

Recent research in vineyard variability and implications for *terroir*

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ECOSYSTEM SCIENCES/SUSTAINABLE AGRICULTURE FLAGSHIP

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‘Telling our story’ – are we telling the right one?

- **Regional differentiation is becoming *de rigeur* in the Australian wine sector as is the notion of winemakers ‘telling their story’**
  - **MVGWTA website: “Relax among beautiful undulating hills dotted with vineyards sweeping down to pristine, sun-drenched beaches”**
- **But is sub-regional differentiation so wise ?**
  - **Assuming that you don’t want to compete with your friends and neighbours, what is its objective ?**
  - **If within-vineyard variation is as potentially significant as within-region variation, do we risk sending a very confused message (or simply one that isn’t true !) ?**
  - **What does all this say about *terroir* ?**

McLaren Vale variation



Terroir is not just about soil (or wine)

- Soil (and geology)
- Climate
  - Controls phenology and especially ripening and its timing
- Viticultural and winemaking practices that may be steeped in tradition /social importance
  - Appellation d'Origine Contrôlée et les Cahiers des Charges
  - Historically, in the 'old world', vines were never produced on land suitable for growing food
  - Cheese
- *Terroir* generally considered and researched on a regional basis
  - Problematic for various reasons including contributing to uncertainty about the role of soil (and other factors)
  - Understanding of vineyard variability can offer some useful insights

Brancott Estate, Marlborough, New Zealand



Does the wine produced from this vineyard most reflect the *terroir* of:

- **New Zealand ?**
- **Marlborough ?**
- **This particular vineyard ?**

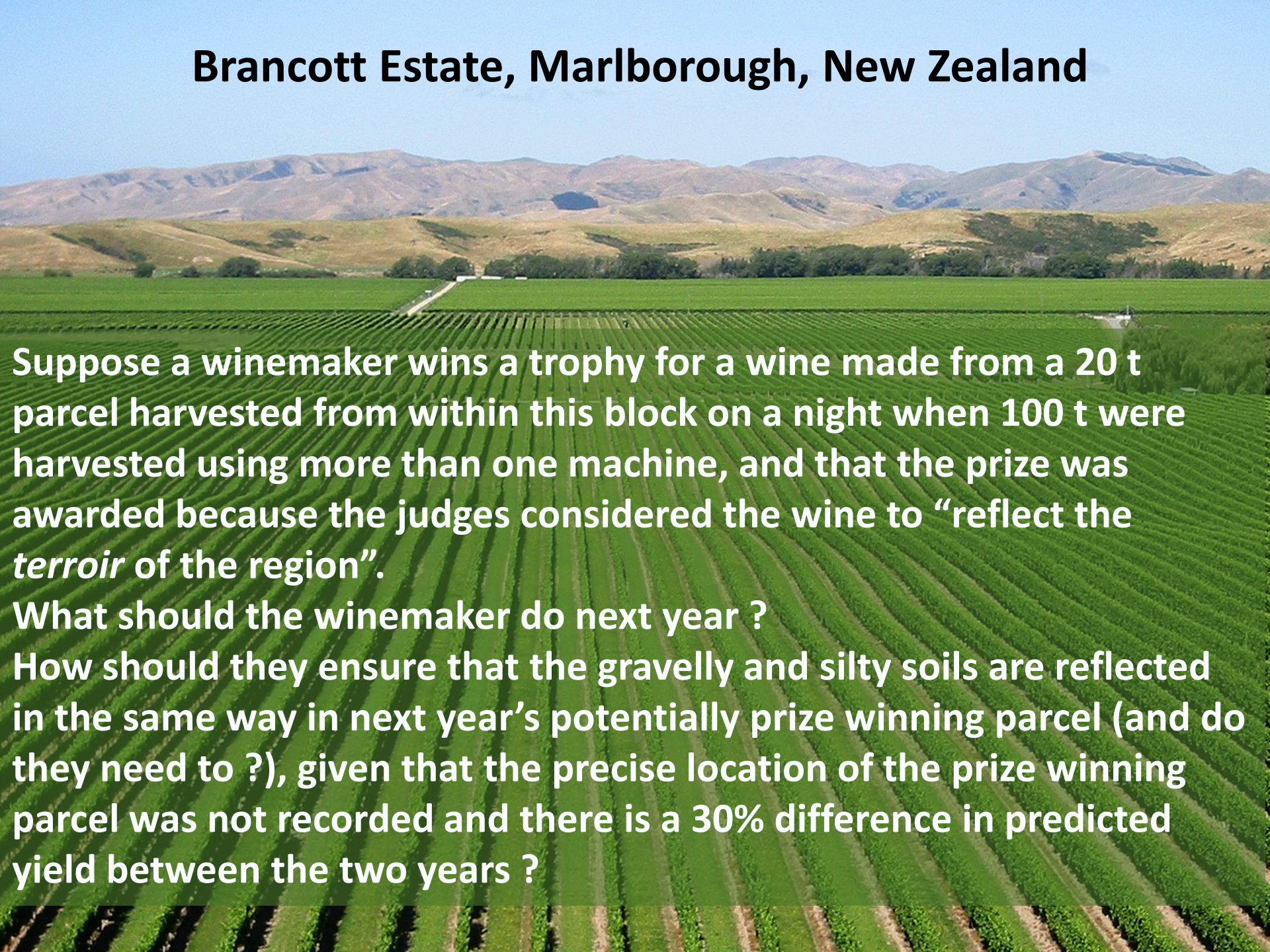
Brancott Estate, Marlborough, New Zealand



Does the wine produced from this vineyard most reflect the vineyard in terms of:

- **the dominant gravelly soils ?**
- **the silty hollows which dissect them ?**
- **some integration of the two ?**

Brancott Estate, Marlborough, New Zealand

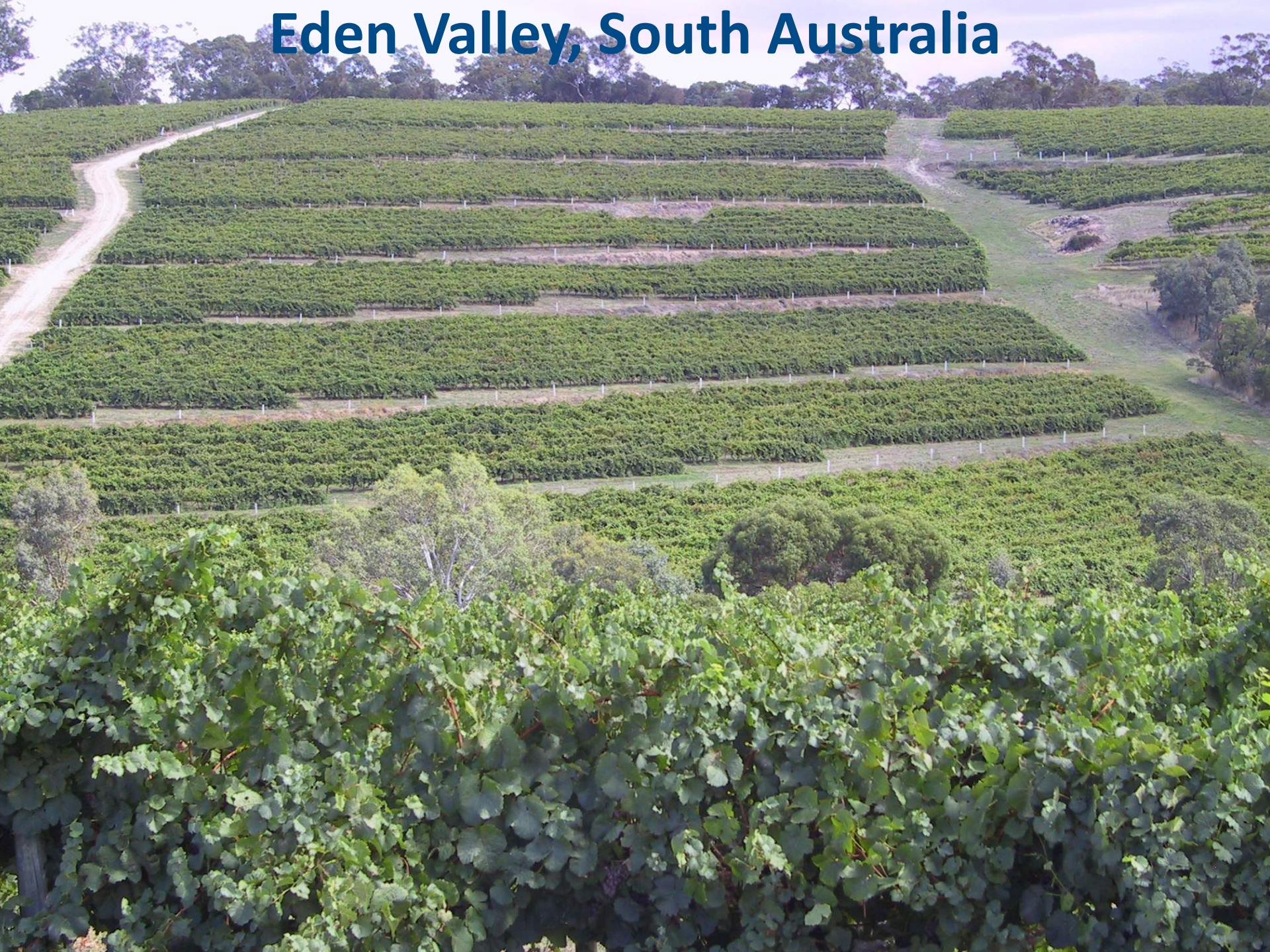


Suppose a winemaker wins a trophy for a wine made from a 20 t parcel harvested from within this block on a night when 100 t were harvested using more than one machine, and that the prize was awarded because the judges considered the wine to "reflect the *terroir* of the region".

What should the winemaker do next year ?

How should they ensure that the gravelly and silty soils are reflected in the same way in next year's potentially prize winning parcel (and do they need to ?), given that the precise location of the prize winning parcel was not recorded and there is a 30% difference in predicted yield between the two years ?

Eden Valley, South Australia



Soil colour variation – Clare Valley




St Emilion, France

St Emilion, France

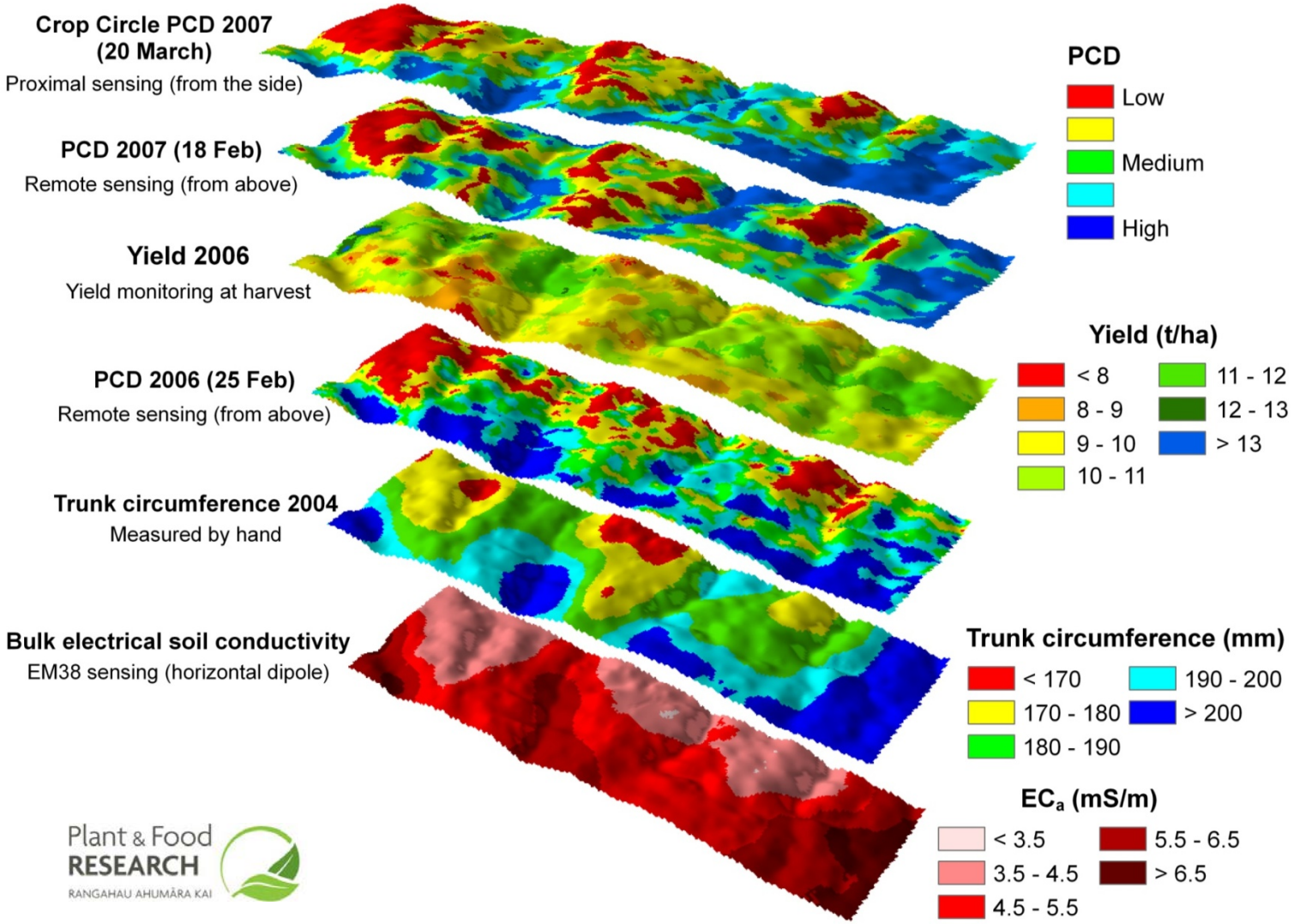




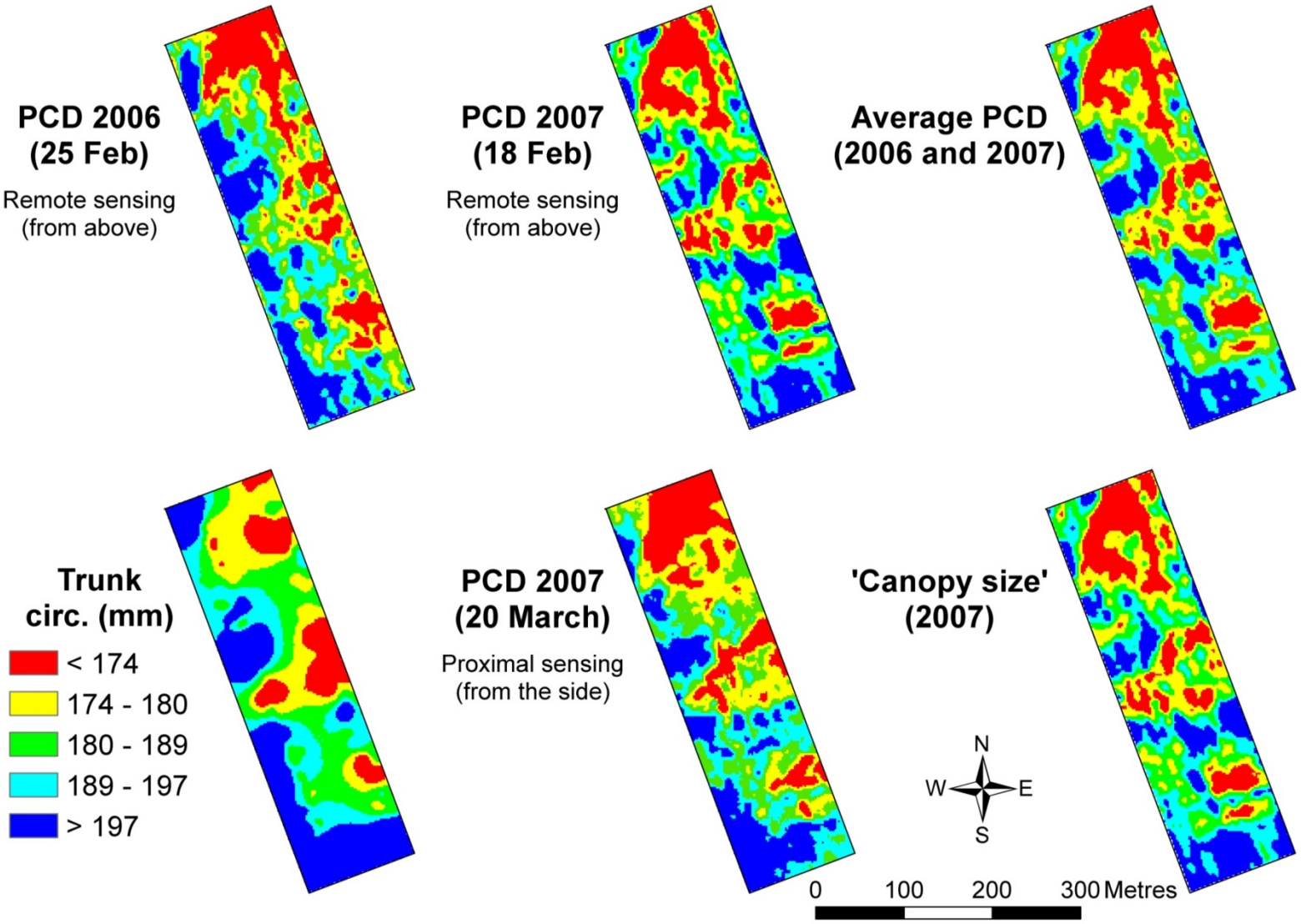

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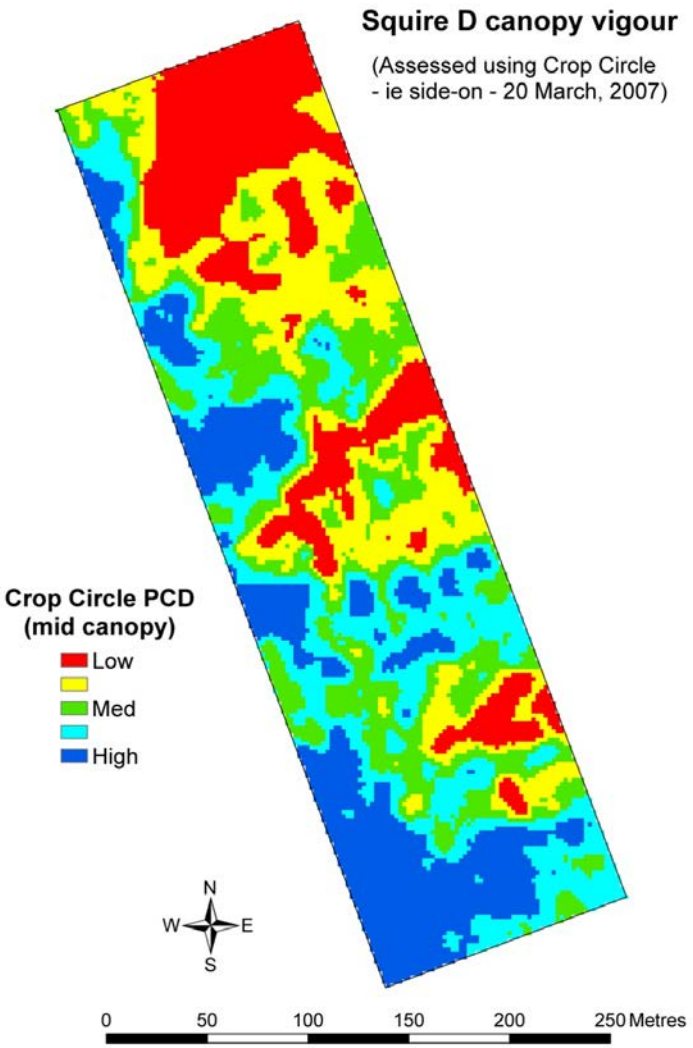
Stoneleigh – Squire Vineyard



