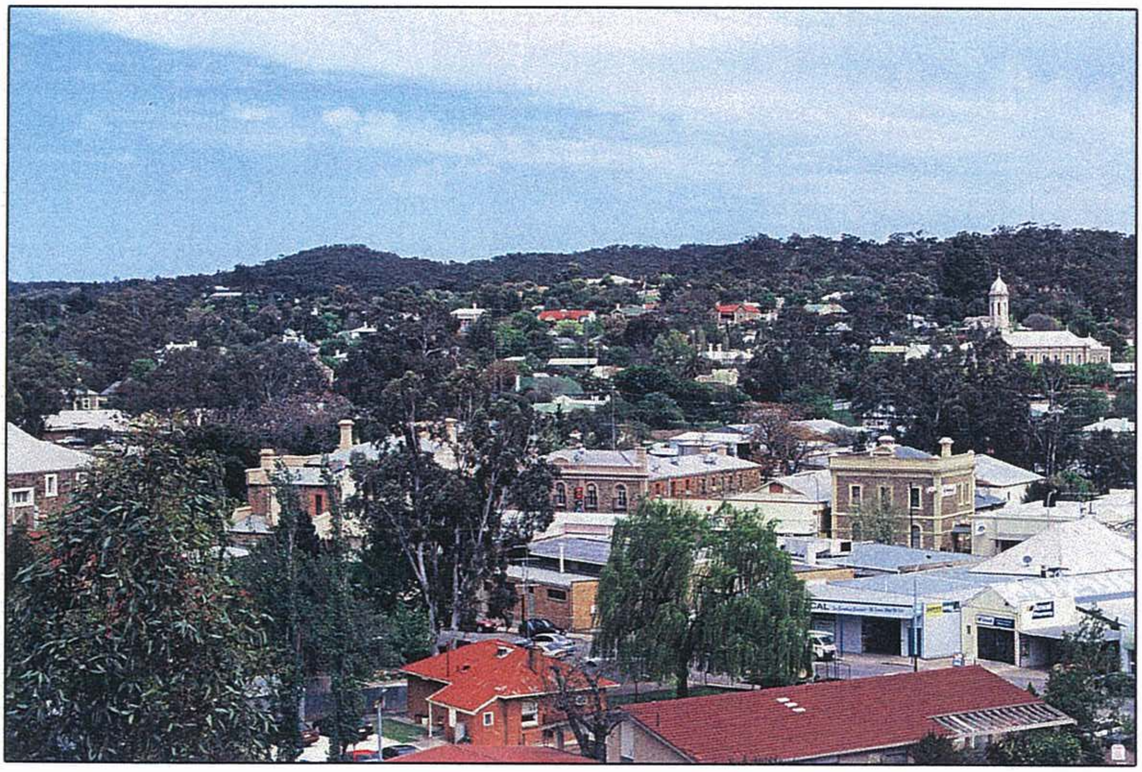
Soils and climate of the Clare Valley



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The concept of regional viticultural profiles arose from recognition that local extension programs should be planned against a background of knowledge about a region's natural resources, climate and wine marketing requirements.

This publication can be regarded as a significant start to building a comprehensive profile of the Clare Valley of South Australia. Components include an account of local practices, soil data of importance to vineyard management, and an examination of climatic factors.

Contents

Soil zones and data for the main soil types

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This chapter is drawn from a broad South Australian Government mapping program that includes an overview of the main soils of a district with emphasis on their potential for sustaining irrigated crops.

Accumulation of salt in the soil is considered to be the main risk associated with irrigation in the Clare Valley and this can be linked to excessive wetness, an impeding layer in the potential rootzone, an impeding layer below the rootzone or a shallow water table. While very much only a general rating, the 20 soils illustrated in the pages that follow have been placed in approximate order of risk of salinisation potential (i.e. Soil 1 has a high risk and Soil 20 a low risk).

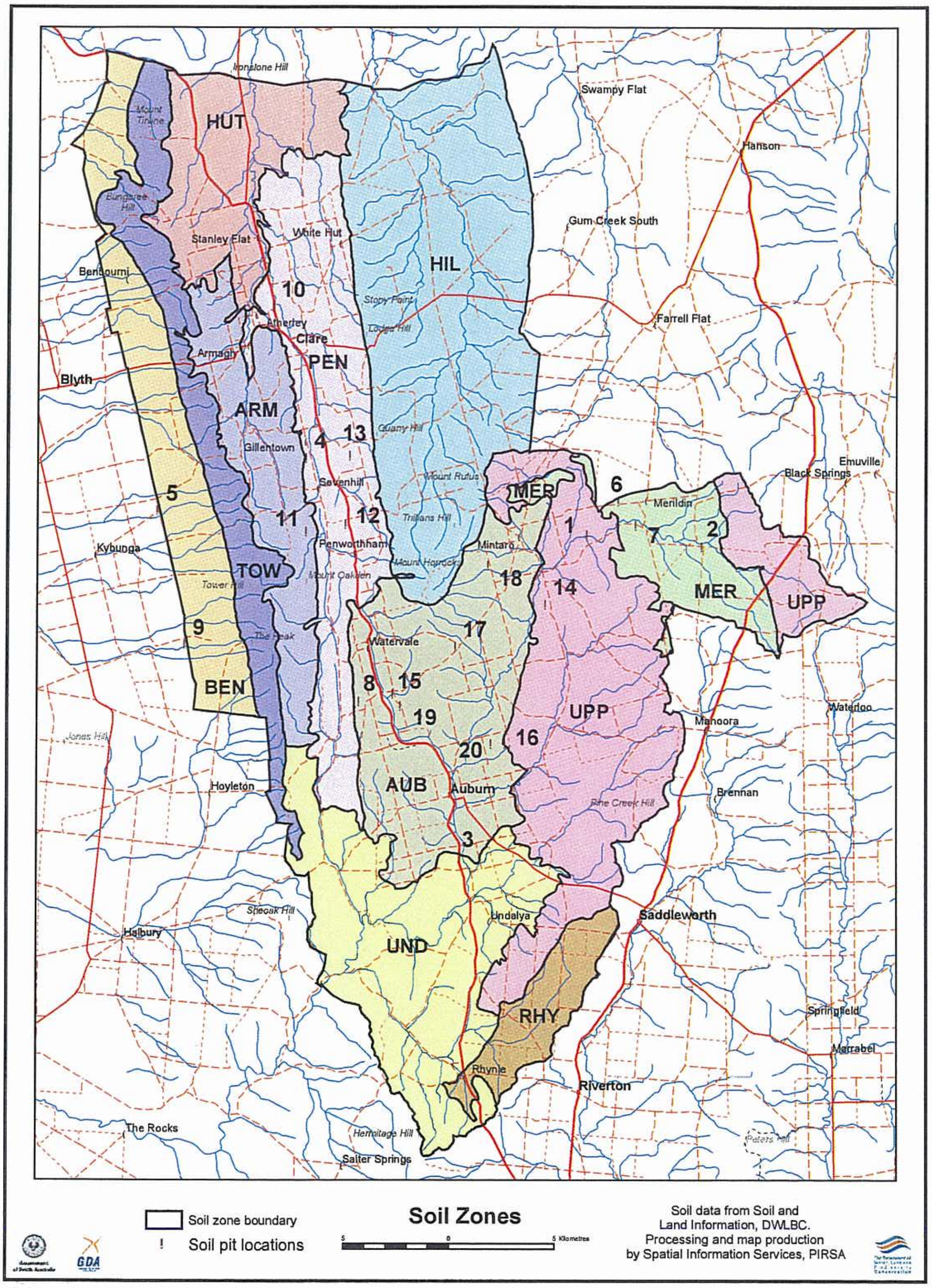
Other considerations have included rootzone depth and water holding capacity, which often can be influenced by the same soil characteristics that predispose the soil to waterlogging. Restricted depth may also be caused of course by chemical barriers like high alkalinity or by such physical barriers as heavily compacted soil or limestone layers.

