BIOAVAILABLE CATION INDEX (BCI) FROM MMI™ SOIL DATA AND ITS APPLICATION TO VINEYARD SOILS

INTRODUCTION

Cations of calcium (Ca), potassium (K) and magnesium (Mg) are essential for plant growth. Calcium appears to be essential for the growth of meristems (dividing cell tissue) and for the proper functioning of root tips and cell walls. Typically Ca is deficient in acid soils, and liming of the soil is a remedy. Potassium also often needs to be added as a fertiliser, usually as saltpetre (potassium nitrate), potassium sulphate or potassium chloride as it appears to also be important in cell structure particularly in large plants and trees. Magnesium is needed by all green plants as it is a constituent of chlorophyll. Collectively the cations of these three elements have been monitored closely in soils, particularly in relation to their exchange to and from clays, historically via the Cation Exchange Capacity (CEC).

CATION EXCHANGE CAPACITY

The Cation-exchange capacity is a measure of how many cations can be retained on soil particle surfaces. Negative charges on the surfaces of soil particles bind positively-charged atoms or molecules, but allow these to exchange with other positively charged particles in the surrounding soil water. It can be estimated by exchanging and measuring the concentrations of Ca, K and Mg which are displaced from a soil by alternative cations such as barium or ammonium. It can also be calculated from partial digestion analysis of soils (e.g. MMI™).

The basic formula for calculating CEC from an MMI™ analysis is CEC= Ca/200 + K/390 + Mg/120. The denominators in each case reflect the fact that the CEC works in equivalents and incorporates a charge factor on the cation. Since MMI™ is a near neutral solution no adjustment for pH is required. However as shown by the analysis of two "hypothetical" samples in Table 1, it is not explicit.

Table 1.: Cation Concentrations (in ppm) and CEC and BCI Values for Two Theoretical Soils

Sample	Ca	K	Mg	CEC	BCI
Hypo 1	200	80	100	2.038462	1600
Hypo 2	230	40	100	2.085897	920

These two samples have very different values for K, yet very similar values for CEC – in fact the sample with least K has a slightly higher CEC. This is a direct function of the additive index – a slightly higher value for Ca in Hypo 2 more than compensates for a much lower value of K. For a situation where all nutrients are important, and Ca is not a proxy for K as far as plant nutrition is concerned, this "index" is not ideal. A more equitable "multiplicative index" is shown (as BCI) in the final column.

BIOAVAILABLE CATION INDEX

The Bioavailable Cation Index (BCI) is defined as Ca*K*Mg/1000 where Ca, K and Mg are the ppm values of elements calcium, potassium and magnesium in the soil measured after MMI™ partial extraction. The denominator 1000 in the formula is simply to return a "value with a sensible number of significant digits". As shown in Table 1, the BCI correctly identifies soil sample Hypo 1 as having nearly twice the nutrition value of soil sample Hypo 2, i.e. it has given equivalence to each of the component cations.

APPLICATION OF BCI TO UNFERTILISED VINEYARD SOILS

One of the main functions historically of the Cation Exchange Capacity was to identify potentially good from poorer agricultural soils. The Bioavailable Cation Index can perform the same function – but perhaps more accurately. The vineyard districts of South Western Australia are shown superimposed onto geology in Figure 1 and provide a good test of the diagnostic potential of the BCI.