Various measures of vigour

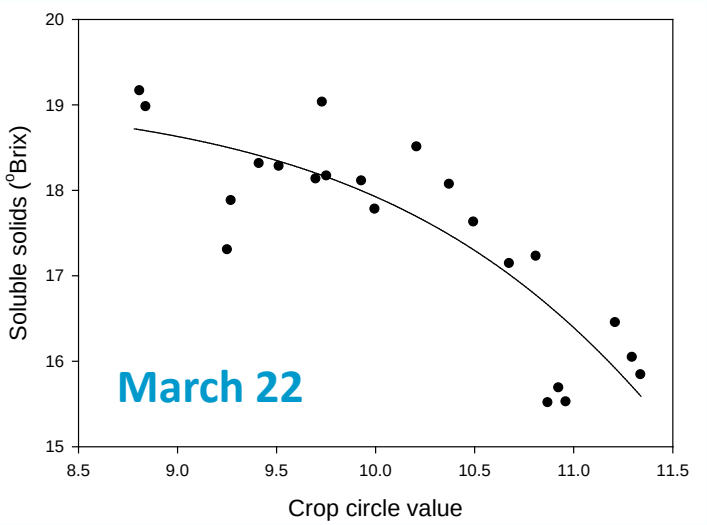


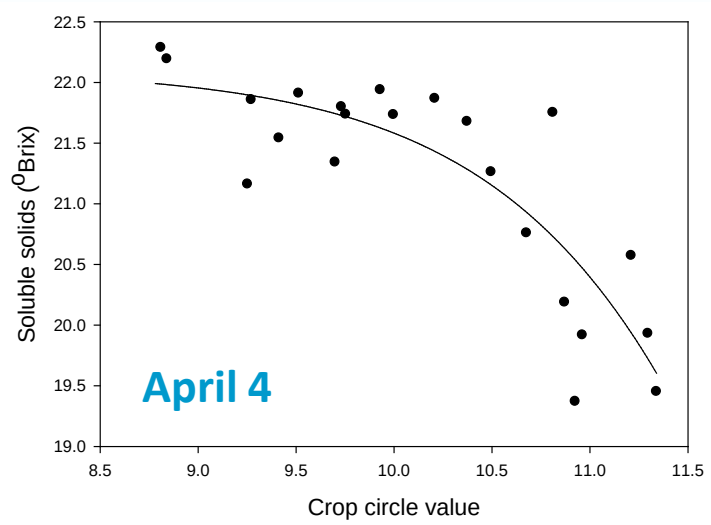
Crop Circle sensing

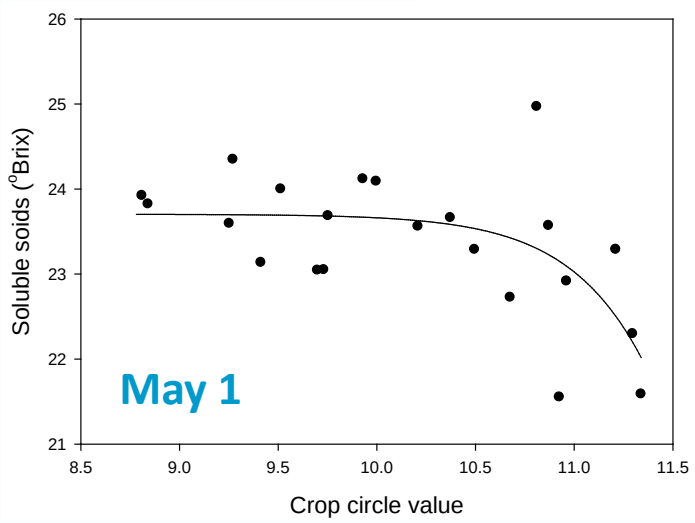




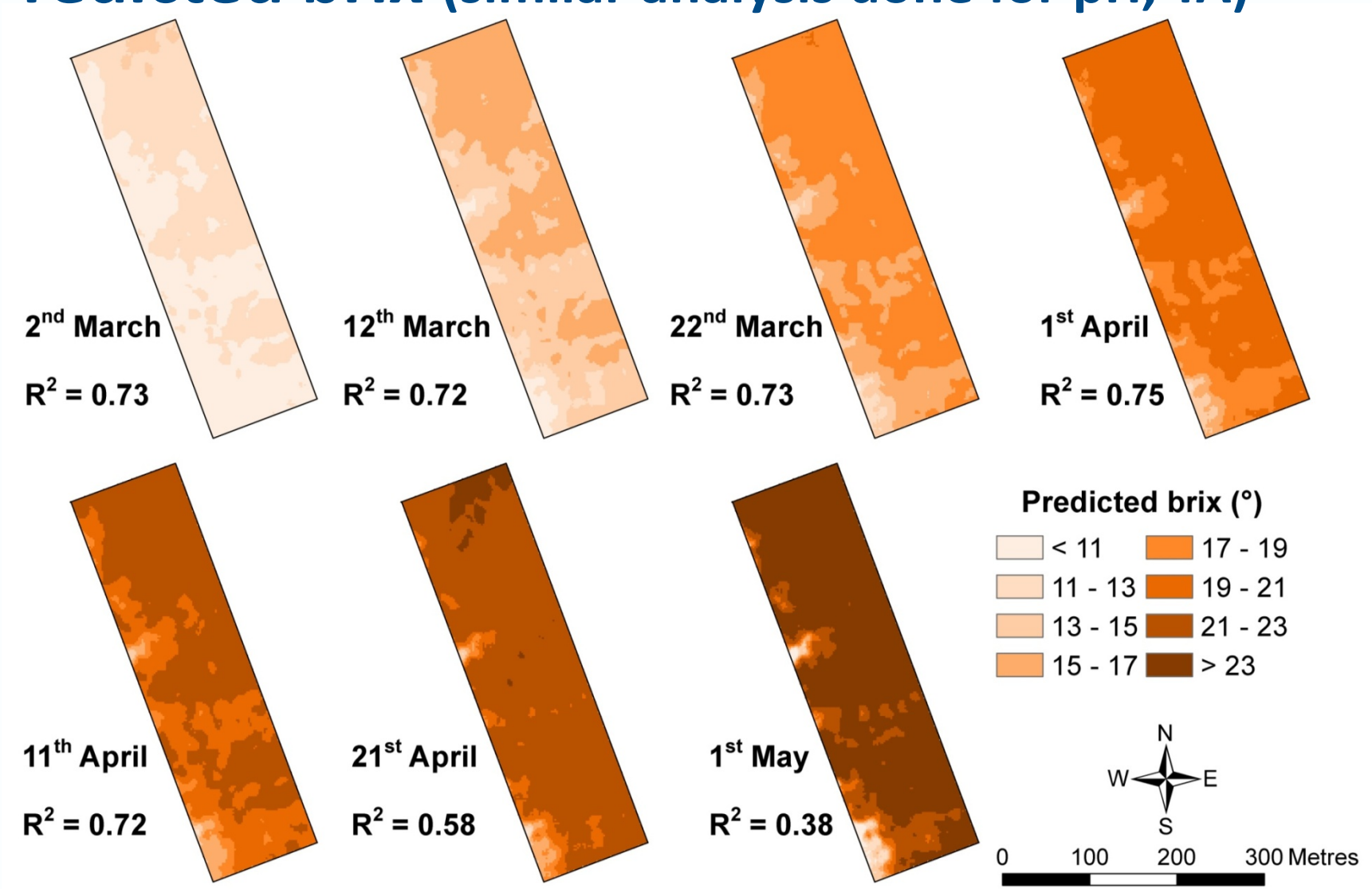
Crop Circle as a predictor of brix in juice



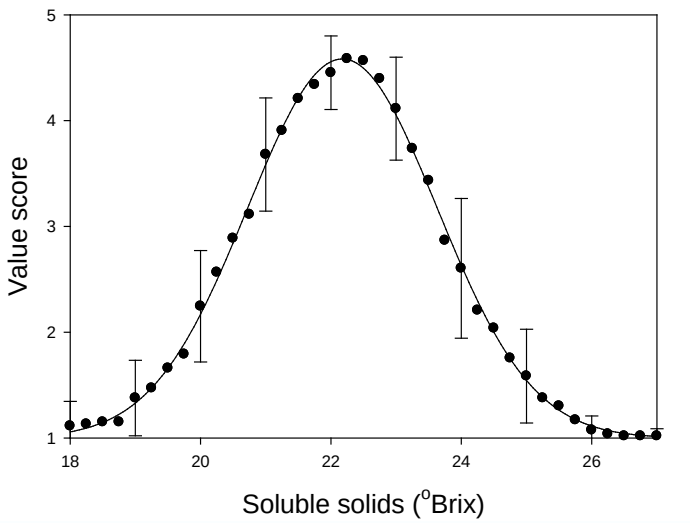


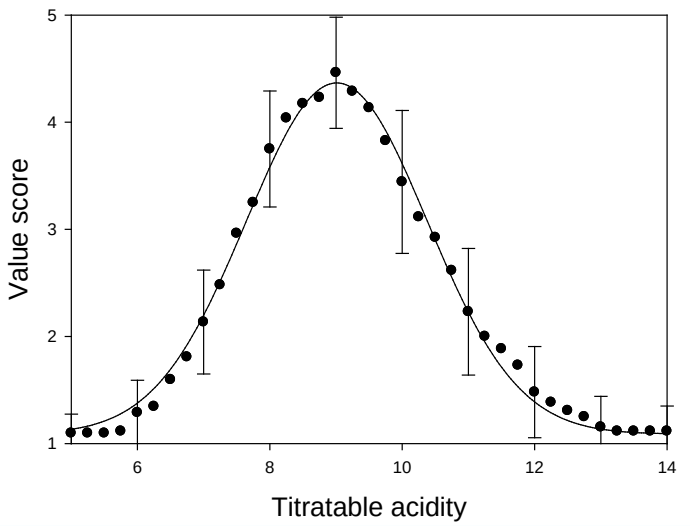


Predicted brix (similar analysis done for pH, TA)



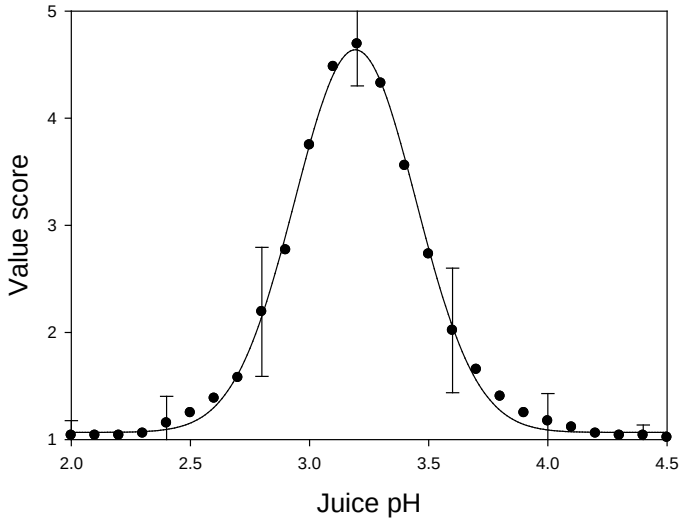
Winemaker survey – quality at harvest





17 grapegrowers / viticulturists
31 winemakers
4 other (consultants, lab staff)

Average industry experience = 11.3 years



Plant & Food RESEARCH
RANGAHAU AHUMĀRA KAI

CSIRO

Juice score

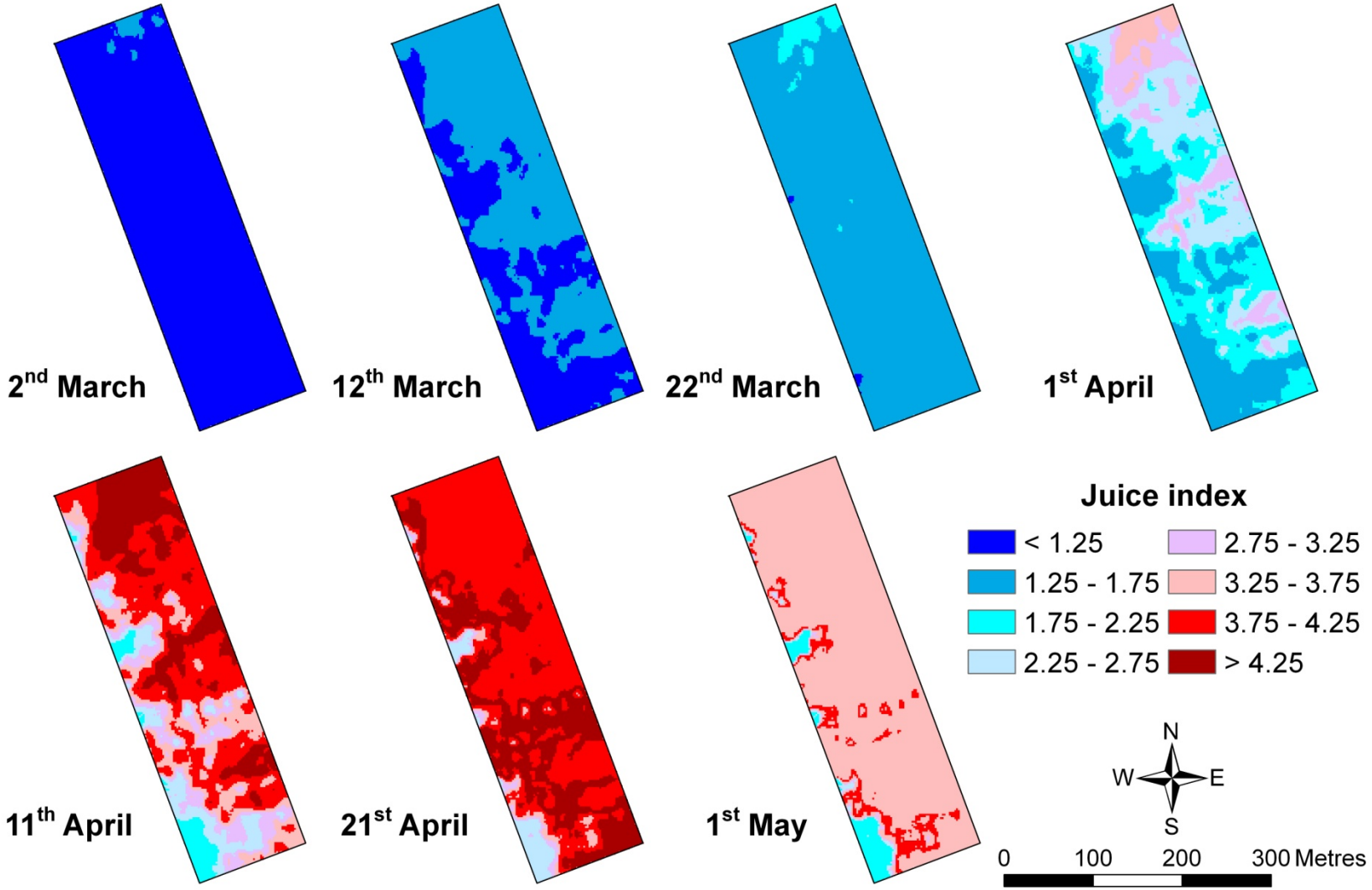
	Brix (°)	TA (g/L)	pH
Optimum	22.5	9.0	3.2
Weighting, *w* (%)	49.3	27.7	23.0