The method used for mapping has been to separate tracts that are easily recognised by local growers. Each has a range of characteristic soils and a key is used to show whether a soil is common (occupying more than 10% of the zone) or minor (accounting for less than 10%). This provides a useful guide that may lead growers to investigate further the distribution of different soil types and variability of depth and other features within their own properties.

Soil data sheets are presented on facing pages, using pictures of a typical profile and the surrounding landscape. Laboratory analyses of relevant components for each layer to 1.5 metres or rock are presented in tables, along with interpretation notes where these are important. Note that in many soil profile pictures a red tape is used to show depths to layers. The numbers on the tape represent 10 cm intervals with the red section measuring one metre.

SOIL ZONES of the CLARE VALLEY

(based on Soil and Land Information (2004) Land Systems)



Legend

Soil Zones – Clare Valley

Legend

Soil Zone		Description	Main soils *	Minor soils
Armagh	ARM	Rolling to steep stony hills with low fertility sandy loam soils	11, 12, 4	13, 16, 19
Auburn	AUB	Undulating low hills with red loamy soils including terra rossa	19, 18, 17, 15	1, 2, 3, 8, 13, 14, 20
Benbournie	BEN	Gentle slopes of the Blyth-Kybunga plains with deep loam to clay soils	5, 14	9, 20
Hill River	HIL	Rises and flats with red loam over clay soils	2, 16, 13, 18	1, 3, 4, 6, 7, 11, 14, 15, 17, 19, 20
Hutt River	HUT	Ridges with red loams and valley flats with grey sandy loam to clay loam soils	13, 4, 16, 2	1, 7, 8, 10, 11, 12, 14, 15, 17, 18, 19
Merildin	MER	Plains and low rises with red and brown clay soils	7, 14, 6, 2	1, 3, 16, 18
Penwortham	PEN	Undulating rises with red loams and stony N-S ridges with grey sandy loams	13, 11, 12, 4	2, 8, 10, 15, 16, 19
Rhynie	RHY	Undulating rises with dark clays and red clay loams	8, 7, 2, 14, 6	1, 3, 16, 19
Tower Hill	TOW	Steep western slopes of Clare Hills with shallow loamy soils	17, 18, 20, 16	1, 4, 19
Undalya	UND	Undulating to steep low hills with red sandy loam to loam soils	16, 19, 18, 17	1, 2, 3, 7, 14, 20
Upper Wakefield	UPP	Undulating rises with red sandy loam to clay loam soils	16, 17, 2, 7	1, 3, 4, 6, 8, 14, 18

* Approximate order of dominance

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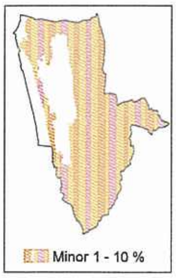
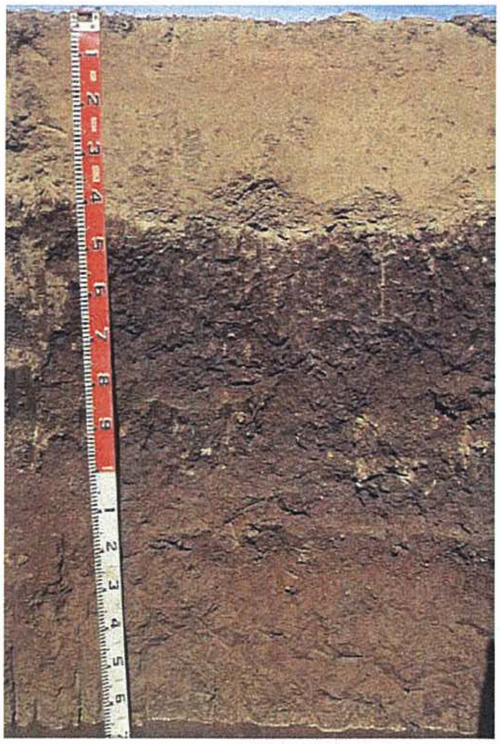
Deep sandy loam over red and brown clay



<u>Landscape</u> River and creek flats formed on medium to coarse grained alluvium. Surface soil is hard setting with no stones.

<u>Profile</u> Thick hard sandy loam over a red and brown mottled clay grading to alluvium.



Depth (cm)	*Description*
0-11	Dark brown firm massive sandy loam. Clear to:
11-40	Light brown very hard massive sandy loam, bleached at base. Abrupt to:
40-60	Dark brown and reddish brown mottled extremely hard medium heavy clay with strong coarse prismatic structure. Gradual to:
60-85	Dark brown and brown mottled hard prismatic medium clay. Gradual to:
85-105	Medium clay (as above) with minor carbonate nodules. Gradual to:
105-170	Brown mottled massive fine sandy clay loam.
170-	Water table.

Management

- Irrigation developments where water tables are shallower than 200 cm should be avoided. The water table restricts leaching of salt, and has potential to introduce more salt to the soil if water salinity and / or water level rises.
- Sodic clay subsoil perches water and restricts root growth. Causes temporary waterlogging at moderately shallow depth (i.e. within 40 cm of surface), and reduces readily available water (RAW) capacity. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.