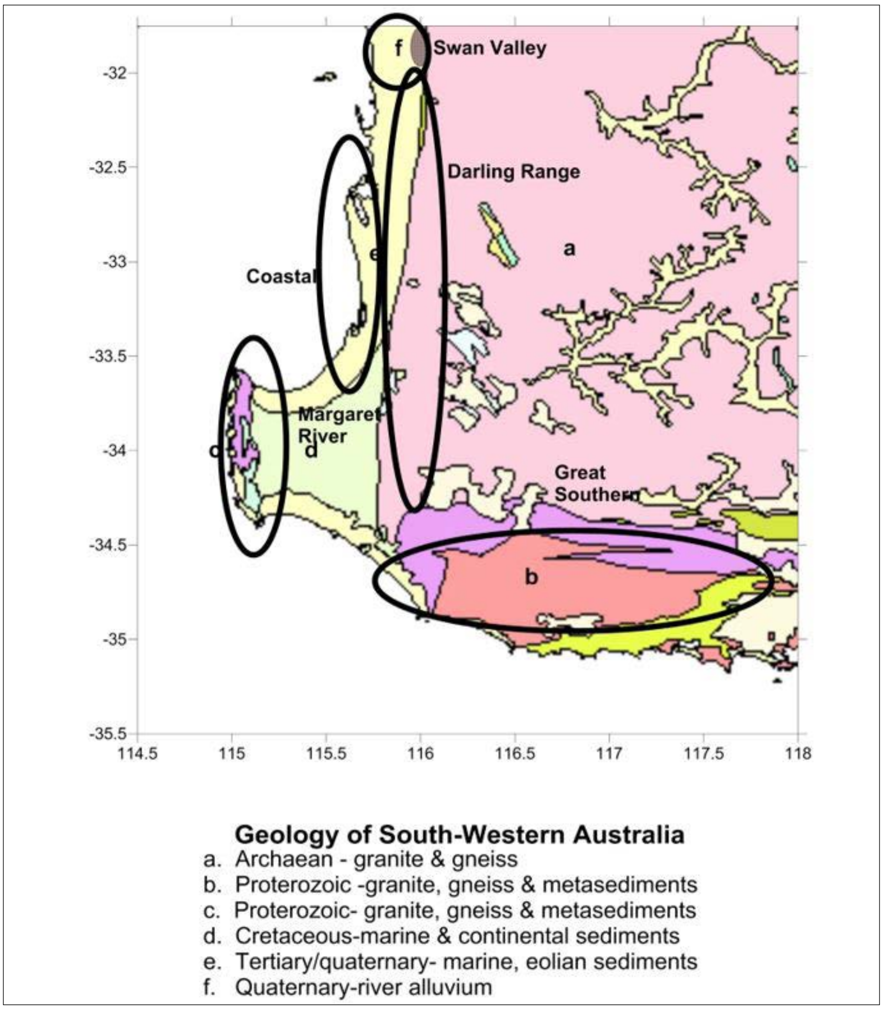

Figure 1: The Vineyard Districts of South-Western Australia Shown Superimposed onto Geology

The important vineyard districts of South-western Australia are from north to south:

1. The Swan Valley. This historically is the oldest vineyard district of Western Australia with vines dating back to the 1830's. They are located on outwash alluvial sediments from the Yilgarn Craton courtesy of the Swan Avon drainage system. The warm climate favours shiraz, muscat and sweet white styles.

2. The Darling Range. These vineyards are located on weathering Archaean granite of the Yilgarn Craton, typically in soils over laterite profiles. Climate varies from north to south –being cooler to the south and there is a corresponding variety of wine styles.

3. The coastal wineries are all located on tertiary and quaternary marine sediments dominated by limestone. They have a marine Mediterranean climate.

4. The Margaret River wine district is relatively recently established (since 1973) but now produces world class cabernet sauvignon, merlot, chardonnay, sauvignon blanc and semillon styles of wine. Vineyards are based on weathering granite gneiss west of the Dunsborough Fault and cretaceous and more recent sediments east of it.

5. The Great Southern has a cooler climate and accordingly favours pinot noir and reisling as their premier wine types. The geology is weathered Proterozoic granite-gneiss.

Seventy six roadside (i.e. unfertilised) samples were taken adjacent to various vineyards in the five districts and subjected to MMI™ extraction and ICPMS analysis for 53 elements at the SGS Perth laboratory. The CEC and BCI for each sample were calculated from the Ca, K and Mg concentrations according to the formulae above. The values are shown in Figure 2.