Juice score = $f\{brix_w, pH_w, TA_w\}$

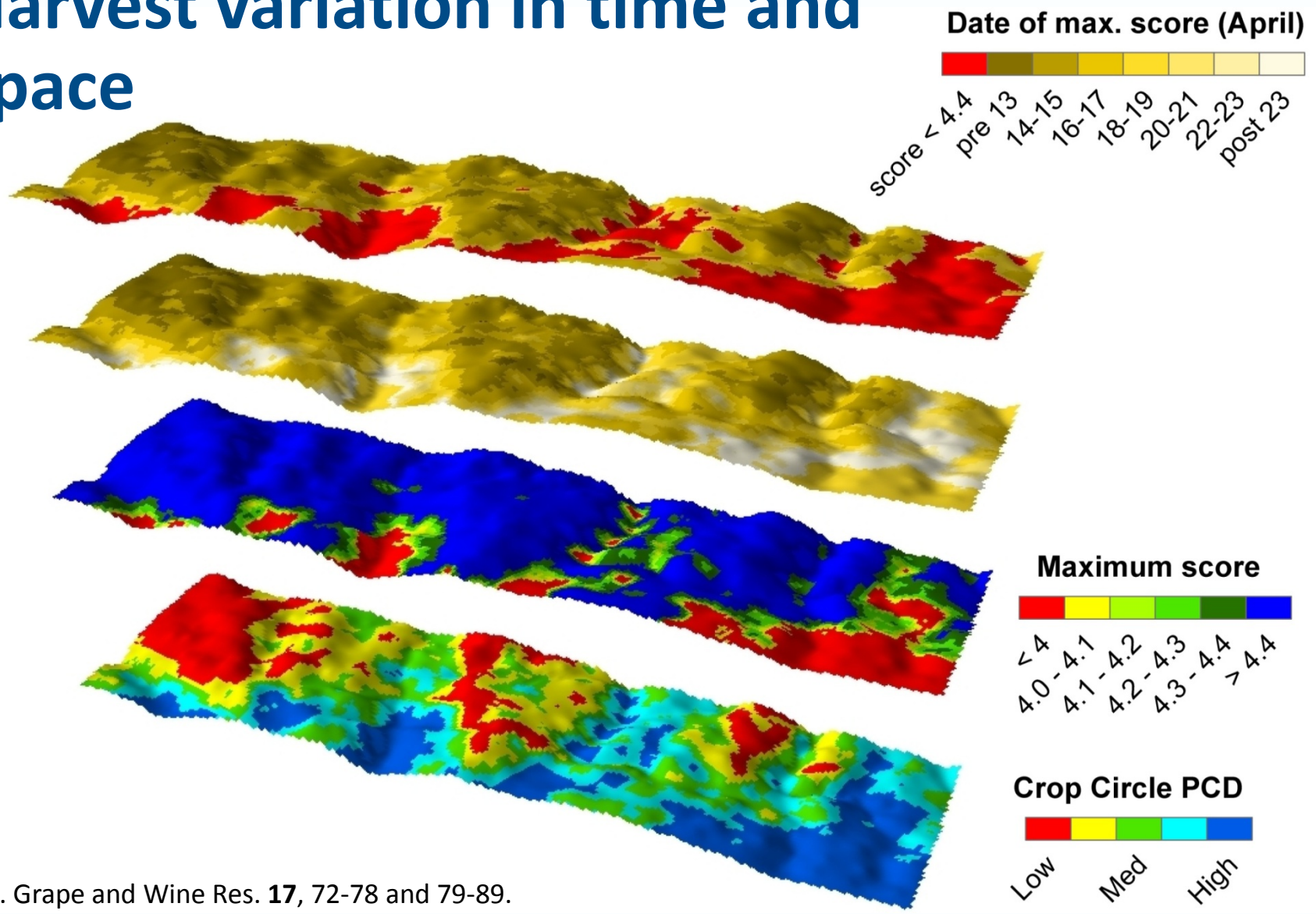
Brix, pH, TA = $f\{PCD_{Crop\ Circle}\}$

- **Crop Circle data can easily be collected, or...**
- **A transect of Crop Circle data could be used to calibrate remotely sensed imagery.**

Predicted Juice Score



Harvest variation in time and space

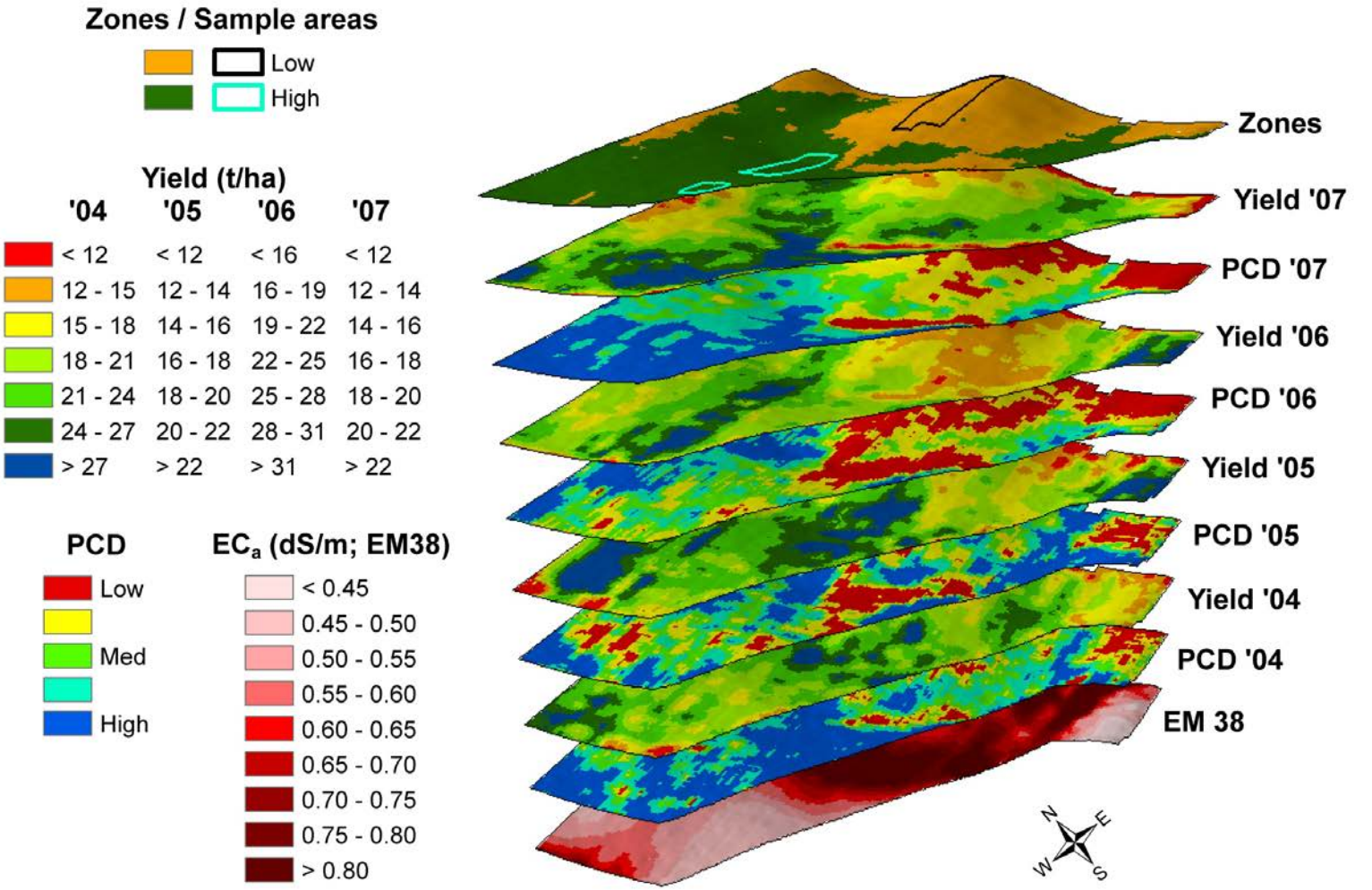


Aust. J. Grape and Wine Res. **17**, 72-78 and 79-89.

Stoneleigh, Marlborough - summary

- **In a vineyard under uniform management, the expression of *terroir* is seen to be variable in both space and time**
  - **What are the implications of this for the *terroir* of Marlborough when considered at the regional scale ?**
- **Understanding this variation nevertheless opens up opportunities for optimising decisions such as the timing of harvest**
- **Development of the juice index was seen as a useful way of characterising fruit quality**
  - **It would not be difficult to generate similar indices for say, McLaren Vale Shiraz**

Understanding vineyard variation and wine quality implications – Deakin Estate



Zonal differences in vigour and yield

Table 1. Mean zone yields (t/ha) and plant cell density (PCD) values for the low and high zones over the course of the study.†

Year	2004		2005		2006		2007	
Zone	PCD	Yield	PCD	Yield	PCD	Yield	PCD	Yield
High	156	22.2a	127	18.9a	151	24.6a	2215	19.2a
Low	109	17.4b	88	15.5b	107	20.8b	1537	14.9b

†Note that these are the means for zones delineated by *k*-means clustering of the available yield and PCD data. In any given year, yields followed by different letters are significantly different ($P < 0.05$) based on a test of significance using the median kriging error (Taylor et al. 2007). This test can not be applied to PCD as this is not kriged. The difference in magnitude between PCD in 2007 and other years is a simple reflection of a different stretch being applied to the data by the commercial provider. All PCD values are dimensionless.

Wine sensory analysis

- **Low and high zone wines were significantly different each year**
  - ***P*<0.01 in 2005, 2007; *P*< 0.05 in 2006**
- **16 aroma and 15 flavour attributes used in descriptive analysis**
  - **Of these, significant differences were identified between the wines for 5 aroma and 10 flavour attributes**
- **Low zone wines were generally more fruity in terms of both flavour and aroma**
  - **Low: 'red berry', 'red confection' and 'floral' aromas; 'red confection', 'fresh berry' and 'dried fruit' flavours**
  - **High: 'olive' and 'meaty' aromas; 'stalky' flavours**
- **Wines derived from different zones within the same uniformly managed block are sensorially different**
  - **How and why ?**

Chemical analysis (Paul Boss, CSIRO)

- 56 volatile compounds were found to occur at significantly different concentrations in the headspace of the wines
  - SPME-GC-MS
- All but 4 of these showed significant between-vintage differences
  - Complicates understanding of between zone differences
  - Wine chemistry changes during ageing ? Seasonal differences ?
- 21 compounds were at significantly different concentrations in the headspace of low compared to high wines
  - 10 of these had higher means in wines from one zone compared to the other across all 3 vintages
- Overall, low zone wines have higher concentrations of a range of volatile compounds which may have led to higher fruit-driven sensory descriptors.

Chemical and sensory analysis

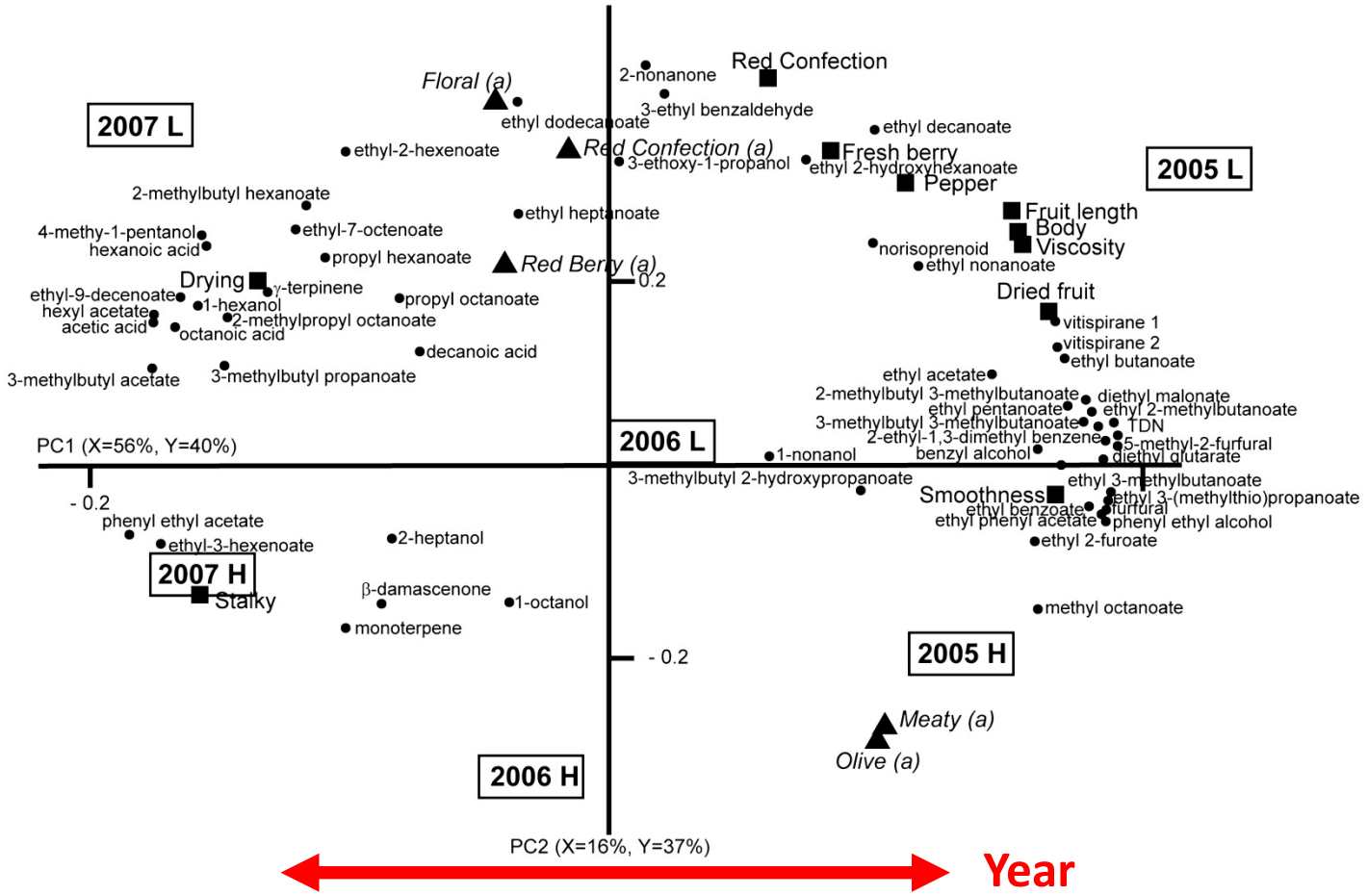


Figure 3. Partial least squares analysis of the wines. Small black circles represent the volatile composition loadings (*x* matrix), the black squares represent the flavour sensory attribute loadings and the black triangles the aroma sensory attribute loadings (*y* matrix), and the large rectangles represent the sample scores for PC1 and PC2. Aroma attributes are in italics and denoted by '(a)', and the flavour attributes are in regular typeface.

Differences in fruit and vine attributes varied from year to year – but there were significant zone effects

Table 4. Zone and seasonal effects on fruit and vine attributes.

	2005			2006			2007			Zone			Year				Int†
	Low	High	Sig‡	Low	High	Sig‡	Low	High	Sig‡	Low	High	Sig‡	2005	2006	2007	Sig‡	Sig‡
Harvest date	27/02	07/03	—	21/02	02/03	—	08/02	28/02	—	—	—	—	—	—	—	—	—
Bunch wt (g)	68.4	74.1	ns	79.7	112.3	***	—	—	—	74.0	93.2	***	71.2^{b}	96.0^{a}	—	***	**
Mean berry wt (g)	0.89	0.90	ns	1.03	1.07	ns	0.89	0.94	ns	0.94	0.97	ns	0.89^{b}	1.05^{a}	0.91^{b}	***	ns
Berries/bunch	76.9	82.5	ns	77.3	104.9	***	—	—	—	77.1	93.7	***	79.7^{b}	91.1^{a}	—	**	**
°Brix	25.0	24.1	**	24.5	24.6	ns	24.2	22.6	**	24.6	23.8	***	24.5^{a}	24.5^{a}	23.4^{b}	***	**
pH	3.47	3.57	**	3.53	3.52	ns	3.31	3.22	***	3.44	3.44	ns	3.53^{a}	3.53^{a}	3.26^{b}	***	***
TA (g/L)	6.71	7.98	***	6.39	6.94	*	8.05	8.09	ns	7.05	7.62	**	7.27^{b}	6.66^{c}	8.07^{a}	***	ns
Colour (mg/g berry wt)	1.35	1.23	ns	1.28	0.88	***	1.40	1.26	ns	1.34	1.12	***	1.29^{a}	1.08^{b}	1.33^{a}	***	*
Phenolics (au/g berry wt)	1.24	1.15	*	1.40	1.07	***	1.56	1.42	**	1.40	1.21	***	1.20^{b}	1.24^{b}	1.49^{a}	***	***
Pruning weight (g)	27.7	37.3	*	18.0	22.0	ns	14.5	28.9	**	19.9	29.4	**	32.5^{a}	19.8^{b}	21.7^{b}	***	ns

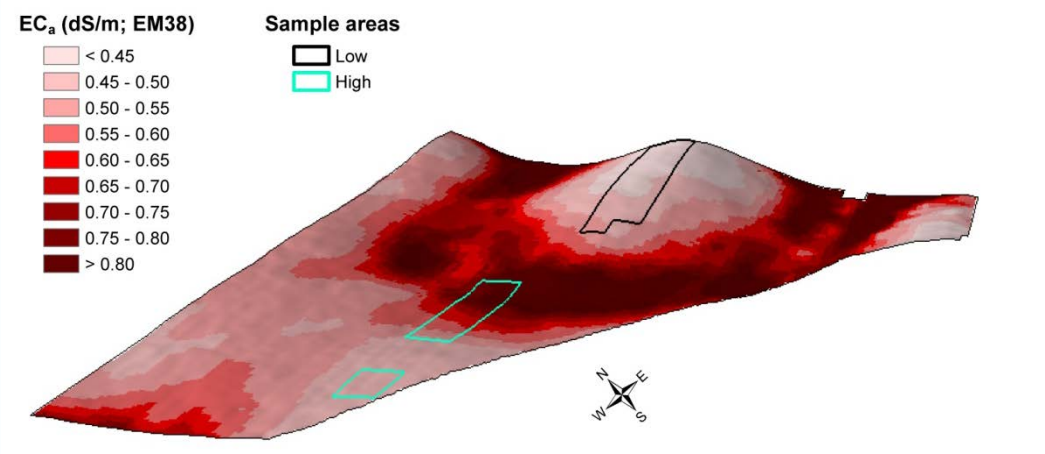
†Interaction, zone × year. ‡Significance of difference where ***, **, * and ns denote $P < 0.001$, $P < 0.01$, $P < 0.05$ and not significant, respectively. In the analysis of between-year differences, numbers followed by different letters are significantly different.