Key properties

Drainage — Imperfectly drained. The poorly structured clayey subsoil perches water so that saturation of part of the profile is likely for several weeks at a time. Drainage is further impeded by the water table.

Potential root zone — 60 cm in sampling pit.

Barriers to root growth

Physical: The massive dense subsurface restricts root density, and root growth is largely confined to the surfaces of subsoil clay aggregates.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available:	55 mm
Readily available:	30 mm

Fertility — The low clay content of the surface layers provides limited capacity for nutrient retention. However, there is ample capacity in the subsoil. Apart from nitrogen and phosphorus, this soil is not naturally susceptible to specific deficiencies, but given the low clay content, regular monitoring is desirable.

Erosion potential — Low water erosion potential due to flatness. These soils occur in flood prone situations so there is a risk of siltation.

Laboratory data

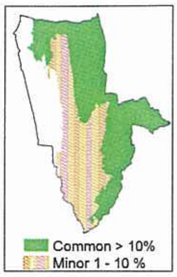
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-11	6.6	6.3	0	1.878	86	19	1.0	28	294	1.61	3.85	0.89	0.35	0.77
11-40	6.1	5.6	0	0.401	16	12	0.8	13	243	0.65	3.15	1.47	0.29	0.45
40-60	7.4	6.4	0	0.662	68	28	2.2	4	445	0.74	9.94	10.8	2.17	1.12
60-85	8.3	7.4	0.4	1.902	272	66	5.4	2	451	0.54	11.4	13.8	3.34	1.18
85-105	9.0	7.9	0.7	2.17	273	61	2.7	5	397	0.39	9.28	9.22	2.71	0.97
105-170	8.8	7.8	0.4	2.39	218	43	1.0	5	366	0.35	6.37	4.31	1.44	0.60

Explanation of highlighted data

Many horticultural crops suffer yield loss when ECe exceeds 2 dS/m. Increased salt loads from irrigation water will raise these presently marginal levels, as the water table will prevent leaching.

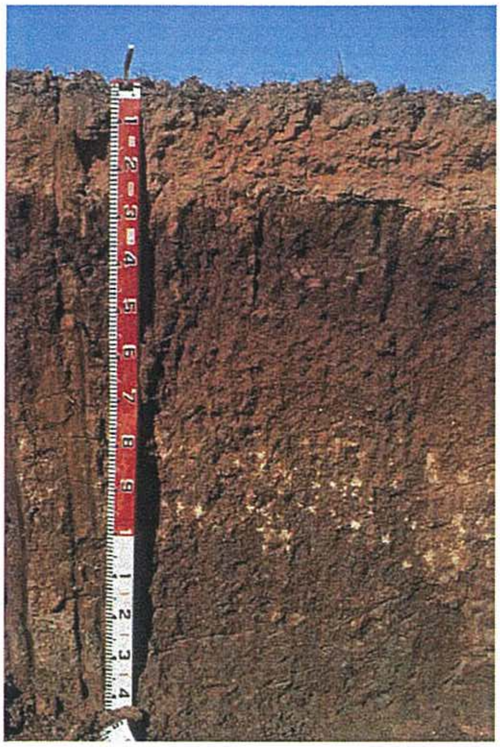
Exchangeable sodium (Na) values should be less than 6% of the sum [Ca+Mg+Na+K].

Hard loam over dispersive red clay



Landscape — Lower slopes and valley flats formed on clayey alluvium. Surface soil is hard setting and stone free.

Profile — Hard setting red brown sandy loam to clay loam overlying a reddish brown coarsely structured clay, calcareous with depth.



Depth (cm)	*Description*
0-10	Reddish brown weakly structured hard fine sandy loam. Clear to:
10-25	Yellowish red massive clay loam. Sharp to:
25-50	Dark reddish brown heavy clay with strong coarse prismatic structure. Gradual to:
50-75	Red heavy clay with strong coarse polyhedral structure. Gradual to:
75-100	Brown highly calcareous light clay with strong polyhedral structure and fine carbonate segregations. Gradual to:
100-	Brown and red mottled light clay with strong polyhedral structure.

Management

- Sodic clay subsoil perches water and restricts root growth. Causes temporary waterlogging at shallow depth (i.e. within 30 cm of surface), and reduces readily available water (RAW) capacity. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.

Key properties

Drainage — Moderately well to imperfectly drained; the sodic clay subsoil restricts water movement, causing saturation for a week or so at a time. The hard setting, sealing surface ponds water.

Potential root zone — 45 cm in sampling pit.

Barriers to root growth

Physical: The hard massive subsurface layer (10-25 cm) and the tight clay subsoil both restrict root growth. Gypsum, broadcast and ripped in, is essential.

Chemical: High boron and exchangeable sodium from 50 cm prevent deeper root development.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 60 mm
Readily available: 25 mm

Fertility — Nutrient retention capacity is moderately low in the surface soil and high in the subsoil. Maintaining adequate levels of nutrition in these soils is straightforward, provided acidity is controlled.

Erosion potential — Low potential for water erosion on flats, but moderate on gentle slopes because of the high erodibility of the surface soil. Wind erosion potential is low.

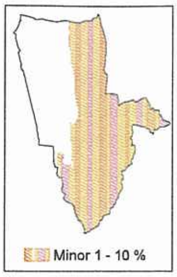
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	6.0	5.6	0	0.4	14	10	2.0	59	247	1.20	5.3	1.1	0.28	0.50
10-25	5.2	4.6	0	0.3	11	16	1.5	12	198	0.32	2.3	0.6	0.26	0.39
25-50	7.5	6.6	<0.1	0.4	16	15	8.6	<4	455	0.49	7.4	11.5	4.36	1.31
50-75	9.1	8.5	0.4	1.4	79	53	14.2	<4	499	0.24	6.8	14.3	6.61	1.34
75-100	9.3	8.5	11.0	2.3	189	99	13.9	<4	424	<0.02	5.2	10.1	5.43	0.97
100-150	9.2	8.6	0.8	3.1	275	127	13.4	<4	395	0.14	4.5	9.5	5.34	0.91

Explanation of highlighted data

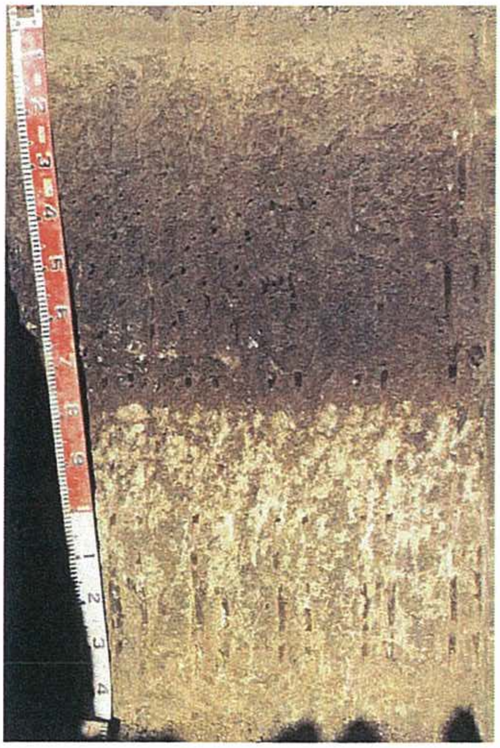
Many horticultural crops suffer yield loss when ECe exceeds 2 dS/m.
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for horticultural crops (American literature).
pH less than 5.0 requires treatment, especially in subsurface layers.