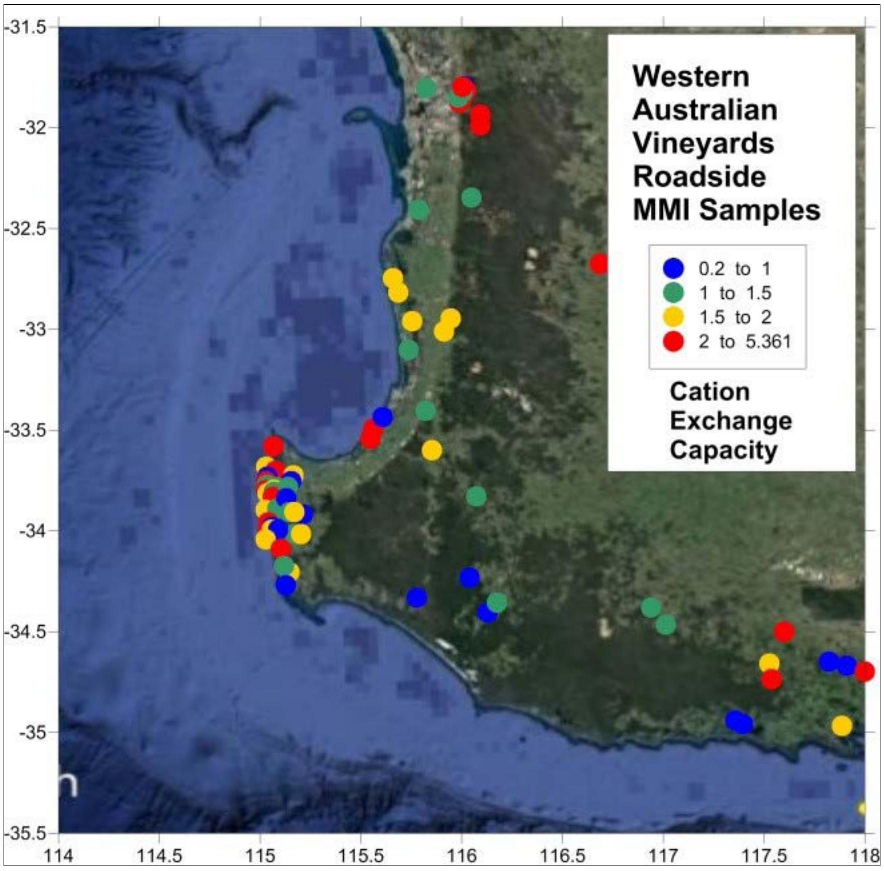

Figure 2a: Roadside CEC Values for W.A. Vineyards by Quartile

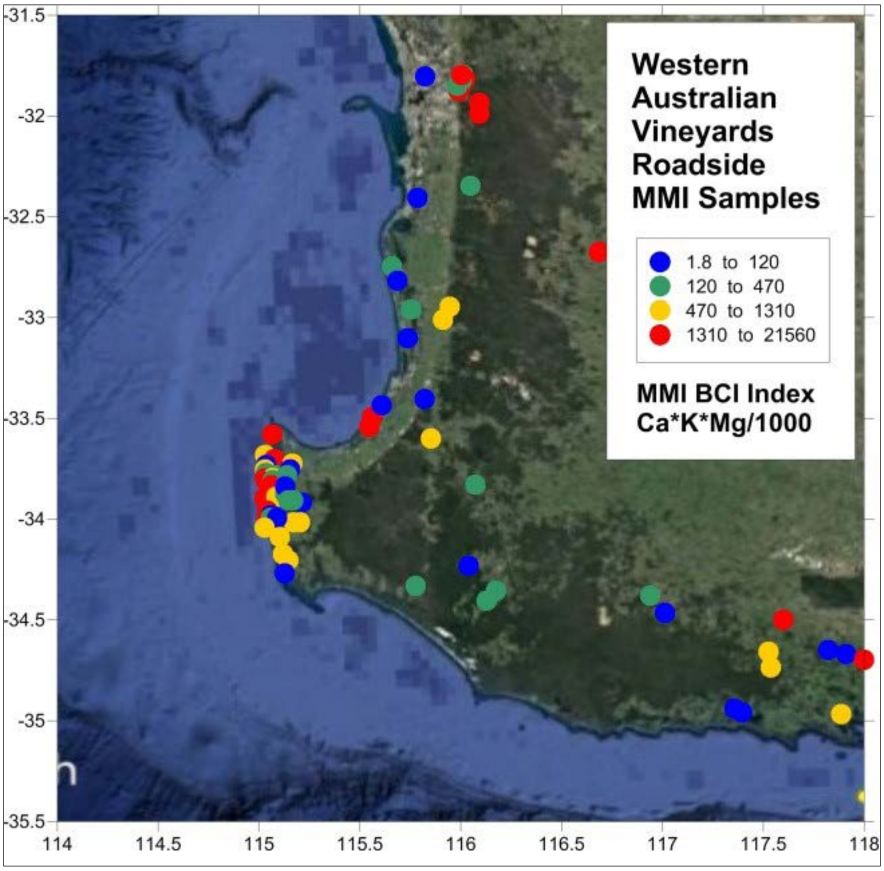

Figure 2b: Roadside BCI Values for W.A. Vineyards by Quartile

In this case the quartile distributions for CEC and BCI indexed samples are similar, and quartile distributions suggest there are a range of qualities of soil within each district with respect to bioavailable cation concentrations. The most northern soil from the Margaret River district west of the Dunsborough Fault is rated most highly of all by both indices; it has bioavailable (after MMI™ extraction) concentrations of 190ppm for Ca, 251ppm for K and 452ppm for Mg. Biggest differences between CEC and BCI are for the lower quartile distribution in the west coastal wineries, where not surprisingly they (west coastal winery soils) are rated more highly by CEC than for BCI, based on their higher Ca concentrations. Whilst this is an important vegetable growing district, these soils produce poorer quality juice in comparison with other vineyard districts. There are of course two components to a vineyard's provenance, climate and soil geochemistry. It is worth examining the Margaret River vineyard district in greater detail, where large differences in climate are not a factor.

BCI AS AN INDICATOR OF VINEYARD SOIL QUALITY AND PROVENANCE

In the Margaret River Wine District of Western Australia, there are vineyards either side of the Dunsborough Fault. Climate for the whole of the Margaret River District is very similar to that of the Bordeaux District of France; there is only a small gradual decrease in rainfall from west to east and south to north. To the west of the Dunsborough Fault the underlying geology is weathered granite gneiss, to the east of the fault Cretaceous and Permian sediments, comprising sandstone, siltstone and coal measures. It is generally accepted that the best natural soils for vineyard development, and those chosen first lie to the west of the Dunsborough Fault. (Selection of best soils for vines in the Margaret River District was in the 20th century based on the stature of the native marri trees (Corymbia calophylla). It is possible that these soils are favoured by both large trees and vines because they contain higher concentrations of the bioavailable cations of Ca, K and Mg. Figure 3 shows quartile values for the BCI index for soils taken alongside roadways outside major vineyards (i.e. in "natural" unfertilised soils) in the Margaret River District.