Vine and grape nutrient status

- **Significant zonal differences in petiole nutrients (2006-07)**
  - N lower in Low zone ($P<0.05$); both zones below the level considered adequate
  - K lower in Low zone ($P<0.001$); but at an adequate level
  - B lower in High zone ($P<0.001$); marginal in High, adequate in Low (cf B toxicity in cereals in Mallee swales; no salinity impacts evident)
  - Mn higher in High zone ($P<0.01$); adequate in Low
- **Vine nutrition generally only considered from a vine health / crop production perspective**
  - Scant attention paid to the possibility of a fruit quality or wine sensory impact in the literature
- **At harvest, grapes in the Low zone contained higher ($P<0.001$) concentrations of Ca, Mg and B, and lower Na, P, S, Fe and Mn (all $P<0.001$ except Fe – $P<0.05$)**

Soil Properties

- **Duplex Calcarosols – sandy topsoils of varying depths (20-70 cm) over calcareous clay subsoils**
  - **Major zonal differences reflective of topsoil depth and texture**
  - **High zone soils have higher clay contents, especially in their poorly drained subsoils and higher B, Na, Cl**
  - **High zone EC_{se} (4 dS/m) might be expected to cause a 25% drop in production (but no evidence of salinity or B impacts in petiole data and no salinity impact evident in wines)**
  - **Shallow Low zone soils have higher carbonate contents closer to the surface.**



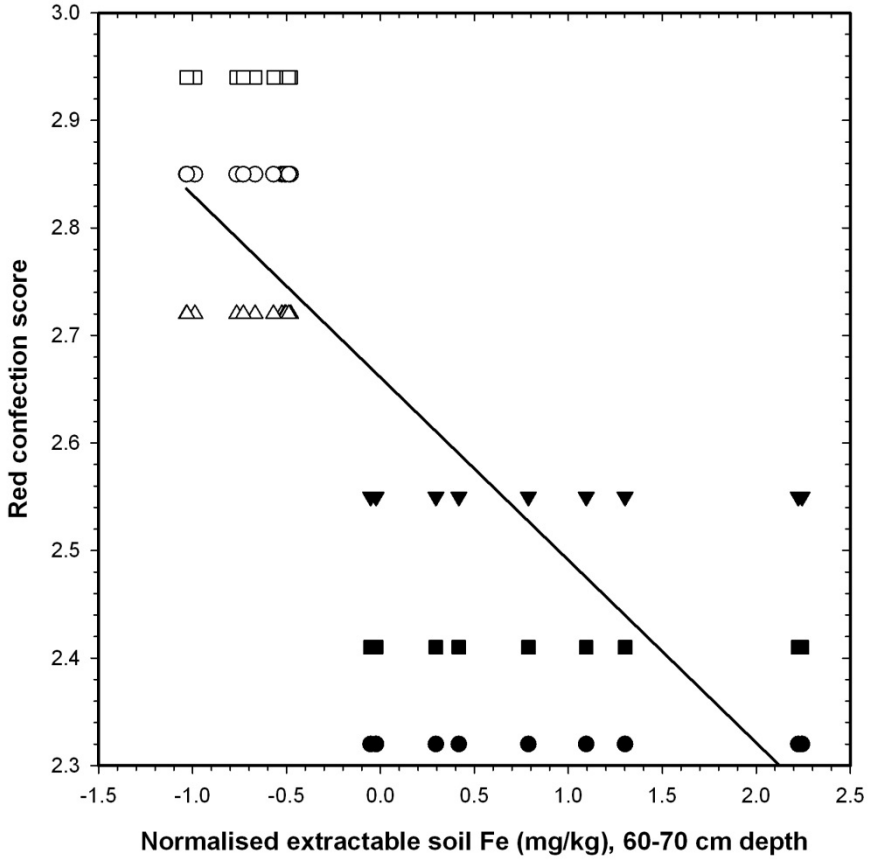
Integrating vine and soil data

- **2006 data used**
  - Minimal between zone difference in brix
  - Stepwise linear diagonal discriminant analysis (Mary Barnes, CCI)
  - Minimal inter-annual effects on soil properties assumed
- **Clear discrimination between Low and High zones**
  - 100% discrimination by berry phenolics alone
  - After removal of berry phenolics, zones were discriminated by bunch weight and extractable Fe at 30-40 cm depth (higher Fe in High zone)
  - Drainage effect ?

Integrating wine and soil data

- **Problematic due to lack of replication**
  - Soil and vine nutrient data not replicated across years
  - In any given year, wine sensory and chemistry only available for 2 zones
- **So we cheated ! (advisedly)**
  - Wine data from High zone repeated 9 times (9 target vines) and 12 times for the Low zone
  - Sensory and wine chemistry assigned to *y*; soil grape and vine assigned to *x*; analysis of simple *x*-*y* relationships
  - Accepted that *P* values and R^2 not statistically valid but some apparently strong relationships identified that would be worthy of further more robust study
- **Several attributes of apparent importance**
  - *x*: Soil Fe and Mn, berry phenolics
  - y: 'red confection', 'fresh berry' and 'floral' aromas; 2-nonanone, ethyl decanoate

Given the importance of Fe as an enzyme co-factor and to enzyme function via Fe-S clusters, is it possible that between zone differences in Fe availability are impacting on the production of compounds which confer the red confection character ?



Deakin Estate summary

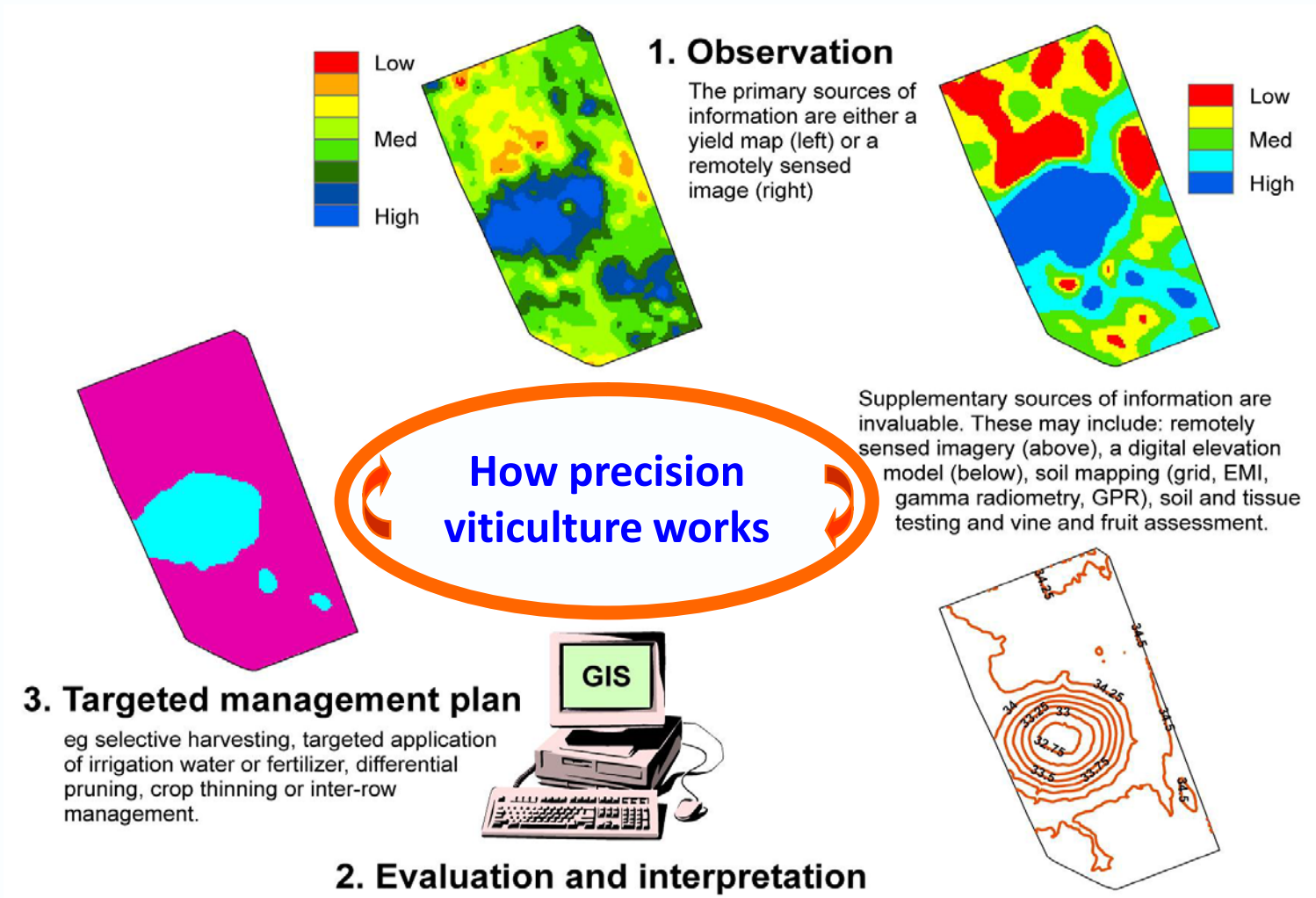
- **In a vineyard under uniform management, zones identified on the basis of differences in soils, vine vigour and yield produced wines with different chemical and sensory characteristics**
  - **Some suggestion of the possibility of specific soil attributes leading to specific wine attributes**
  - **Soil fertility / vine nutrition maybe more relevant than suggested by previous studies**
  - **But a lot of additional work required to enable understanding of what is going on**
- **Clearly, *terroir* varies at the within-vineyard scale**

Aust. J. Grape and Wine Res. **17**, 217-229.

On-the-go sensing of crop quality



Precision Viticulture is about understanding vineyard variability and so making better management decisions



Multiplex® 3

OPTICAL MEASUREMENT OF POLYPHENOLS AND CHLOROPHYLL



Thanks to more than 15 years of research, MULTIPLE
of constitutive and induced polyphenolics and chlor
multiple excitations to measure various compounds i
MULTIPLEX® 2 is the appropriate tool to easily monit

MULTIPLEX® 2 measures:
- Anthocyanin content. Epidermal Visible absorbance by FER method.
- Flavonol content. Epidermal UV absorbance by FER method.
- Chlorophyll content. Chlorophyll fluorescence emission ratio.
- UV-excited Blue-Green fluorescence (BGF)

The advantages of the technology are:
- Simultaneous measurement of various compounds
- Non contact and fast measurement (less than a sec
- Active sensing with measurement possible under ar
- Non destructive measurement
- No preparation of the plant
- Portable device for field measurement

MONITORING OF THE

The phenolic maturity has a different time course than t
anthocyanins in red berries and flavonols and chloroph
parameters and estimated indirectly.
However, polyphenols measurements are expensive, la
Polyphenols measurements can now be realized with a
With MULTIPLEX® 2 the monitoring of the phenolic mat





Multiplex – Laboratory mode



Multiplex – Laboratory mode



Multiplex – field mode (2009)



From the ‘gardens’ of Bordeaux...



… to the vineyards of South Australia

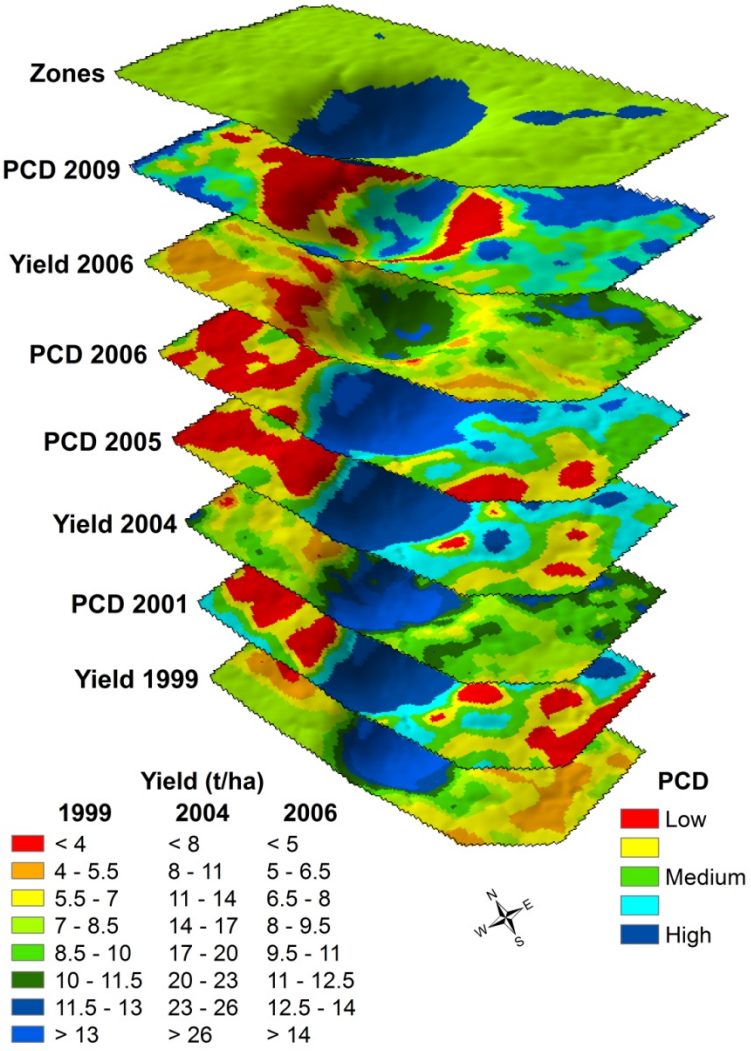


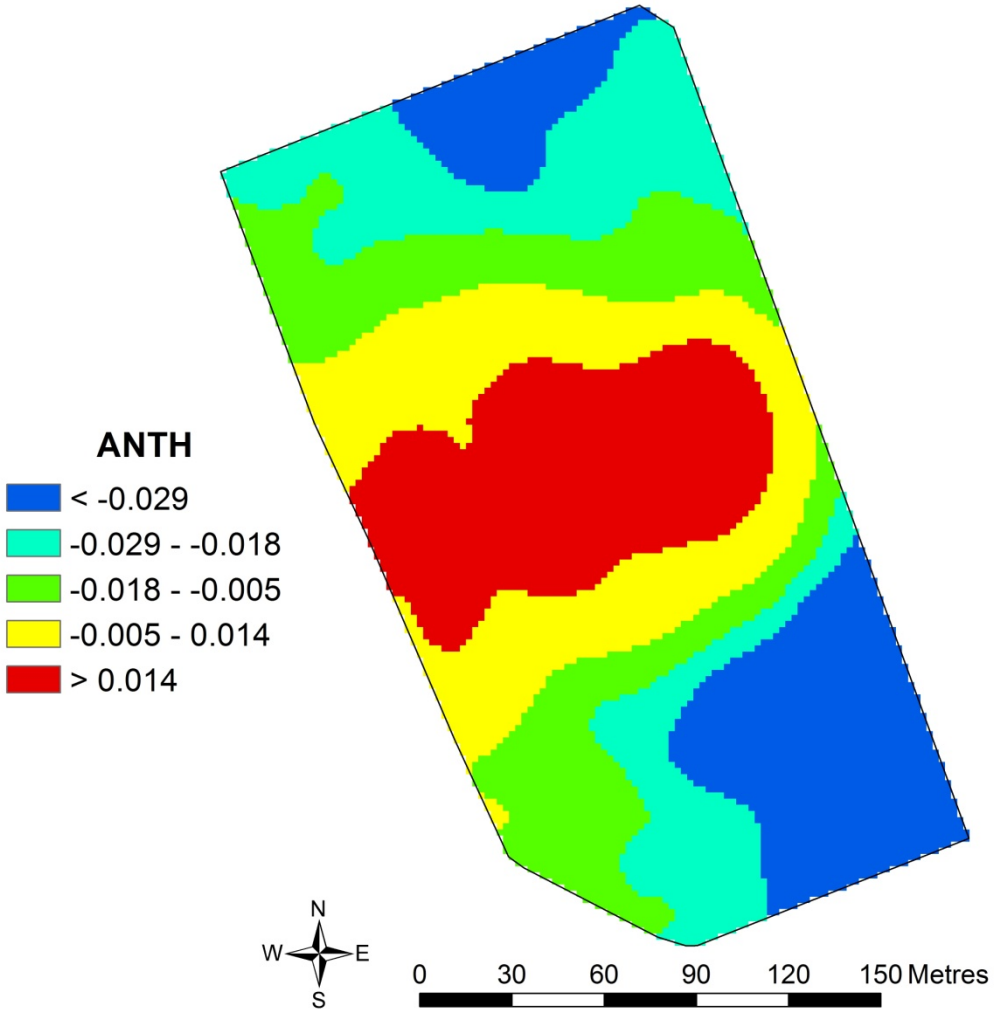
Multiplex experience – hand held

- **2009**
  - Too cumbersome.
  - Most values ‘off-scale’, leading to useless maps.
  - Basically it didn’t work !

- **2010 – focus on anthocyanins**
  - Sensor modified to accommodate effects of higher ambient UV.
  - Good calibrations obtained in lab and hand-held mode.
  - Major focus in developing on-the-go capability.