Dark gradational loam



Landscape — Flats and terraces of major watercourses, on fine grained alluvium. Surface soil is hard setting with no stones.

Profile — Dark loam becoming more clayey with depth grading to a highly calcareous clay within 100 cm.



Depth (cm)	*Description*
0-10	Dark brown firm weakly structured loam. Clear to:
10-20	Dark brown hard weakly structured clay loam. Clear to:
20-40	Very dark grey hard light medium clay with moderate polyhedral structure. Diffuse to:
40-80	Very dark grey and dark brown mottled hard medium clay with weak coarse prismatic structure. Clear to:
80-120	Greyish brown and yellowish brown mottled hard very highly calcareous prismatic structured medium clay. Gradual to:
120-	Brown and yellowish brown mottled hard coarse blocky calcareous light clay.

Management

- Risk of shallow water table on river flats (although not evident at this site). Where present, there is potential for increasing soil salt concentrations should water table level and/or salinity rise.
- Ripping with applied gypsum may improve soil permeability and root growth conditions, although root zone soil is not sodic.
- Hard surface will benefit from broadcast gypsum to help stabilize soil aggregates and mulching to conserve moisture.

Key properties

Drainage — Moderately well to imperfectly drained. The coarsely structured clayey subsoil has moderately low permeability, so the profile is not freely draining. Waterlogging may occur for periods of a week or more. Deep drainage is restricted – salts may accumulate over time under irrigation.

Potential root zone — 80 cm in sampling pit.

Barriers to root growth

Physical: The deep subsoil clay imposes a slight restriction on root growth. Although the soil is not sodic, sub-optimal structure in both surface and subsoil may be improved with gypsum applications combined with ripping.

Chemical: Elevated salt (EC) and chloride levels affect sensitive plants. Clayey substrate material restricts salt leaching.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 110 mm
Readily available: 50 mm

Fertility — Inherent fertility is high. Apart from phosphorus and nitrogen, deficiencies of other nutrients will not occur routinely.

Erosion potential — Low.

Laboratory data

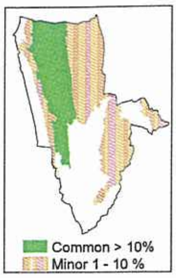
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	7.7	7.1	0	1.703	86	97	1.0	27	685	2.53	13.7	3.49	0.34	1.64
10-20	7.7	7.0	0	0.871	65	80	0.8	10	504	1.76	14.6	3.31	0.27	1.20
20-40	7.8	7.2	0	0.551	64	235	0.9	7	323	1.35	21.7	4.29	0.44	0.83
40-80	8.0	7.5	1.2	1.355	307	680	1.1	8	349	1.10	23.1	9.12	1.08	0.88
80-120	8.2	7.8	7.9	4.34	845	1693	1.1	7	408	0.35	14.9	11.6	2.29	0.97
120-145	8.6	8.1	4.8	6.90	1123	142	1.6	3	457	0.24	8.47	13.1	3.35	1.06

Explanation of highlighted data

Many horticultural crops suffer yield loss when ECe exceeds 2 dS/m. Increased salt loads from irrigation water will raise these levels, because the water table will prevent leaching.

Exchangeable sodium less than 6% of total of all four cations is desirable.

Sandy loam over poorly structured clay



Landscape	Lower slopes and flats in hilly country and adjacent higher rainfall landscapes.
Profile	Up to 50 cm massive greyish sandy loam over a coarsely structured brown mottled heavy clay continuing below 100 cm.

Depth (cm)	*Description*
0-12	Dark brown friable massive fine sandy loam. Clear to:
12-30	Grey massive loamy fine sand. Clear to:
30-38	Bleached massive fine sandy loam with 20-50% ironstone gravel. Abrupt to:
38-60	Brown and olive mottled very hard heavy clay with coarse prismatic structure. Diffuse to:
60-100	Brown and yellow mottled very hard weakly structured heavy clay with manganese veins. Diffuse to:
100-	Brown and grey mottled very hard coarsely structured heavy clay with minor veins of manganese and carbonate.

Management

- Tight clay subsoil perches water causing temporary waterlogging in the 20-40 cm zone, and may restrict root growth. Where clay is shallower than 30 cm, waterlogging is more severe, the rootzone is significantly reduced, and low water applications are essential to avoid drainage. Pre-plant ripping will help, but gypsum is unlikely to have much effect. For row crops, mounding will keep water away from base of plant, and increase rootzone depth.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.
- Leached acidic soils are prone to nutrient depletion. Soils with bleached (washed-out) subsurface layers invariably need an intensive fertilizer program.

Key properties

Drainage — Imperfectly drained. Heavy clay subsoil perches water so at least part of the topsoil will be saturated for periods of several weeks. Mounding is desirable.

Potential root zone — 60 cm in sampling pit.

Barriers to root growth

Physical: The dense subsurface soil, and the coarsely structured heavy clay subsoil both impose physical restrictions on root growth. Ripping will open the clay. Gypsum is of marginal benefit as soil is not sodic.

Chemical: There are no chemical barriers, other than low fertility status, which can be readily restored.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available:	60 mm
Readily available:	30 mm

Fertility — The low clay content restricts the capacity of the soil to retain nutrients. However, the clayey subsoil has significantly higher capacity to store and release cations such as calcium, magnesium and potassium. Regular nitrogen and phosphorus applications needed. Soil is highly susceptible to acidification.

Erosion potential — Moderately low water erosion potential, provided that run-off water from upslope is controlled.