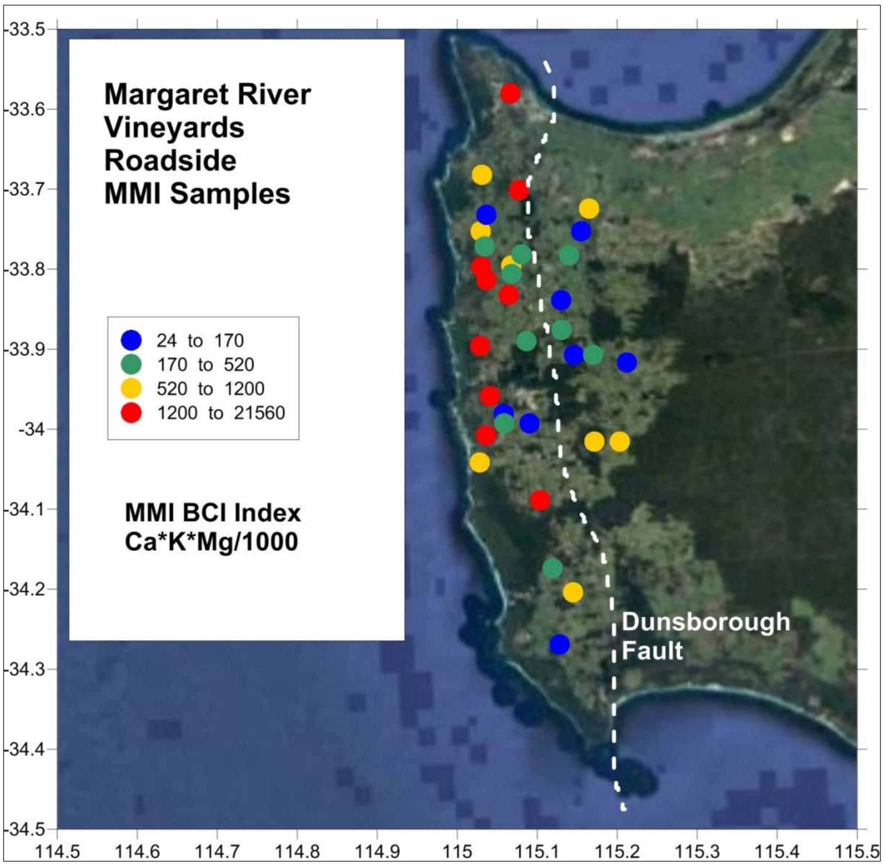

Figure 3: Quartile Values for the BCI Obtained from Analysis of Roadside Soils, Margaret River Wine District, Western Australia

All of the upper quartile values for the BCI lie to the west of the Dunsborough Fault signifying higher combined values for bioavailable Ca, K and Mg. Soils to the east of the Dunsborough Fault, derived from sediments which may include feldspathic sandstone derived from the neighbouring granite gneiss, would require additional Ca, K and/or Mg to bring their BCI values up to those naturally occurring west of the fault.

APPLICATION OF BCI TO AN OPERATING VINEYARD

Figure 4. shows the BCI values obtained from soil sampling and MMI™ analysis of a block of chardonnay vines from the McHenry Hohnen vineyard, Rocky Road, Margaret River.