2010 – Padthaway





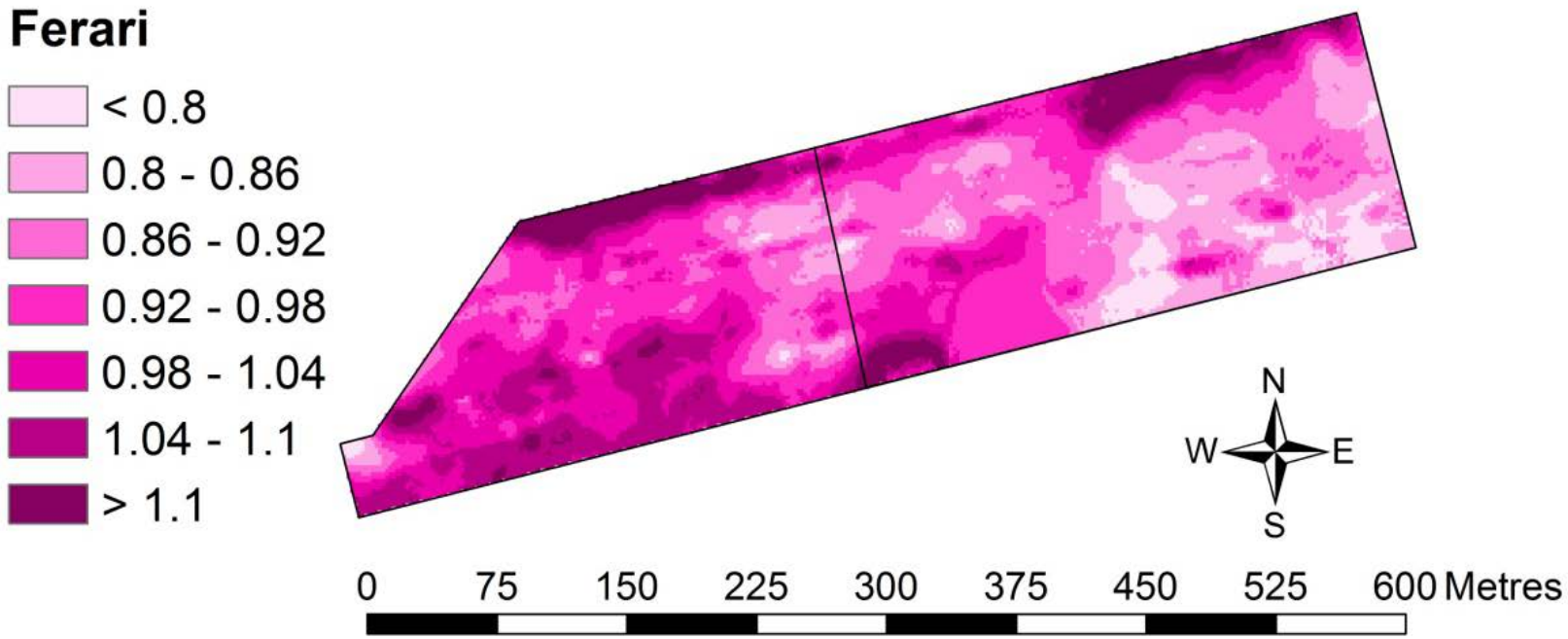
Multiplex mounted on discharge chute (2010)



On the go sensing of fruit colour during commercial harvest



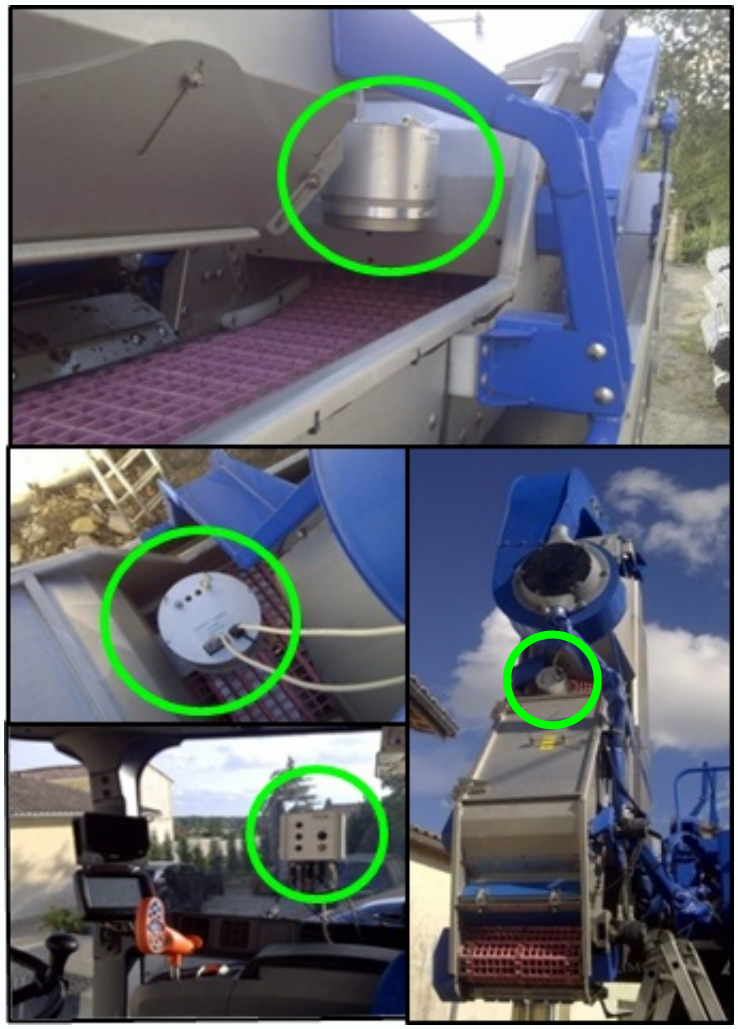
World first: Anthocyanins sensed on-the-go at harvest – Taylors Wines, Clare Valley, 2010



Aust. J. Grape and Wine Res. **17**, 316-326.

On-the-go sensor now commercially available





ForceA SEE TO ACT

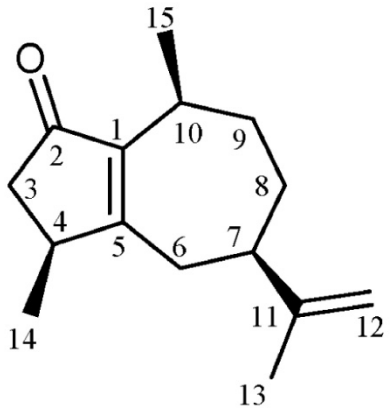
‘QUALI-GRAPPE’

CSIRO

Rotundone

MOUNT LANGI GHIRAN

AWRI



- $C_{15}H_{22}O$
- Found in the skins of Shiraz berries
- An 'impact' aroma compound
  - > 75% tasters will detect its peppery character during sensory analysis, even at very low concentrations
- Detection threshold of 16 ng/L in wine
- Discovered by AWRI team in 2008
- Only compound identified to date in wine or in pepper which has an obvious pepper aroma
- The peppery character is considered desirable in many markets and has been suggested as evoking the *terroir* of some cooler climate Australian Shiraz

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Rotundone in plants / plant products

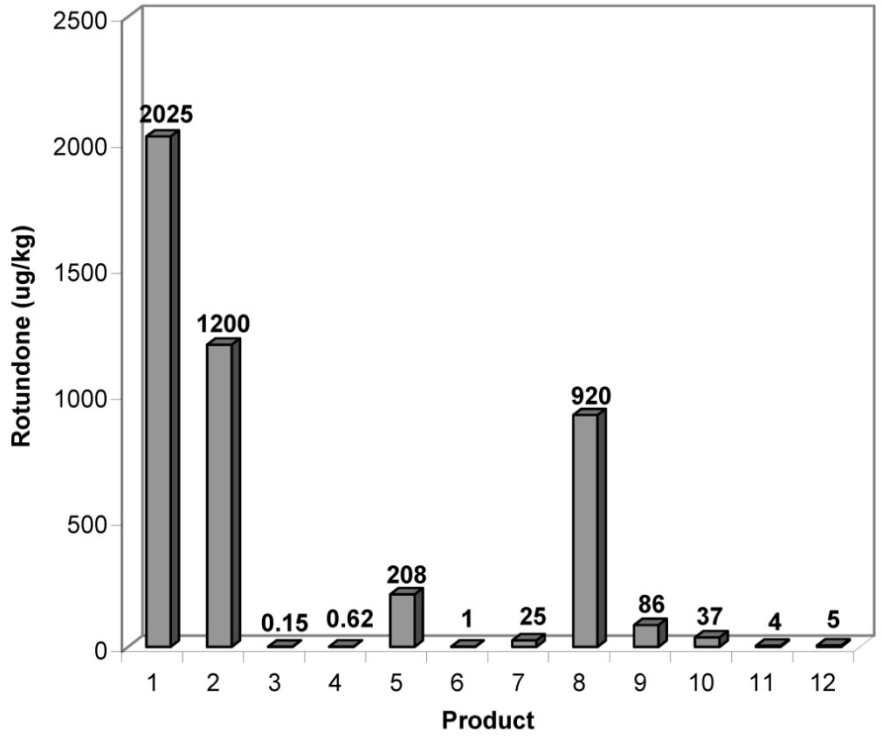


Figure 2. Concentration of rotundone found in various plants and plant products (μg of rotundone/kg of product, duplicate extraction and analysis, mean result shown): 1, white pepper (*Piper nigrum*); 2, black pepper (*P. nigrum*); 3, wine (*Vitis vinifera* cv. Shiraz); 4, grapes (*V. vinifera* cv. Shiraz); 5, marjoram (*Origanum majorana*); 6, oregano (*Origanum vulgare*); 7, geranium (*Pelargonium alchemilloides*); 8, nut grass (*Cyperus rotundus*); 9, rosemary (*Rosmarinus officinalis*); 10, saltbush (*Atriplex cinerea*); 11, basil (*Ocimum basilicum*); 12, thyme (*Thymus vulgaris*).

Wood, C. et al. (2008) J. Agric Food Chem. **56**, 3738-3744.

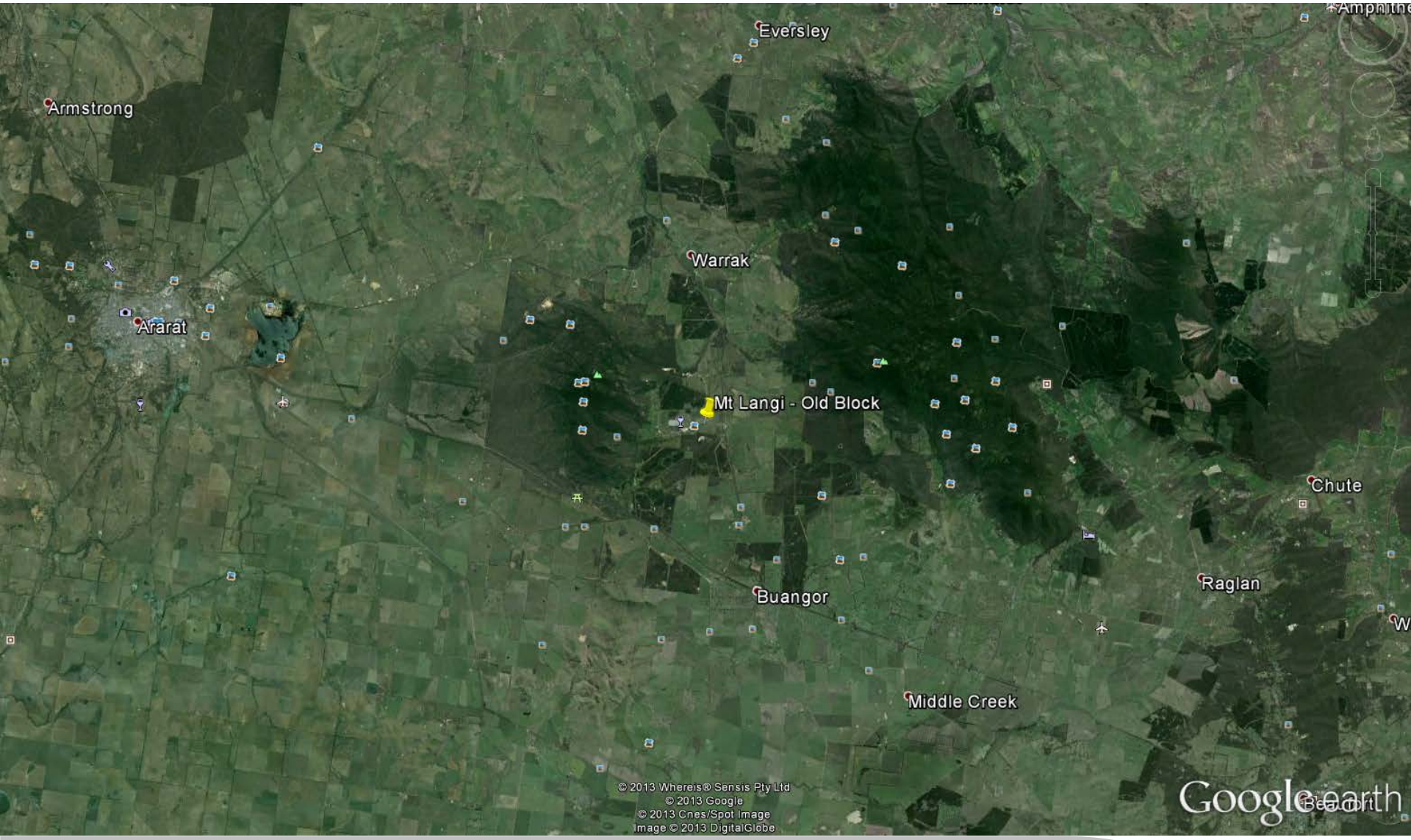
Shiraz from the Grampians is ‘peppery’



Figure 1. Results for commercial Australian wines where rotundone was present

Jeffery, D.W. et al. (2009) Technical Review **180**, 11–16. AWRI.

Mt Langi vineyard – ‘Old Block’

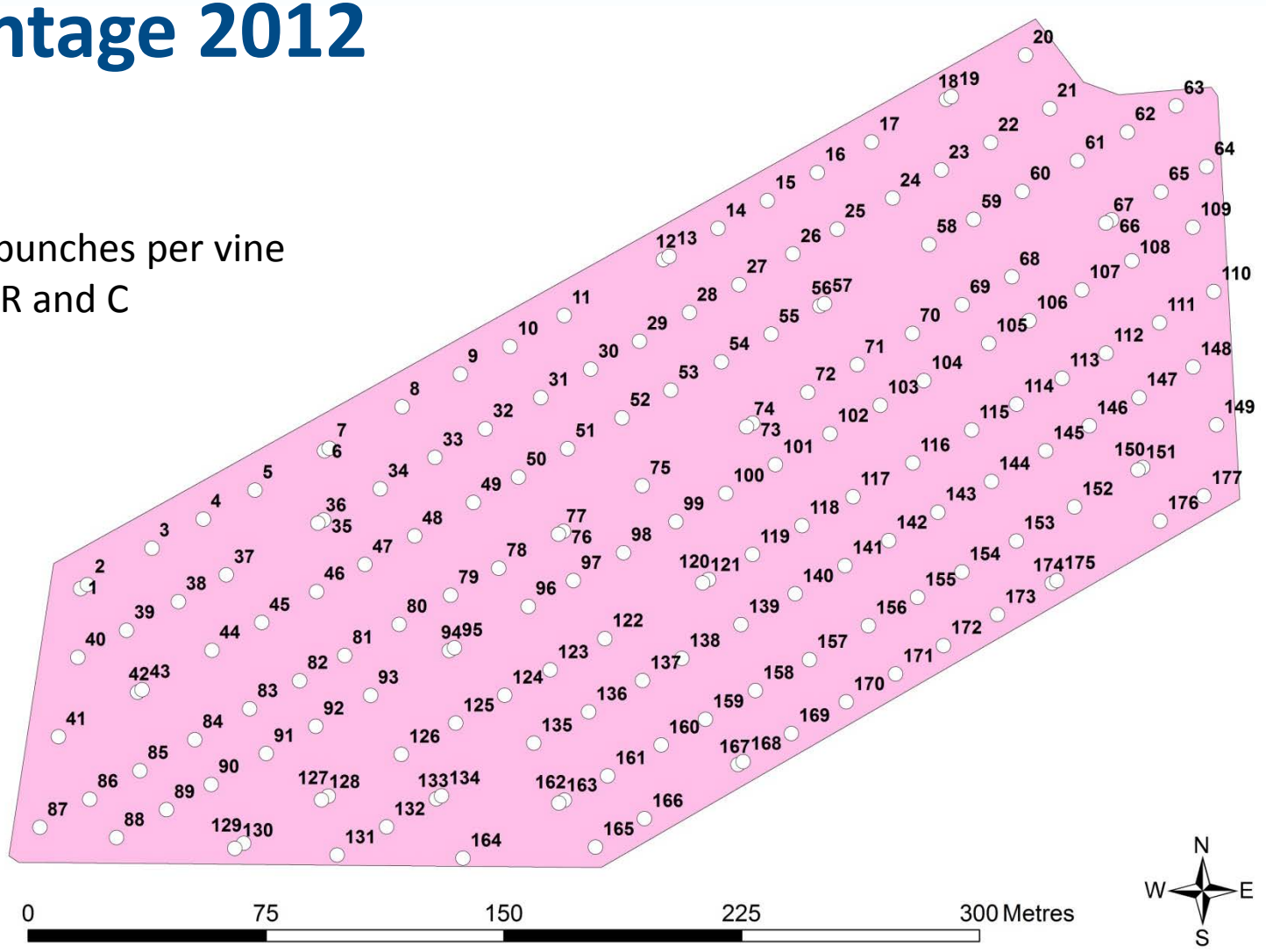


Mt Langi vineyard – ‘Old Block’