Laboratory data

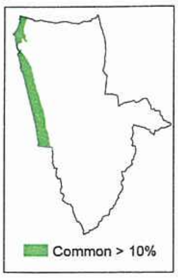
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-12	6.0	4.9	0	0.262	3	3.9	0.4	5	160	1.55	3.28	0.59	0.06	0.37
12-30	5.8	4.6	0	0.198	2	2.1	0.3	4	82	0.61	2.42	0.49	0.05	0.17
30-38	5.9	4.7	0	0.181	4	2.7	0.3	4	73	0.56	2.63	0.72	0.11	0.19
38-60	6.2	4.6	0	0.119	4	3.2	1.2	4	167	0.64	13.1	10.8	0.44	0.48
60-100	6.7	5.1	0	0.131	1	5.9	1.1	1	143	0.35	9.58	8.30	0.35	0.40
100-140	7.9	7.0	0	0.165	5	7.6	0.9	6	164	0.26	12.0	6.77	0.46	0.42

Explanation of highlighted data

pH less than 5.0 requires treatment. Less than 4.2 is critically low, especially in subsurface layers.

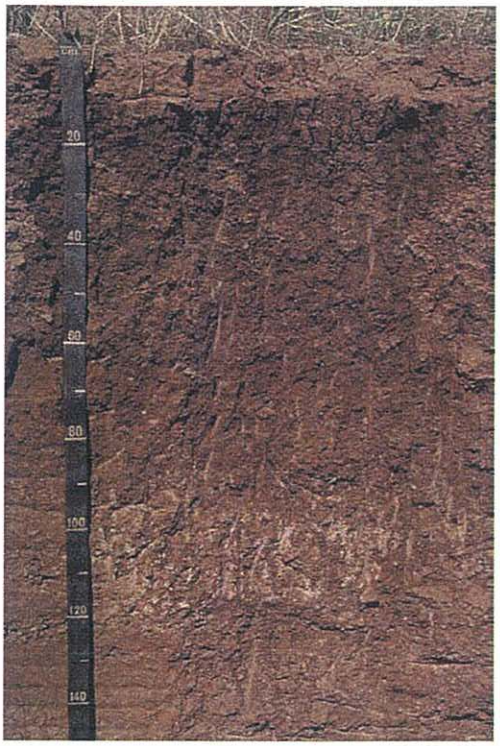
Low figures indicative of low fertility status, e.g. desirable P = 30-80 mg/kg, K = 120-200 mg/kg, sum of cations should be more than 10 cmol(+)/kg.

Hard loam over dispersive red clay



Landscape — Gently sloping outwash fans of the Blyth plains formed on fine grained alluvium. Surface soil is hard setting with no stones.

Profile — Hard red brown sandy loam to clay loam over a coarsely structured red brown clay, calcareous with depth.



Depth (cm)	*Description*
0-10	Brown massive hard setting sandy clay loam. Sharp to:
10-36	Dark reddish brown light medium clay with strong coarse prismatic structure. Clear to:
36-55	Dark reddish brown highly calcareous light medium clay with moderate polyhedral structure. Gradual to:
55-80	Dark reddish brown highly calcareous weakly structured light clay. Diffuse to:
80-160	Red very highly calcareous weakly structured light clay with gravel lenses. Diffuse to:
160-	Yellowish red weakly structured very highly calcareous light clay.

Management

- Sodic clay subsoil perches water and restricts root growth. Causes temporary waterlogging at very shallow depth (i.e. within 10 cm of surface), and reduces readily available water (RAW) capacity. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Sustainable irrigation of this soil is highly dependent on the permeability of the deep subsoil. Unless there is capacity for salts (including boron) to be leached, prospects are poor.
- Boron tolerance in varieties and rootstocks may be worth investigation.
- Hard surface will benefit from gypsum application to help stabilize soil aggregates and mulching to conserve moisture.

Key properties

Drainage — Moderately well to imperfectly drained. Dispersive clay subsoil causes topsoil to remain water-logged for a week or so at a time. Deep drainage is variable depending on structure of 80 cm + layers.

Potential root zone — 36 cm in sampling pit.

Barriers to root growth

Physical: Poor structure in both the surface and subsoil impedes root growth.

Chemical: Toxic levels of boron and exchangeable sodium, high pH (restricting nutrient availability) and moderate salinity from 36 cm.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 50 mm
Readily available: 25 mm

Fertility — The inherent fertility of the soil is moderate; the clay subsoil has a high nutrient retention capacity, but the surface soil with lower clay content and very low organic matter has a poor retention capacity. Apart from phosphorus and nitrogen requirements, zinc is needed occasionally.

Erosion potential — Moderate, due to gentle slope, but the soil itself is highly erodible.

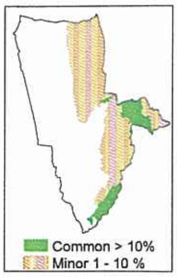
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	6.9	6.2	0	1.0	64	7.8	-	42	420	0.9	3.20	0.82	0.39	0.83
10-36	8.1	6.6	1.4	0.9	62	12	-	5	550	0.6	6.65	8.02	4.08	1.72
36-55	9.4	8.2	3.1	6.2	538	180	17.5	2	530	0.2	3.55	8.92	6.76	1.62
55-80	9.4	8.3	3.7	6.2	747	262	17.7	6	550	0.2	3.23	8.59	6.77	1.53
80-160	9.4	8.4	22.9	9.8	891	267	17.7	7	670	0.2	3.16	7.51	6.24	1.77
160-180	9.3	8.4	46.7	10.3	1268	268	20.9	10	530	0.2	3.00	6.74	5.83	1.82

Explanation of highlighted data

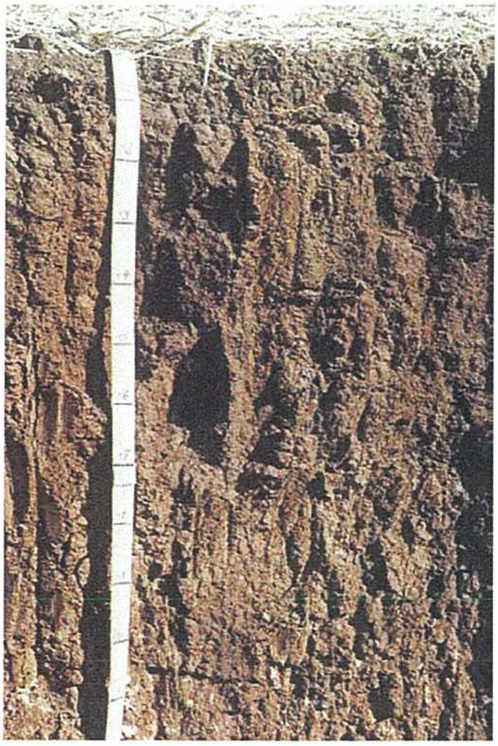
Many horticultural crops suffer yield loss when ECe exceeds 2 dS/m and chloride exceeds 350 mg/kg.
Exchangeable sodium (Na) values should be less than 6% of the sum [Ca+Mg+Na+K].
Boron concentrations exceeding 3 mg/kg may be a problem for horticultural crops (American literature). Concentrations more than 10 mg/kg almost certainly a problem.
Root growth generally poor where pH exceeds 9.2

Brown cracking clay



<u>Landscape</u> Plains formed on coarsely structured heavy clay. Surface soil is firm, seasonally cracking and stone free.