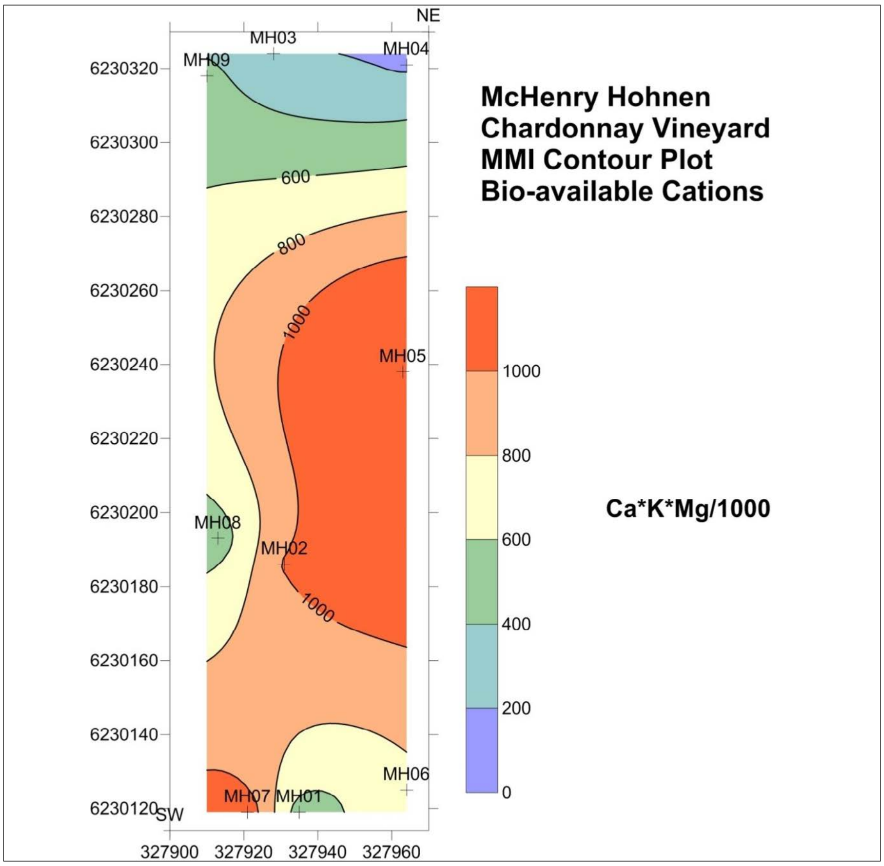

Figure 4: The Contoured BCI Index for Nine Soil Samples from the Chardonnay Block, McHenry Hohnen vineyard, Margaret River

Prior to sampling this vineyard, the manager explained that the best, and earliest ripening chardonnay grapes came from the vines at the south end of the vineyard, to the extent that annually these are picked and processed separately. The vineyard slopes from south to north, the southern end having deeper (gravelly) soils. Soils at the lower northern end of the vineyard are over a thinner probably weathering granite-gneiss laterite profile, deduced from the higher Al, Ga, and rare earth concentrations in the MMI™ analysis These soils may also be more acidic.

The contoured BCI map clearly shows lower BCI values for soil samples MH03, MH04 and MH09 from the northern end, and higher BCI values for samples in the middle and southern end of the vineyard where deeper soil profiles exist, and grape quality is noted to be better.

It is possible, with judicious fertilisation in early spring that the BCI values for the soils at the northern end of the vineyard could be improved, as shown by the next exercise carried out on a separate small vineyard in the Margaret River District.

IMPROVEMENT IN BCI VALUES BY FERTILISATION

Figures 5(a) and 5(b) show BCI maps of a small vineyard (lineal units are row and panel numbers) in which poor growth and yield from both merlot and cabernet sauvignon vines had been noted over previous seasons.

Nine samples were taken over the vineyard area, before and after fertilising, two of which were located outside the area to be fertilised, shown within the green border on Figure 3(b). The period between sampling exercises was one week, and after 150kg/ha of potassium nitrate (saltpetre) and 150kg/ha of dolomite was applied. In this period (August 2018) 100mm of rain fell.

The above BCI maps in Figures 5(a) and 5(b) show, that with the exception of the area around the two samples in the SW corner where fertiliser was not applied, that there is a significant increase in BCI values after fertilisation.