Sampling design – 177 ‘target vines’ Vintage 2012

3 bunches per vine
L, R and C

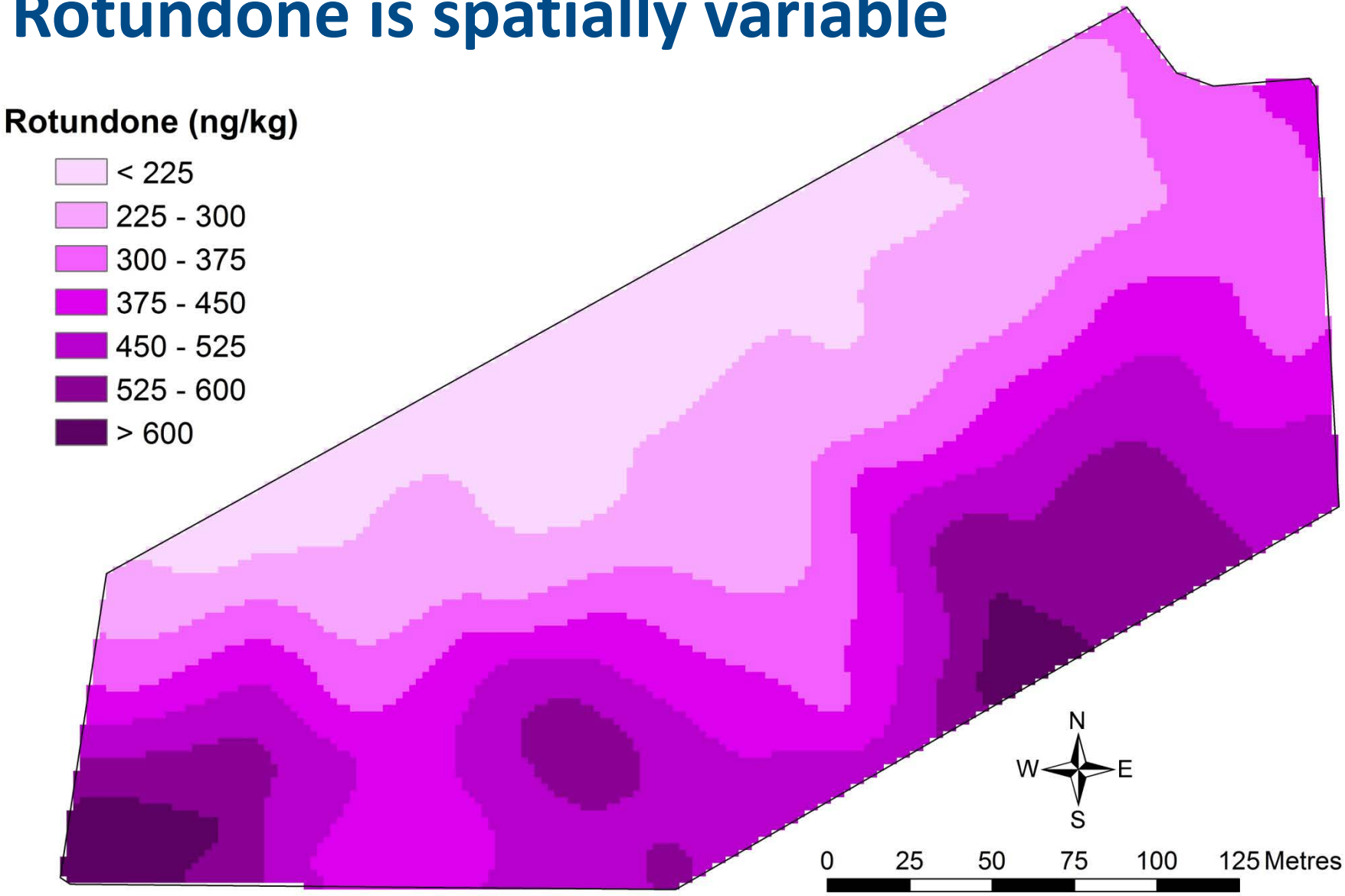


Rotundone was highly variable

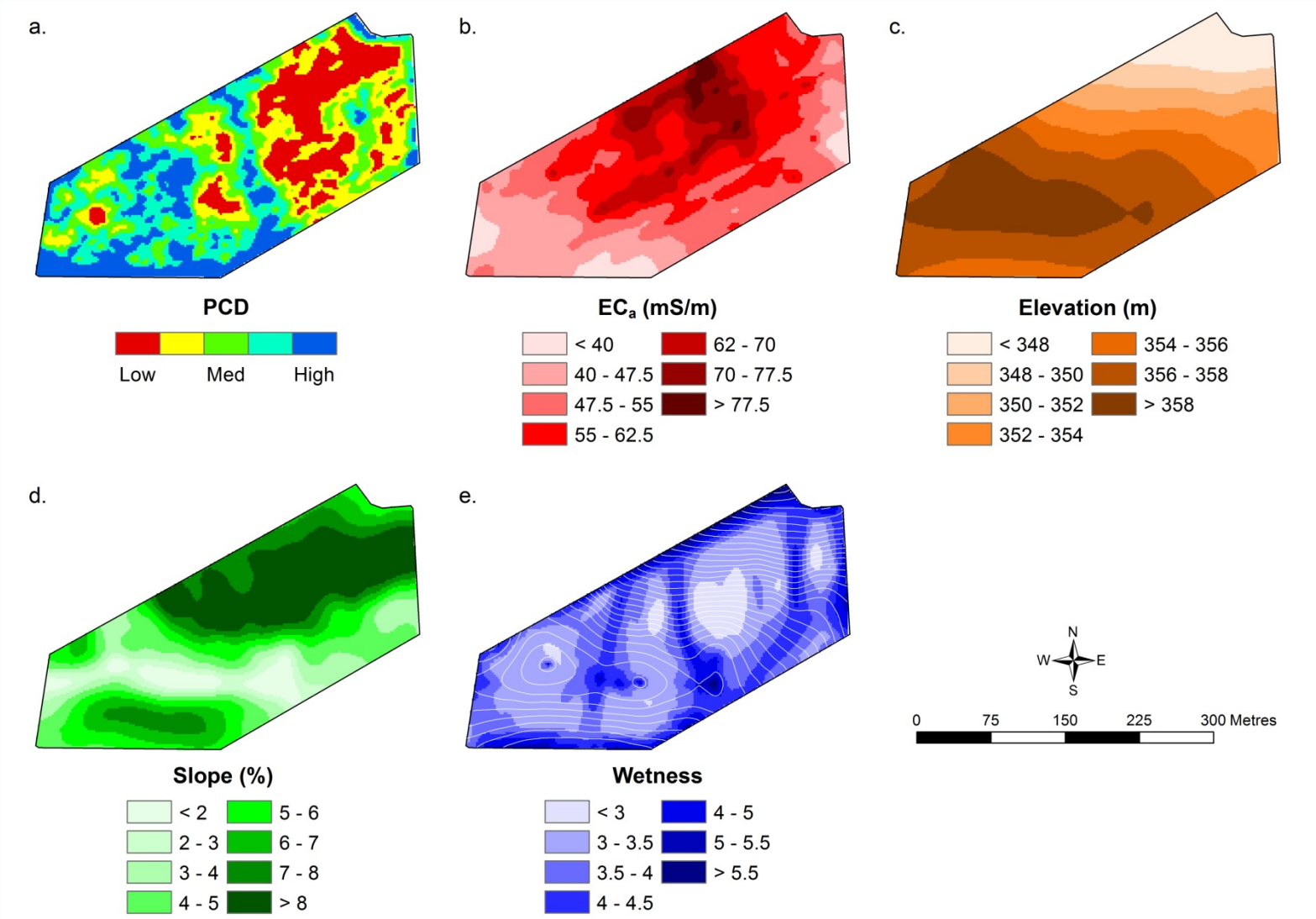
- Range of variation in concentration = 73-1082 ng/kg
- Mean = 399
- Median = 379
- CV = 54.1%
- [A]Spread = 266%
- Variation of the order of 15-fold, equivalent to more than 2.5 times the median value

- [A]Spread (%) = 100 × (max – min)/median

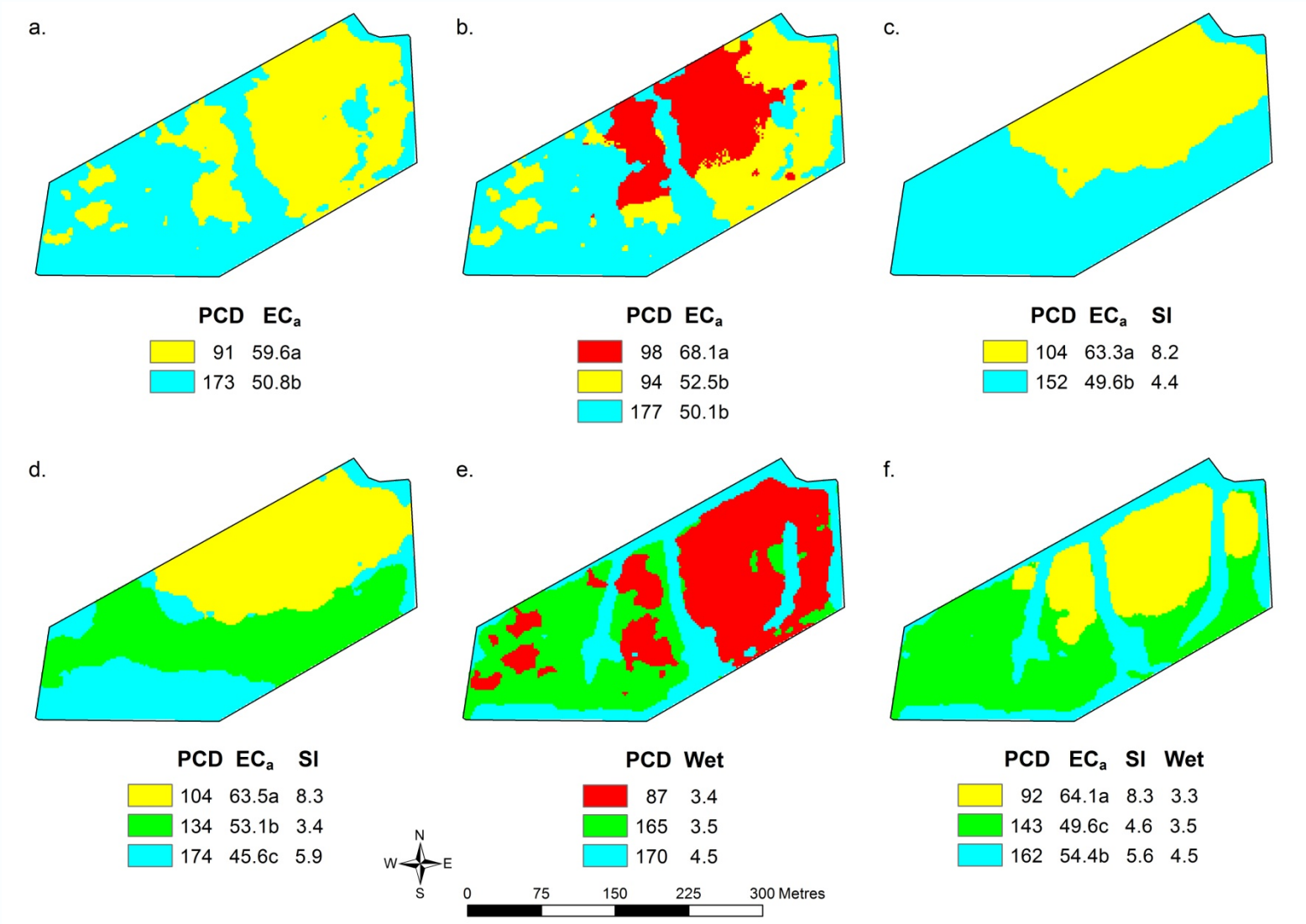
Rotundone is spatially variable



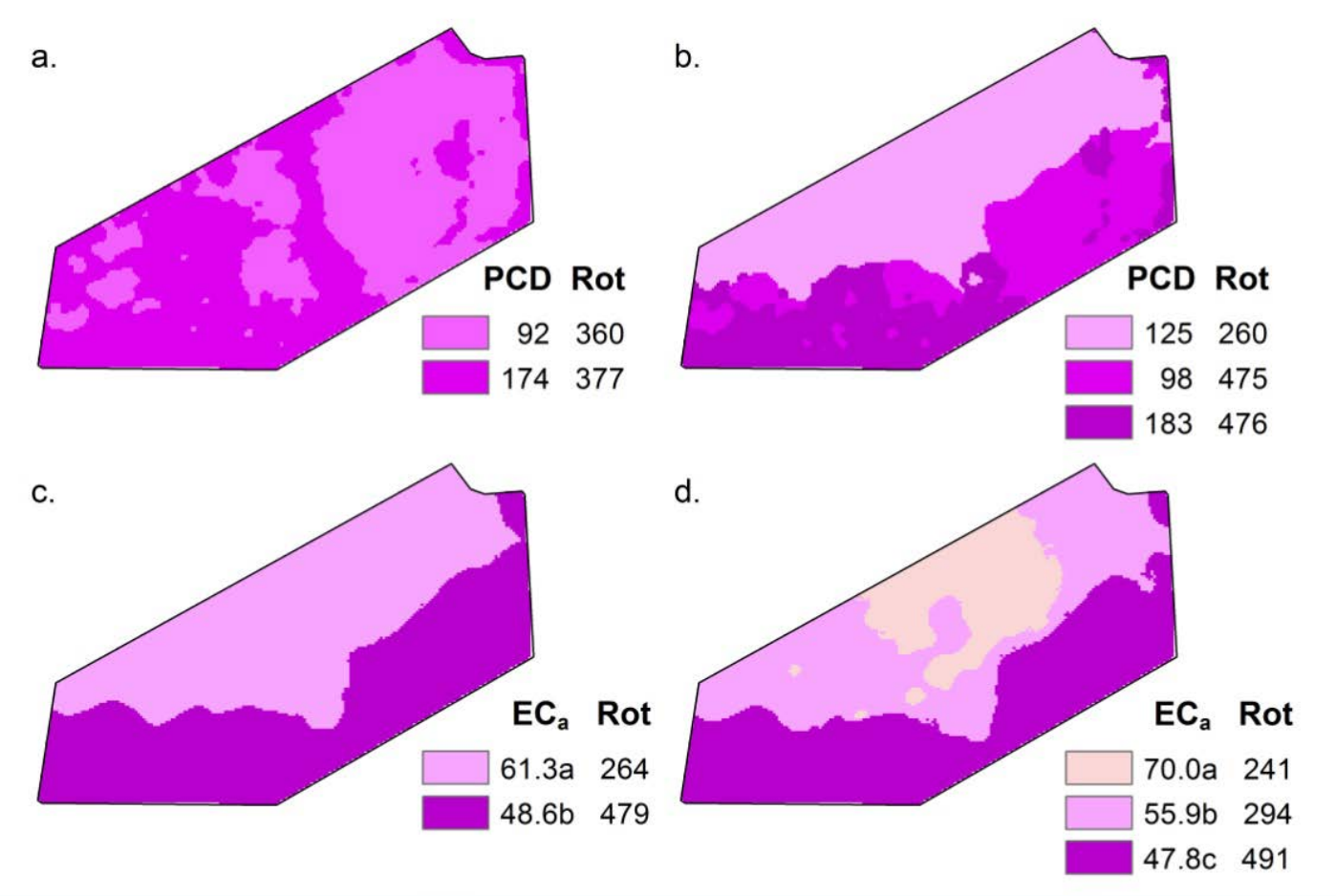
Other relevant spatial data (acquired pre-project)