<u>Profile</u> Brown well structured clay, becoming more clayey and coarser structured with depth, calcareous with depth and sometimes throughout.



Depth (cm)	*Description*
0-15	Dark brown firm light clay with strong medium granular structure. Abrupt to:
15-40	Brown hard medium clay with strong coarse prismatic structure. Gradual to:
40-80	Brown hard heavy clay with coarse prismatic structure. Gradual to:
80-100	Brown hard very highly calcareous heavy clay with very coarse prismatic structure.

Management

- Deep subsoil has high clay content and coarse structure, indicating low permeability. This places a severe restriction on irrigation as an option, as salts will accumulate into the root zone.
- Clayey subsoil at shallow depth also has low permeability, which can be partly overcome by incorporation of gypsum.
- Broadcast gypsum will help alleviate surface stickiness.
- Mulching to conserve surface moisture will help reduce the effects of cracking and water stress caused by the high surface clay content.

Key properties

Drainage — Imperfectly drained. The soil may remain wet for up to two weeks at a time, due to high clay content. Deep drainage is also impeded by the heavy clay at depth. This has implications for temporary water table development and salt accumulation.

Potential root zone — 35 cm in sampling pit.

Barriers to root growth

Physical: High soil strength restricts root growth. Surface cracking affects root development. Mulching to maintain stable moisture levels near the surface is desirable.

Chemical: The highly calcareous clay from 80 cm prevents deeper root growth. However, the calcareous clay lies below the potential root zone at this site.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 60 mm
Readily available: 25 mm

Fertility — Inherent fertility is high, due to high surface clay content and organic carbon concentration. Nitrogen and phosphorus are routinely required. These soils are also prone to zinc depletion.

Erosion potential — Low potential for both water and wind erosion.

Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe* dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg Ca	Mg	Na	K
0-15	6.6	6.2	2	0.7	-	-	2.3	86	-	1.56	-	-	-	-
15-40	7.8	7.0	3	0.2	-	-	2.6	7	-	0.62	-	-	-	-
40-80	8.4	7.4	3	0.8	-	-	2.5	7	-	0.49	-	-	-	-
80-100	8.5	7.7	55	1.5	-	-	4.0	6	-	0.46	-	-	-	-

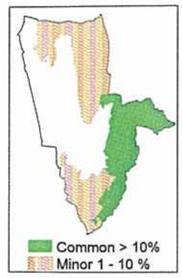
Incomplete data set at this site

* Estimated from EC1:5

Explanation of highlighted data

Root growth of most horticultural crops restricted in clays with more than 20% carbonate.
High sodicity at shallow depth is likely, indicating low permeability.

Red cracking clay of rises



Landscape: Rises on coarsely structured clay. Surface soil is usually well aggregated, and cracks in summer. Minor quartzite stones are common.

Profile: Red well structured seasonally cracking clay - more clayey, more coarsely structured and calcareous with depth.

Depth (cm)	*Description*
0-10	Dark reddish brown hard granular medium heavy clay. Clear to:
10-35	Dark reddish brown very hard heavy clay with strong coarse prismatic structure. Diffuse to:
35-60	Dark reddish brown very hard heavy clay with coarse lenticular structure. Diffuse to:
60-90	Red very hard calcareous heavy clay with coarse lenticular structure. Diffuse to:
90-125	Red and brown very hard calcareous heavy clay with coarse lenticular structure. Diffuse to:
125-	Red, yellow and brown hard massive sandy medium clay with minor fine carbonate.

Management

- Waterlogging unlikely to be controlled by ripping or gypsum applications, as seasonal shrinking and swelling will counteract ripping benefits, and upper layers of soil are not sodic. However gypsum will make sticky surfaces more tractable.
- Restricted deep drainage a permanent limitation on these soils, but low water applications will minimize salt accumulation.
- Mounding for row crops and use of tolerant varieties / rootstocks best options for managing wetness. Surface drains unlikely to last long in cracking soils.
- Mulching to conserve surface moisture will help reduce the effects of cracking and water stress caused by the high surface clay content.
- Boron tolerance in varieties and rootstocks may be worth investigation.

Key properties

<u>Drainage</u> Moderately well drained. The clayey texture causes saturation for a week or so after the cracks have closed. Restricted deep drainage is likely to cause salt accumulation in subsoil.

<u>Potential root zone</u> 30 cm in sampling pit.

<u>Barriers to root growth</u>

<u>Physical</u>: Surface cracking affects root development. Effective root growth is restricted to the upper 20 cm of the coarsely structured subsurface clay.

<u>Chemical</u>: High pH and boron concentrations in the deep subsoil will impact on sensitive crops, but at this site hostile conditions are below the main rootzone.

<u>Water holding capacity</u> (Estimates for potential root zone of grape vines)

Total available: 50 mm
Readily available: 20 mm

<u>Fertility</u> Cracking clays have a very high capacity to store and release nutrients. Regular nitrogen and phosphorus inputs with occasional zinc are required. Excessive vigour likely where nutrient levels are high.

<u>Erosion potential</u> Moderately low potential for sheet erosion, due to stability of clayey surface soil. However, gullies develop where water flow is channelled.

