
(McClymont et al., in preparation)

## 3. Quantifying the cost – real terms

| | I+R = $CWR_{mean}$ | I+R = $CWR_{max}$ |
|---|---|---|
| Water supply (ML/ha) | 9.0 (3.2 – 12.7) | 13.1 (5.1 – 16.4) |
| Yield penalty (t/ha) | 2.1 (1.0 – 4.3) | 0 |
| Water losses (ML/ha) | 0.3 (0.1 – 0.7) | 3.4 (0.6 – 7.3) |
| Water use efficiency (t/ML) | 5.0 (4.8 – 5.10) | 3.6 (2.0 – 4.6) |

## 4. Improving performance

Decision framework




## Measurements

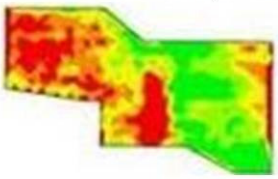
Canopy cover - field measurements, aerial photographs or spectral imagery
www.dpi.vic.gov.au/ search 'determining effective area of shade'

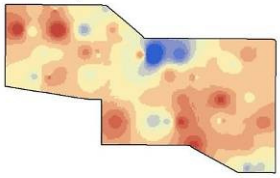


Emitter rates - www.irrigateway.net/tools/du/

## Case study 3

- Canopy cover not uniform (0.34 – 0.62)
- Emitter rate uniform (8 – 12.2 L/hr/vine)





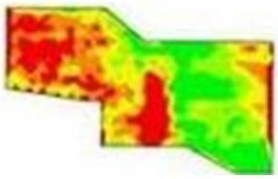
| | $CWR_{mean}$ | $CWR_{max}$ |
|---|---|---|
| $Y_P$ (%) | 4 | 0 |
| $W_L$ (%) | 6 | 26 |

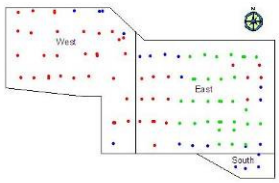
CV of CC = 15 % (stdev/mean)
Spread = 61 % (max – min)/mean

DU = 93 %

## Case study 3

- Canopy cover not uniform ⟶ Irrigation management units
- Emitter rate uniform






| | |
|---|---|
| $Y_P$ (%) | 26 |

CV of CC = 15 % (stdev/mean)
Spread = 61 % (max – min)/mean

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