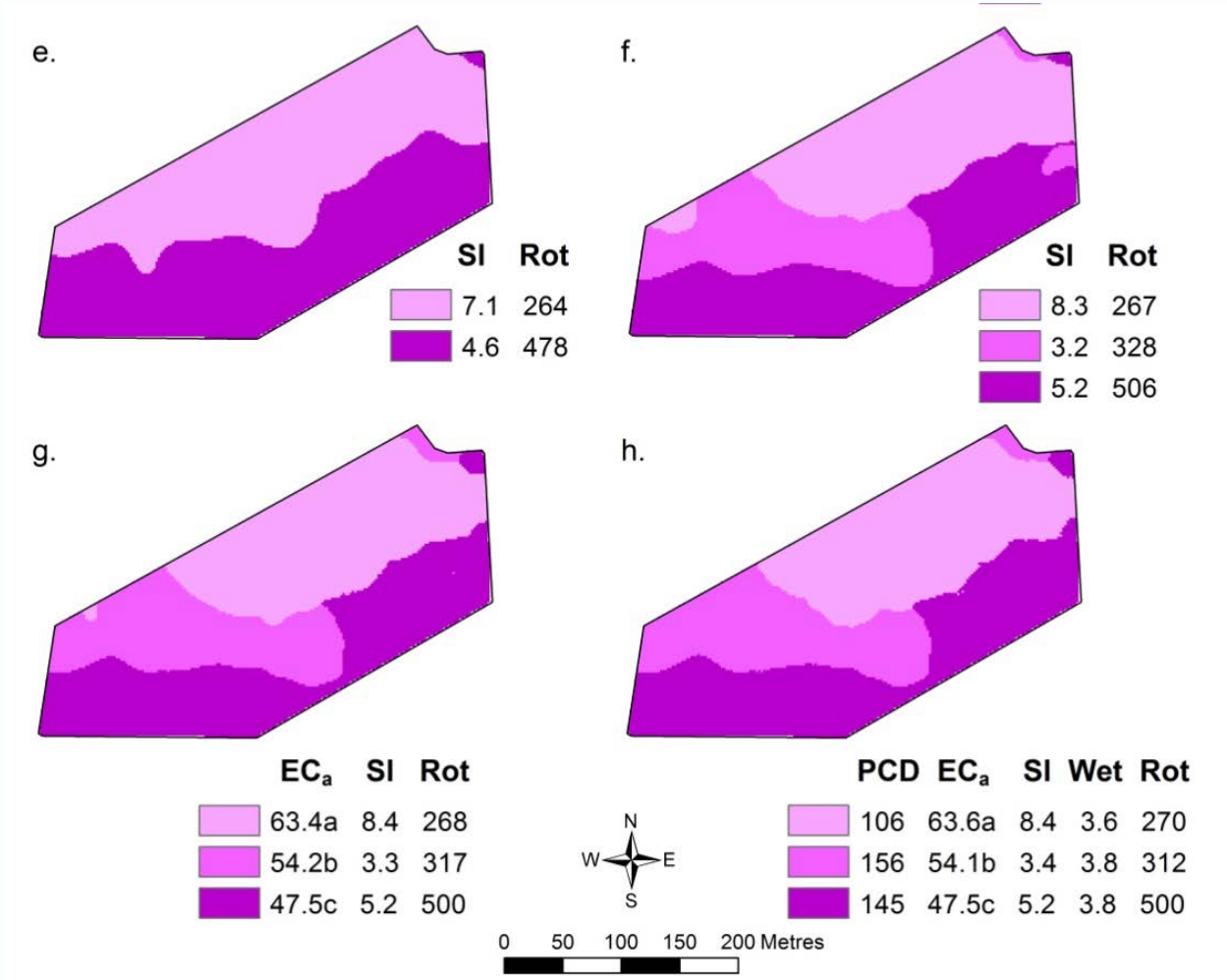
k-means clustering – pre-project data



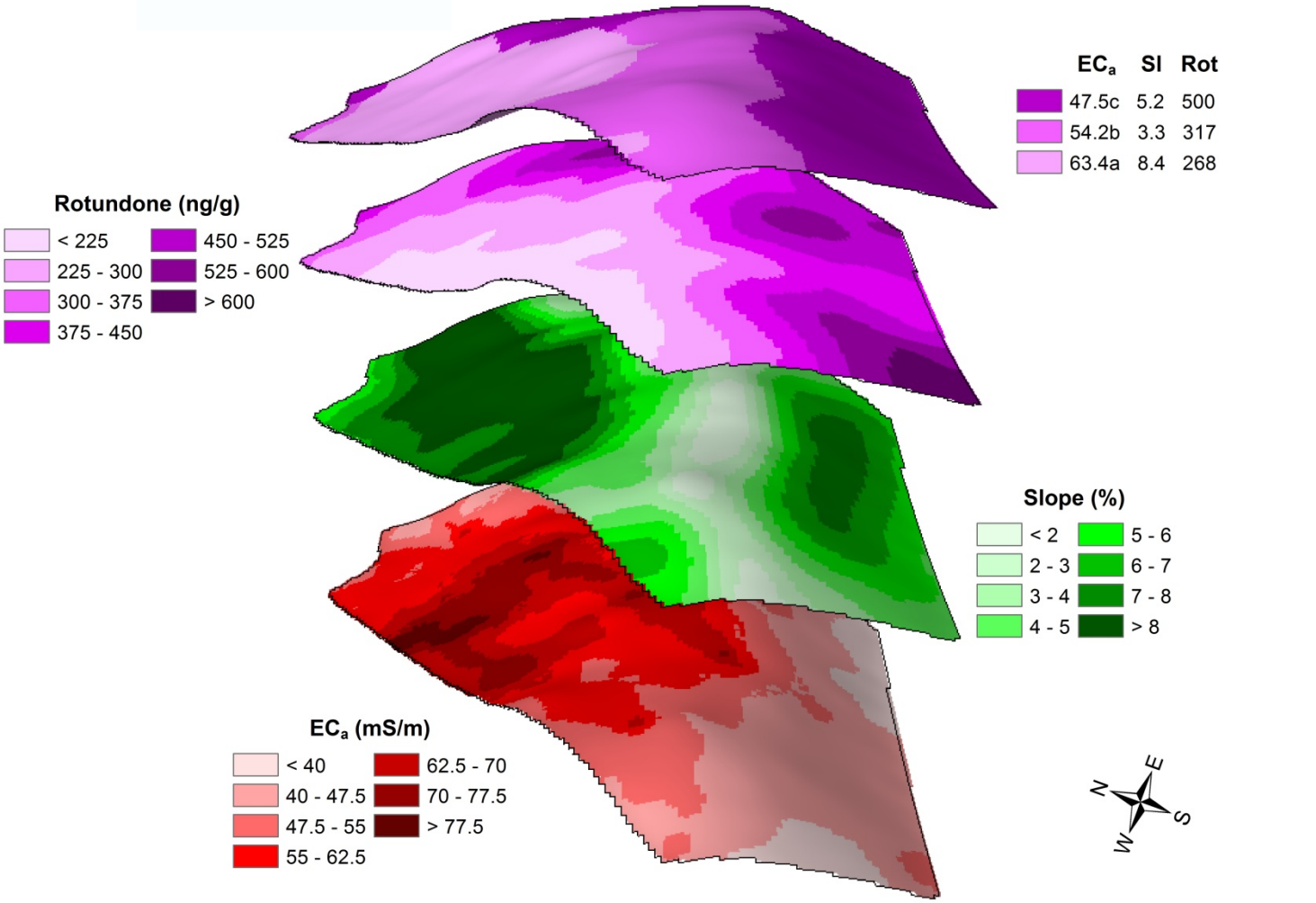
Variation in berry rotundone concentration and other vineyard factors



Variation in berry rotundone concentration and other vineyard factors



Topography a key driver of rotundone variation



Shiraz from the Grampians is ‘peppery’

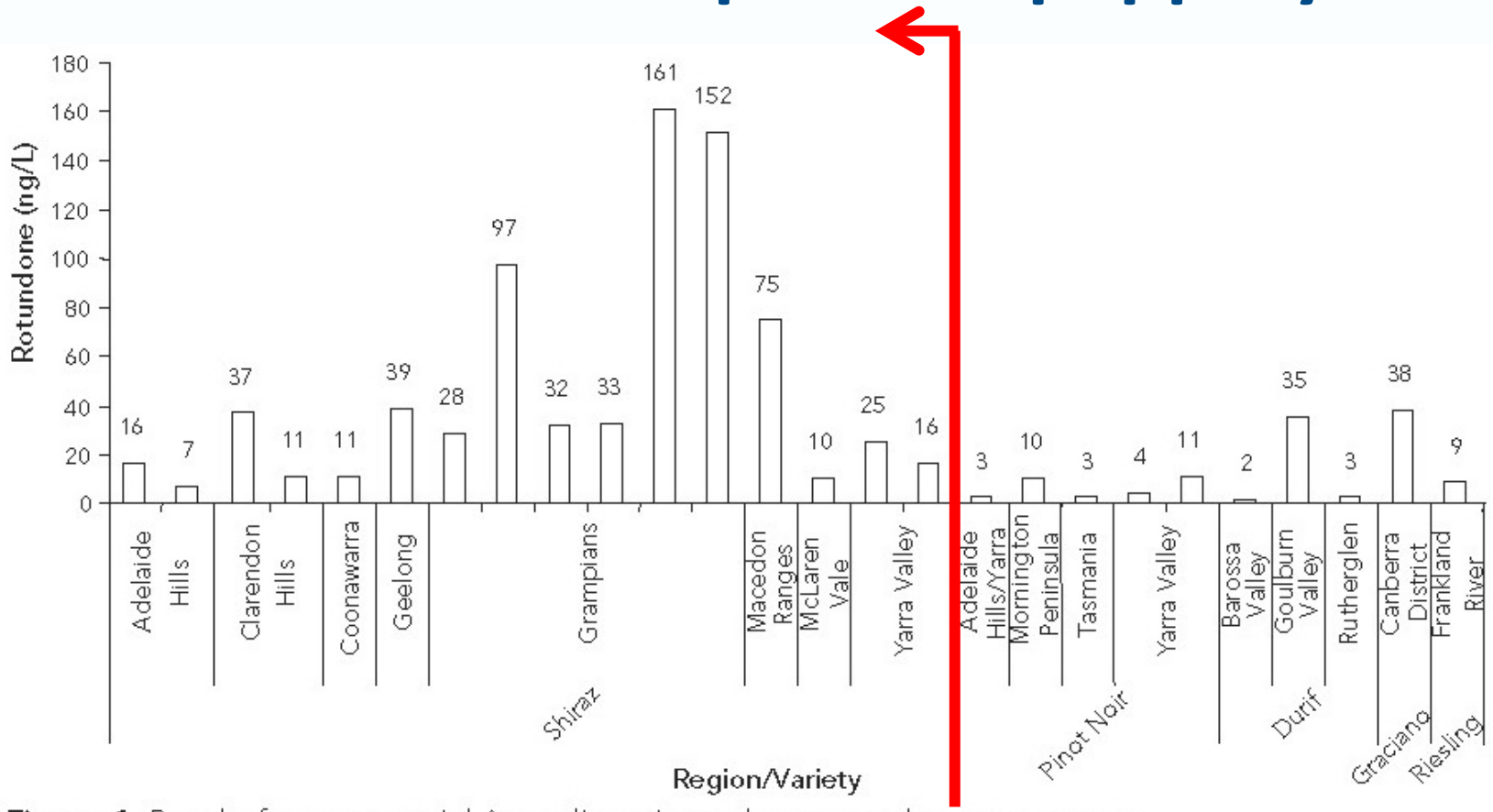
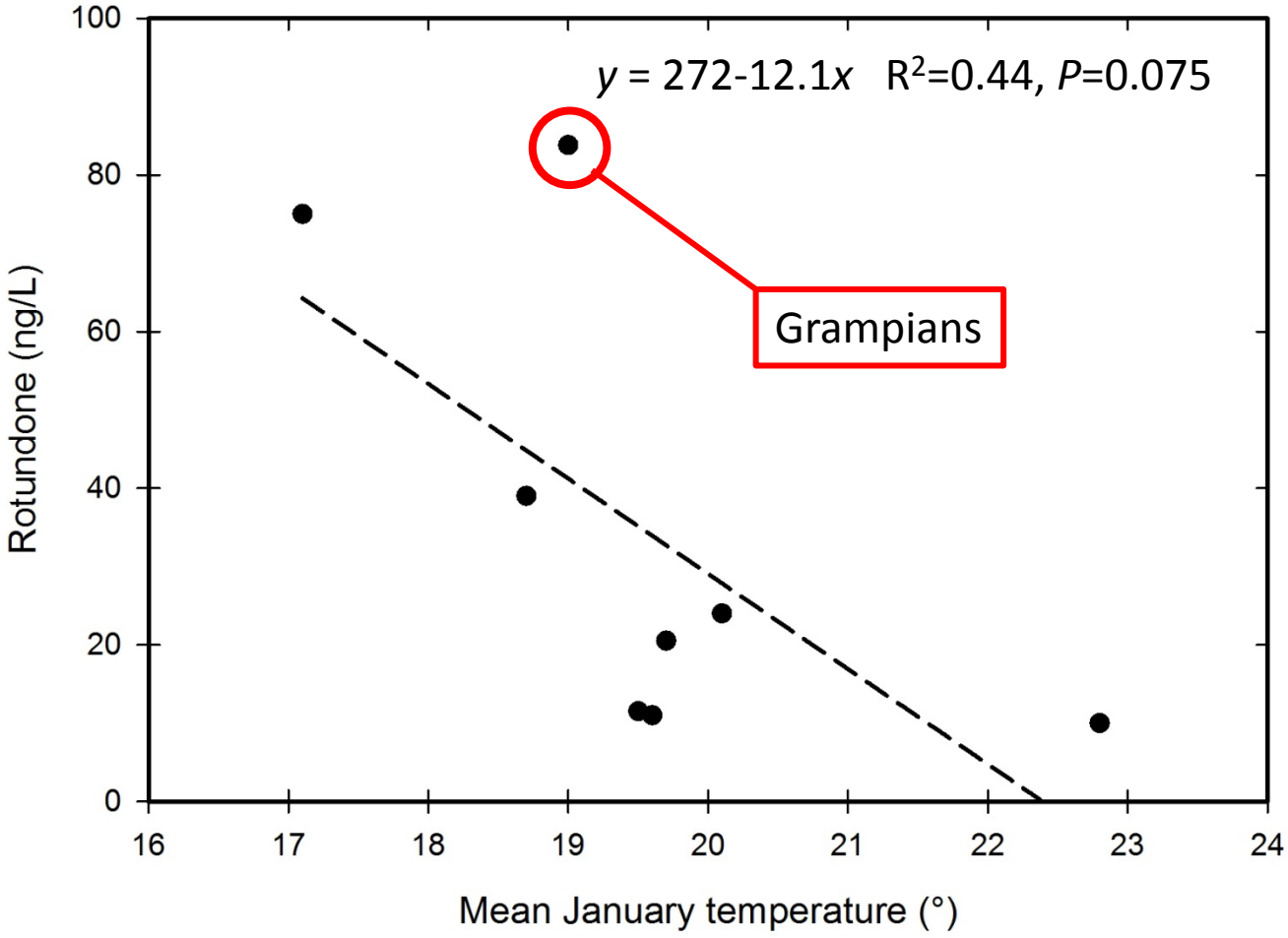


Figure 1. Results for commercial Australian wines where rotundone was present

Jeffery, D.W. et al. (2009) Technical Review **180**, 11–16. AWRI.

Rotundone concentrations seem to be higher in wines from cooler places



Between season differences in berry rotundone may be temperature-related

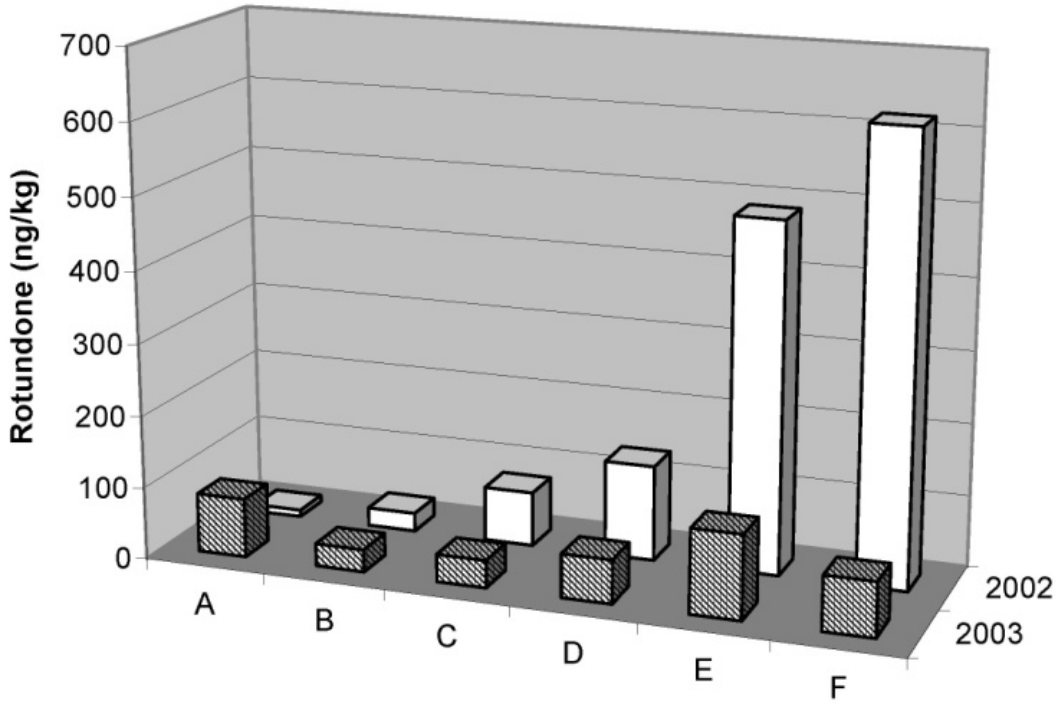


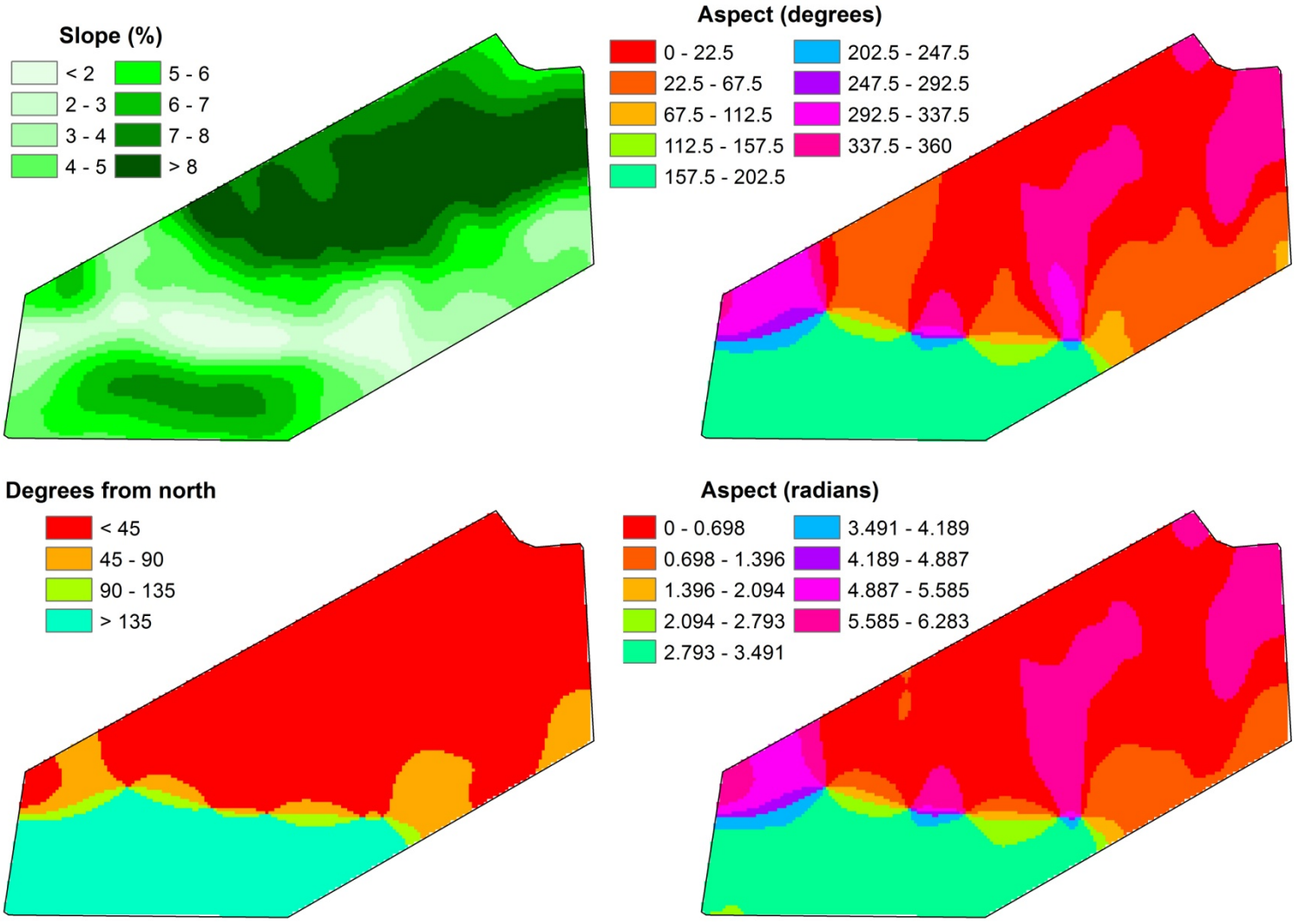
Figure 3. Concentration of rotundone (ng/kg) in Shiraz grapes from six vineyards (A−F) over two vintages (2002 and 2003). Vintage 2002 was widely regarded as being a more "peppery" year than vintage 2003 for Shiraz grapes in several wine regions in Australia.