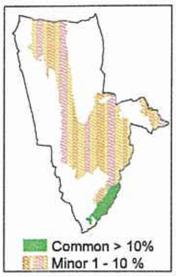
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	6.9	6.3	0	1.107	61	20	1.3	66	627	2.23	20.9	5.28	0.40	1.57
10-35	7.8	7.0	0	0.215	8	20	1.5	7	365	1.27	25.8	7.79	0.53	1.01
35-60	8.4	7.6	1.1	0.331	17	21	1.4	5	275	0.75	24.9	11.7	1.18	0.80
60-90	9.1	8.0	10.9	0.319	9	15	2.8	5	264	0.37	16.1	12.5	1.95	0.71
90-125	9.3	8.2	6.8	0.500	9	12	8.5	3	271	0.23	11.9	13.8	2.95	0.74
125-140	9.0	8.1	0.4	0.767	40	24	12	13	248	0.45	7.76	7.61	2.29	0.68

Explanation of highlighted data

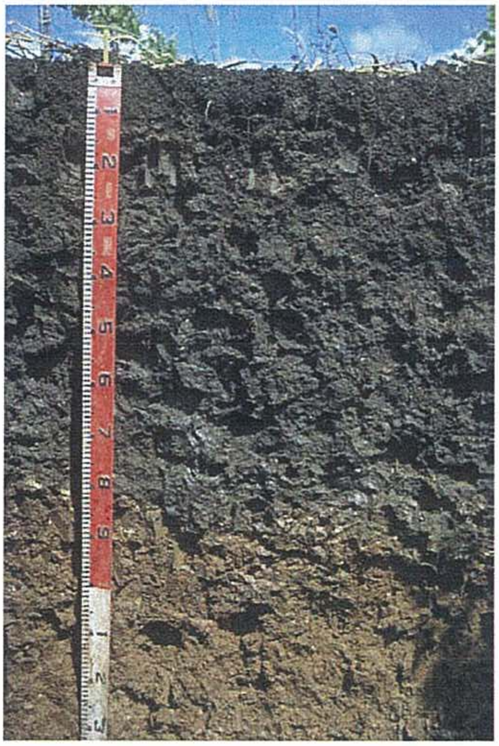
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for horticultural crops (American literature).

Black cracking clay



Landscape: Gently undulating slopes and flats. Seasonally cracking, friable surface soil with minor quartzite stones.

Profile: Well structured dark cracking, more clayey and more coarsely structured with depth, over a redder heavy clay within 100 cm.



Depth (cm)	*Description*
0-10	Very dark brown well structured medium clay. Clear to:
10-20	Very dark brown medium clay with strong blocky structure. Clear to:
20-40	Dark brown heavy clay with strong coarse blocky structure. Gradual to:
40-55	Very dark brown heavy clay with strong coarse blocky structure and slickensides. Gradual to:
55-85	Dark brown medium heavy clay with strong lenticular structure. Clear to:
85-140	Orange highly calcareous heavy clay with strong lenticular structure.

Management

- Waterlogging unlikely to be controlled by ripping or gypsum applications, as seasonal shrinking and swelling will counteract ripping benefits, and soil is not sodic. However gypsum will make sticky surfaces more tractable.
- Mounding for row crops and use of tolerant varieties / rootstocks best options for managing wetness. Surface drains unlikely to last long in cracking soils.
- Mulching to conserve surface moisture will help reduce the effects of cracking and water stress caused by the high surface clay content.
- Cover crops may help use up nutrients where excessive vigour is a problem.
- Boron tolerance in varieties and rootstocks may be worth investigation.

Key properties

Drainage — The soil is imperfectly drained due to its high clay content. Parts of the profile may remain wet for several weeks following heavy or prolonged rainfall. Mounding will help alleviate waterlogging problems.

Potential root zone — Approximately 85 cm.

Barriers to root growth

Physical: Surface cracking can affect root development. Mulching to maintain stable moisture levels near the surface is desirable. High strength of deeper subsoil clay also restricts root growth. Ripping unlikely to have any lasting impact because of the shrink-swell properties of the soil.

Chemical: High boron levels are associated with the orange clay, the depth to which can vary from less than 50 cm to over a metre in these soils. Toxic effects likely where this clay is shallower than 50 cm.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 130 mm
Readily available: 45 mm

Fertility — Exchangeable cation data indicate high inherent fertility. Apart from phosphorus and nitrogen, these soils are commonly zinc deficient. Excessive vegetative growth caused by high fertility soils can be a problem in vineyards.

Erosion potential — Low.

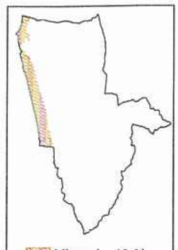
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	7.0	6.9	0	1.69	12	125	2.9	54	669	2.3	26.8	4.76	0.31	1.72
10-20	7.0	6.8	0	0.90	10	105	2.3	7	461	1.7	25.1	6.90	0.47	1.29
20-40	7.2	6.9	0	0.94	22	92	2.9	<4	309	1.2	28.0	10.9	1.11	0.98
40-55	8.0	7.6	0.3	0.84	19	81	3.5	<4	242	0.8	22.4	12.7	2.25	0.76
55-85	8.3	8.0	1.1	0.91	37	76	5.8	<4	232	0.7	21.9	16.2	3.86	0.72
85-140	8.7	8.1	9.7	0.93	63	66	13.6	<4	345	0.3	15. 6	18.3	6.72	0.80

Explanation of highlighted data

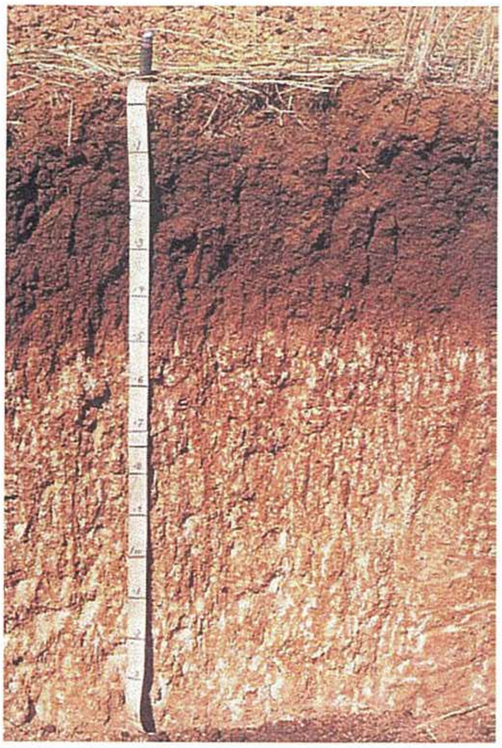
Exchangeable sodium less than 6% of total of all four cations is desirable.
Boron concentrations exceeding 3 mg/kg may be a problem for horticultural crops (American literature). Concentrations more than 10 mg/kg almost certainly a problem.

Red cracking clay of plains



Landscape — Gently sloping outwash fans of the Blyth plains formed on fine grained alluvium. Surface soil is self-mulching and cracking with no stones.

Profile — Deep red cracking clay, highly calcareous at depth.