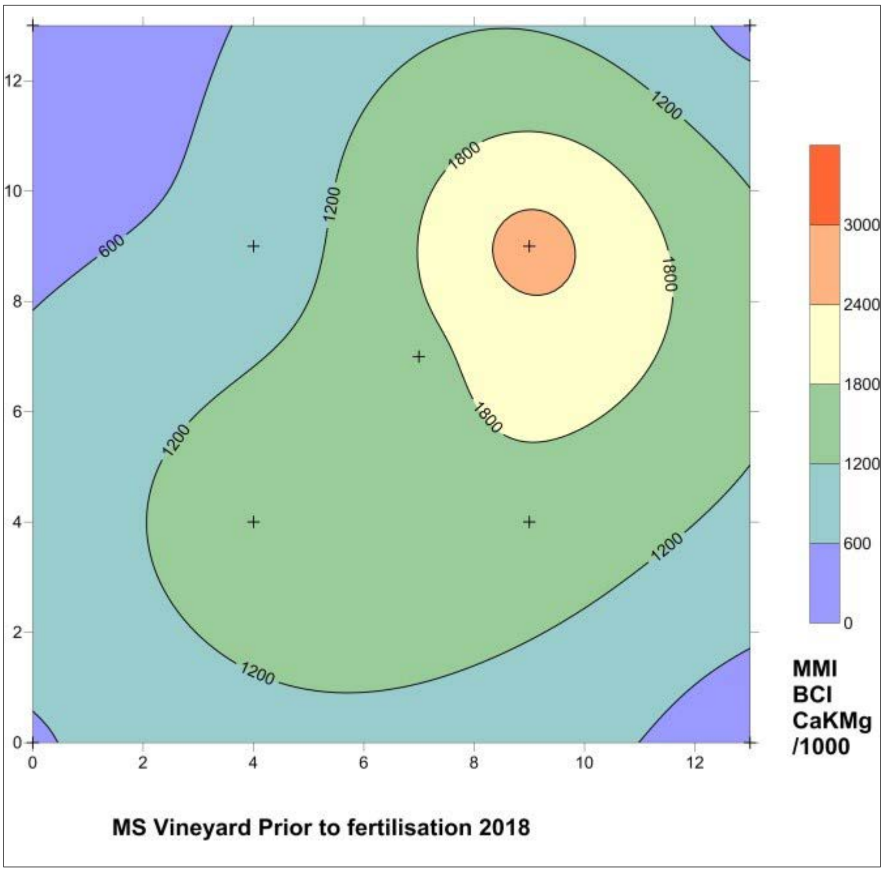

Figure 5a: BCI Map prior to Fertilising

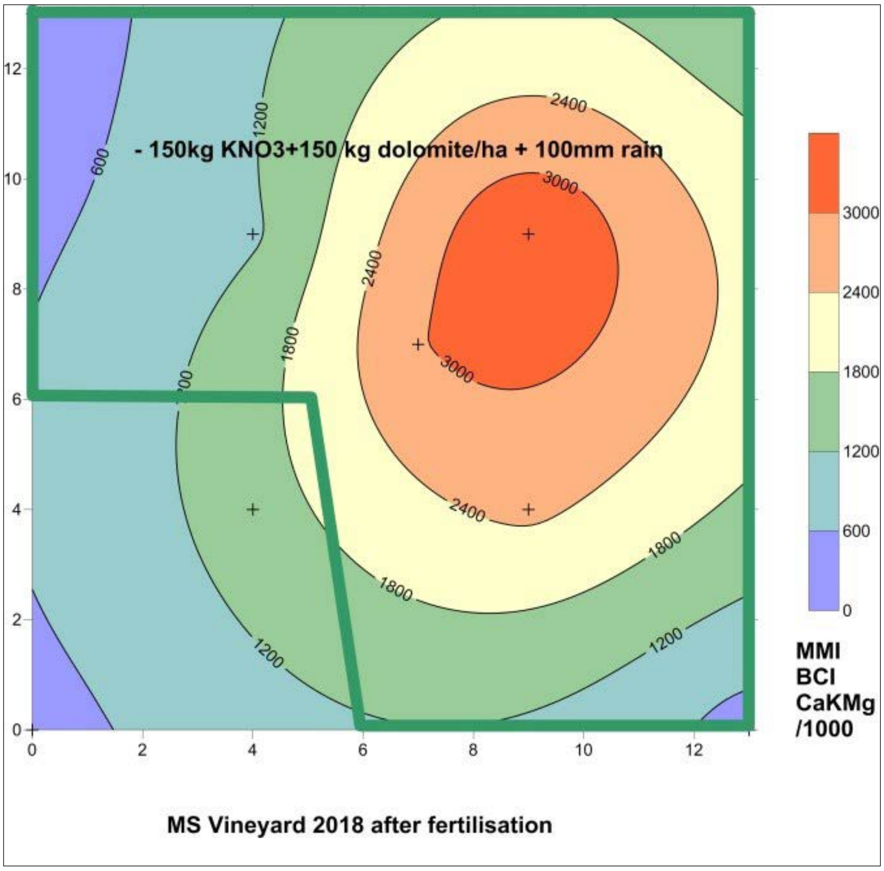

Figure 5b: BCI Map after Fertilising and Rain

CONCLUSIONS

1. The BCI is a reliable and accurate indicator of nutritional status of the alkali and alkali earth elements Ca, K and Mg in soils.

2. In Western Australia soils with higher BCI values coincide with "better vineyard soils" as adduced by vigour of natural vegetation. Values of BCI>1000 indicate good vineyard soils.

3. Soils with higher BCI values in operating vineyards coincided with areas of vines identified by vineyard managers as producing "better" quality grape juice.

4. BCI values in soils increase after application of potassium nitrate and dolomite.

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