	MJT (°)[A]
2002	17.3
2003	19.6

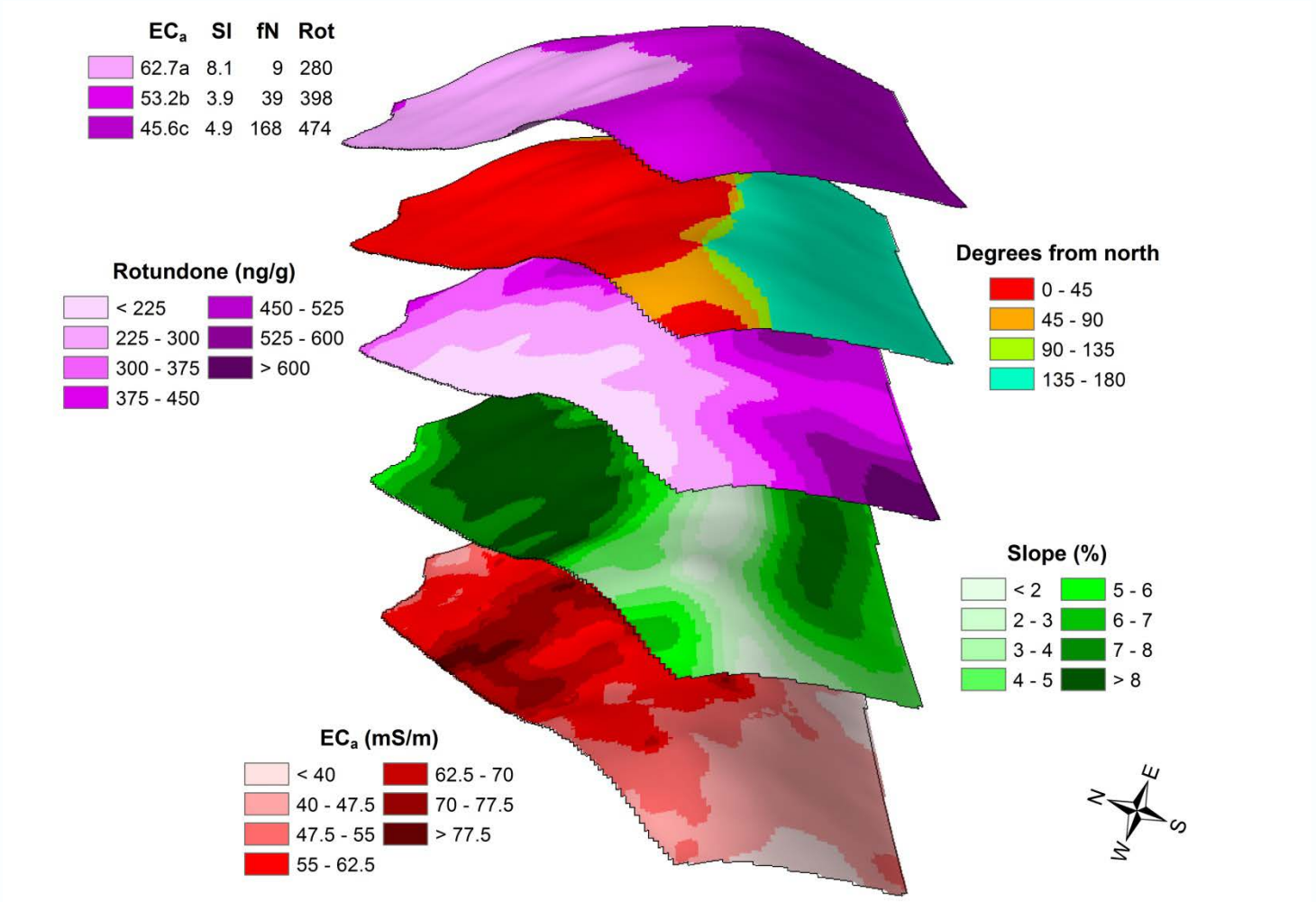
[A]Ararat Prison

Wood, C. et al. (2008) J. Agric Food Chem. **56**, 3738-3744.

Spatial analysis of aspect is problematic !



Aspect (and its likely effect on temperature and/or incident radiation) seems important !



Aust. J. Grape and Wine Res. **20**, in press (available online – early view)

2013 postscript...

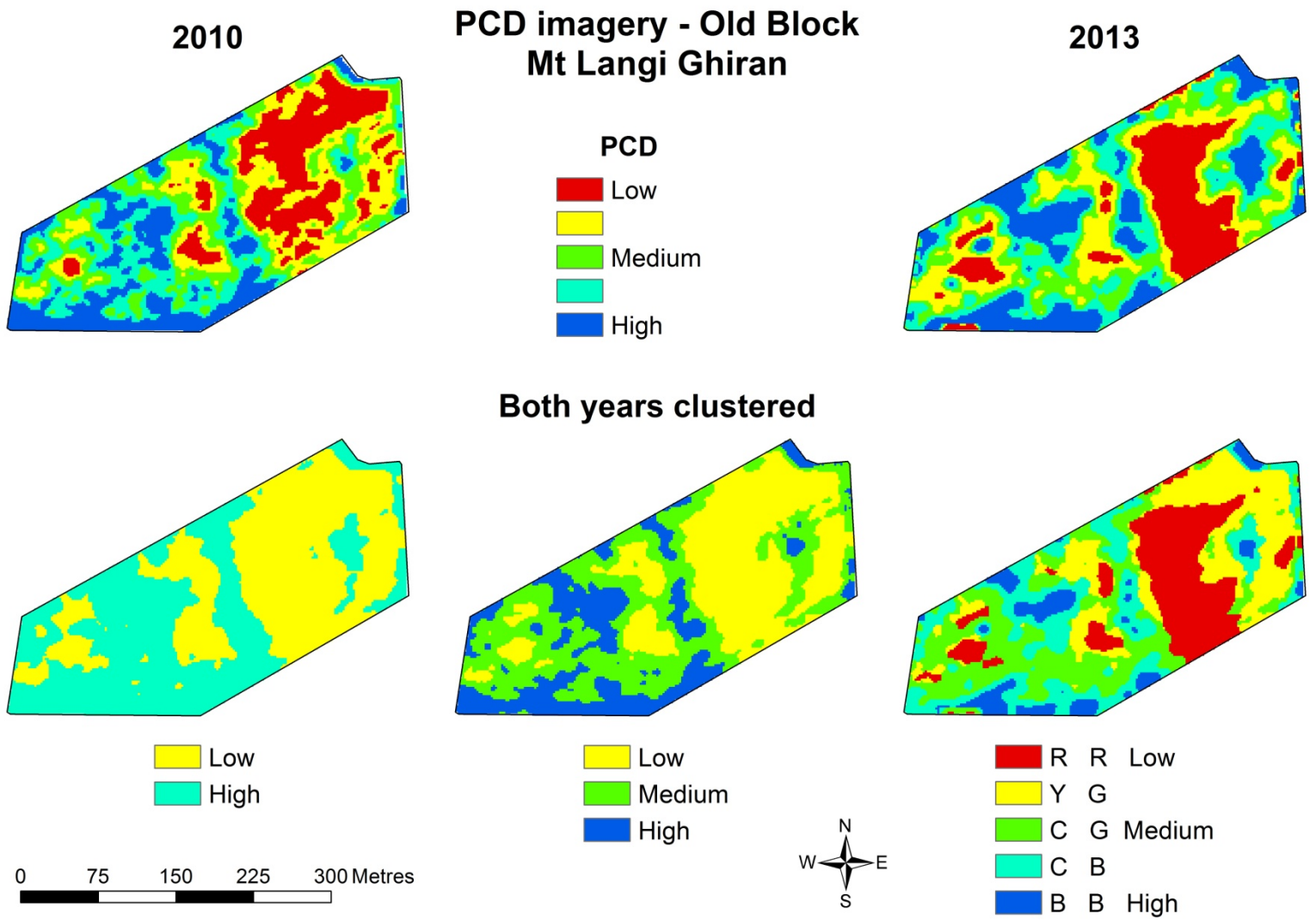
- 2012 and 2013 were very different years.

- Mean rotundone concentrations:

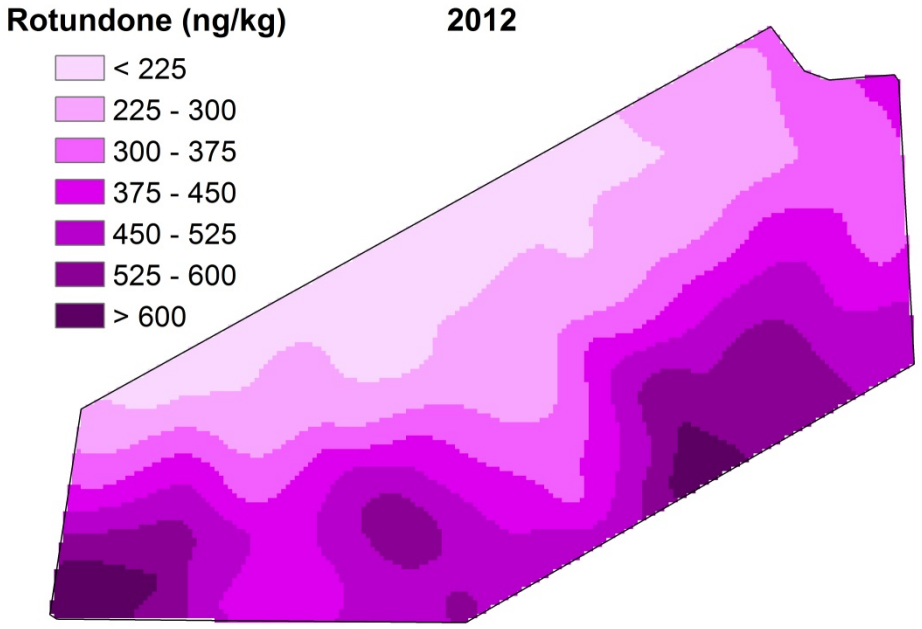
  2012: 399 ng/kg

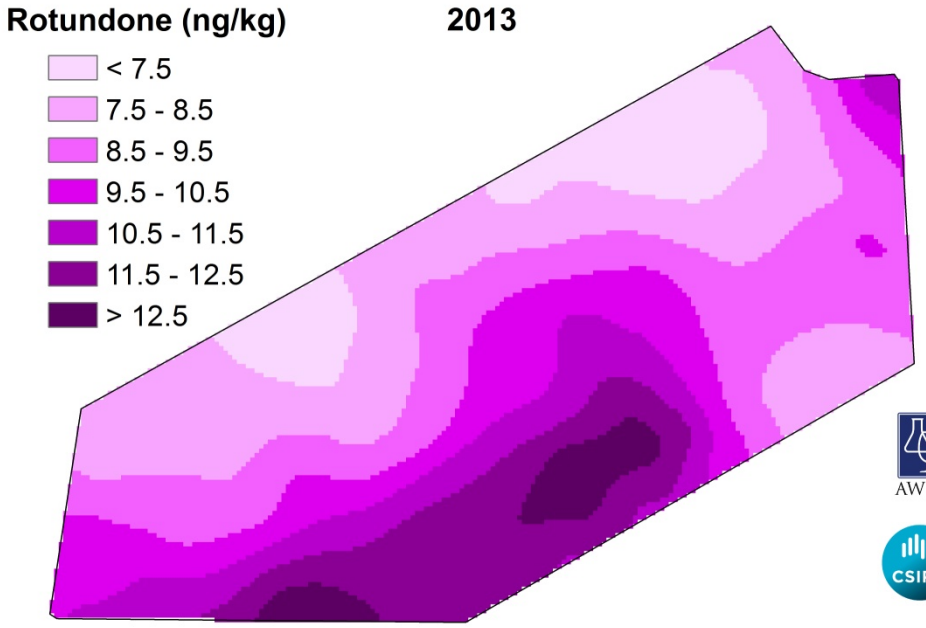
  2013: 10 ng/kg

Patterns of variation in PCD were also similar



Rotundone concentration in 2013 was ~1/40 of what it was in 2012, yet its spatial structure was essentially the same.





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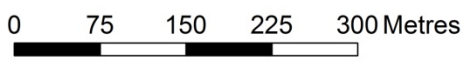
0 25 50 75 100 125 150 175 Metres

k-means clustering of 2012, 2013 maps

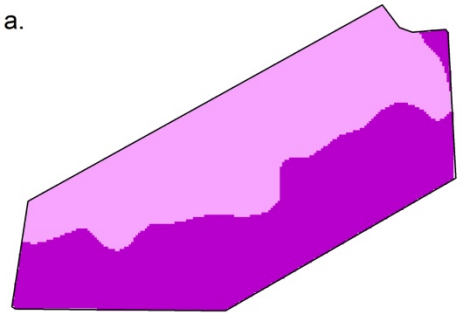
Even over two very contrasting years, variation in concentrations of berry rotundone (ng/g) follow similar patterns.

Accordingly, as seemed apparent in 2012, rotundone variation in 2013 appears related to variation in slope, aspect and soil properties.



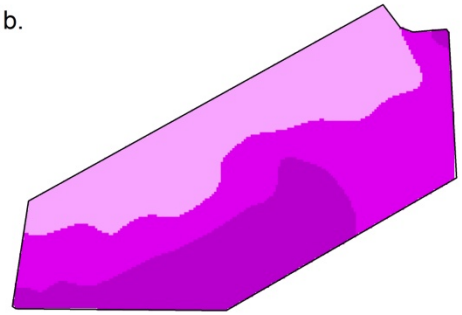


a.



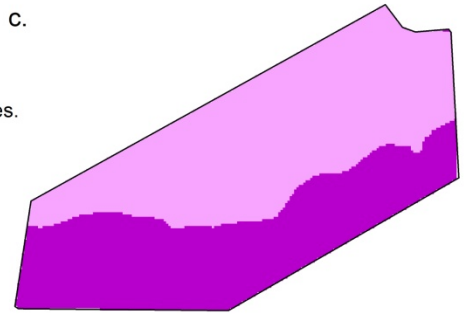
2012	2013
264	8.3
479	10.5

b.



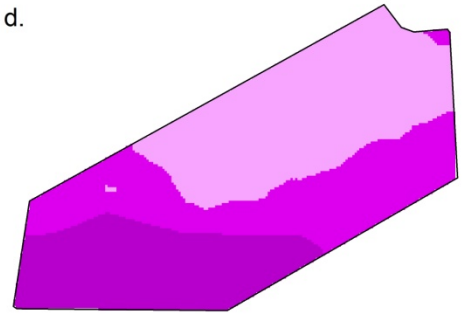
2012	2013
244	7.8
418	9.3
475	11.7

c.



2012	2013	EC_a	fN	SI
282	8.5	61	14	7.1
481	10.5	48	122	4.4

d.



2012	2013	EC_a	fN	SI
277	8.5	63	9	8.1
401	9.3	53	39	3.9
474	10.9	45	168	4.9

Why the difference between years in rotundone concentration ?

- Was 2013 hotter ?
  - No !

		Ararat Prison	Ballarat
MJT (°C)	2012	21.0	20.0
	2013	19.6	19.1

- Was 2013 sunnier ?
  - Yes !

		Ararat Prison			Beaufort		
		Jan	Feb	Mar	Jan	Feb	Mar
Solar Exposure	2012	26.0	20.4	16.5	25.3	19.1	16.4
(MJ/m2)	2013	27.6	22.7	17.4	27.5	22.0	16.6

- Were these differences enough for rotundone conc to differ by a factor of 40 ?
  - No idea !

Rotundone

- **Within-vineyard variation in berry rotundone concentration is spatially structured**
  - **and appears to be driven by variation in the land (soil, topography) underlying the vineyard;**
  - **But rotundone variation did not closely match variation in vigour**
  - **seasonal temperature / solar radiation may well play an important role.**
- **This study highlights the potential opportunity, with further understanding of rotundone biosynthesis, to use selective harvesting and/or viticultural manipulation as a means of influencing wine style – in this case the 'pepperiness' of Shiraz.**
- **Again, *terroir* appears to be spatially variable at the within vineyard scale.**

Aust. J. Grape and Wine Res. **20**, 214-222

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Soil, *terroir*, vines and wines

- Vineyards are variable
- Within vineyard variation is driven by variation in the land (soil, topography) underlying the vineyard
  - Elucidating the specific factors that impart specific effects on vines, grapes and wines is a (highly complex) work in progress (which needs funding !)
- *Terroir* is real !
  - However, at least some of the elements of *terroir* are potentially manageable
- So at what scale is *terroir* a meaningful concept ?
  - In my opinion, when considered at its conventional regional scale, *terroir* is a largely meaningless concept with a relevance that is mainly confined to wine marketing (especially in the New World)
  - However, at sub-block scale, an understanding of *terroir* could be a very powerful tool in grape and wine production
  - Such understanding may also provide winemakers with a more compelling basis for 'telling their story'


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