Depth (cm)	*Description*
0-10	Dark reddish brown slightly calcareous light clay with strong granular structure. Clear to:
10-14	Dark reddish brown slightly calcareous light medium clay with strong coarse subangular blocky structure. Clear to:
14-45	Reddish brown moderately calcareous heavy clay with strong coarse subangular blocky structure. Clear to:
45-100	Red very highly calcareous, moderately structured medium clay with more than 20% soft carbonate. Gradual to:
100-	Yellowish red very highly calcareous moderately structured heavy clay with more than 20% soft carbonate.

Management

- Sustainable irrigation on this soil is highly dependent on the permeability of the deep subsoil, which can be low. Unless there is capacity for salts to be leached, prospects are poor. Clays with coarse (bigger than 20 mm) aggregates, and dense massive sandy clays have low permeabilities and should be avoided where present within the upper 150 cm.
- Broadcast gypsum will help alleviate surface stickiness.
- Mulching to conserve surface moisture will help reduce the effects of cracking and water stress caused by the high surface clay content.
- Cover crops may help use up nutrients where excessive vigour is a problem.

Key properties

Drainage — The soil is moderately well drained. The soil profile does not generally remain saturated for more than about a week. Deep drainage is variable depending on structure of deep subsoil.

Potential root zone — 65 cm in sampling pit.

Barriers to root growth

Physical: The clayey subsoil is coarsely structure and impedes root growth to some extent.

Chemical: Most irrigated horticultural crops will not penetrate more than 20 cm into highly calcareous layers.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 90 mm
Readily available: 40 mm

Fertility — Natural fertility is very high, as indicated by the exchangeable cation values and high calcium saturation. Apart from phosphorus and nitrogen, zinc depletion is common in these soils. Where residual levels of these elements are high, excessive vigour may be a problem in grape vines.

Erosion potential — Low potential for sheet erosion by water, but gullies rapidly form if flow is channelled. Low potential for wind erosion.

Laboratory data

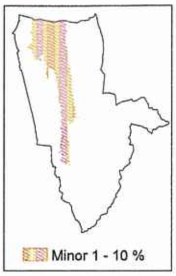
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	8.4	7.6	3.1	0.5	41	64	-	27	840	1.56	23.1	3.17	0.16	2.95
10-14	8.3	7.4	3.5	0.4	23	9.4	2.2	7	540	1.15	24.1	3.78	0.24	2.24
14-45	8.5	7.5	3.5	0.3	5	4.5	1.8	5	260	0.70	26.4	6.14	0.35	1.22
45-100	8.8	7.8	26.9	0.3	8	7.7	1.6	4	160	0.29	15.6	7.60	0.48	0.73
100-155	9.7	8.2	47.9	0.8	23	4.3	4.1	2	210	0.13	4.90	8.56	2.47	0.76

Explanation of highlighted data

Most root growth is restricted by pH more than 9.2, boron concentration more than 3 mg/kg, and exchangeable sodium more than 6% of sum of all four cations, but at this depth, they are below the potential root zone of most irrigated crops except lucerne. However, lucerne is more tolerant than horticultural crops.

Root growth of most horticultural crops restricted in clays with more than 20% carbonate.

Deep black gradational clay



Landscape: Valley flats formed on fine grained alluvial sediments.

Profile: Well structured dark grey or black clay loam to clay, becoming more clayey and mottled with depth, continuing below 100 cm.

Depth (cm)	*Description*
0-15	Very dark greyish brown finely structured light medium clay. Gradual to:
15-35	Very dark greyish brown finely structured medium clay. Clear to:
35-60	Dark grey finely structured calcareous medium heavy clay. Clear to:
60-80	Dark grey and brown mottled coarsely structured calcareous medium heavy clay. Gradual to:
80-110	Dark brown, grey and yellow mottled coarsely structured calcareous heavy clay, minor carbonate nodules. Gradual to:
110-	Brown, grey and yellow coarsely structured heavy clay.

Management

- High clay content and low lying position predispose soil to waterlogging. Ripping and subsoil gypsum application unlikely to have much effect. Mounding of row crops will help. Tolerant varieties / rootstocks desirable. Surface drainage (where feasible) may help in existing plantings.
- Maintaining adequate water at the surface is a periodic problem due to high clay content. Mulches will help to conserve moisture.
- Surface gypsum application will correct the low calcium:magnesium ratio, thereby improving nutritional status and reducing surface stickiness.

Key properties

Drainage: The soil is imperfectly drained due to its high clay content and low lying position in the landscape. Parts of the profile may remain wet for several weeks. Mounding will help alleviate the problem.

Potential root zone: 110 cm in sampling pit.

Barriers to root growth

Physical: The only possible barrier is high clay strength at moderately dry moisture status. Low available water in the surface soil due to its high wilting point is likely unless mulches are used to control evaporation.

Chemical: The only apparent chemical barrier is the high pH in the deep subsoil, reducing the availability of a range of nutrients, notably zinc.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 150 mm
Readily available: 60 mm

Fertility: High natural fertility as indicated by its high base status, although calcium saturation is less than in very fertile soils. There is ample phosphorus at the sampling site and organic carbon levels are adequate. The risk of acidification is low.

Erosion potential: Low.

Laboratory data

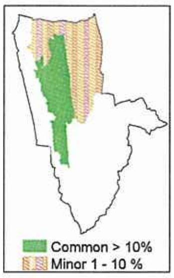
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-15	6.9	6.6	0	0.23	3	8.1	1.6	55	736	1.8	8.58	4.47	0.21	1.06
15-35	7.8	7.5	0.4	0.37	4	4.8	1.6	21	535	1.3	9.12	7.44	0.24	0.95
35-60	8.4	8.0	2.5	0.35	5	4.4	2.1	7	577	0.8	8.80	15.5	0.57	1.30
60-80	8.8	8.4	8.9	0.43	8	4.2	3.8	<4	509	0.5	3.23	15.7	1.33	1.05
80-110	9.2	8.5	4.7	0.56	14	6.0	4.1	<4	520	0.2	2.57	13.2	3.04	1.00

Explanation of highlighted data

Exchangeable sodium less than 6% of total of all four cations is desirable.

Calcium saturation (i.e. percentage of exchangeable calcium relative to total exchangeable cations) ideally 70% +. Here, it is 60%, and decreasing with depth.

Sandy loam over red clay on rock



Landscape	Hillslopes on sandstone or quartzite bedrock. Surface soil is hard setting with variable amounts of rock fragments.
Profile	Massive grey brown sandy loam, between 10 and 30 cm thick, over a coarse blocky brown and red mottled clay overlying rock within 100 cm.

Depth (cm)	*Description*
0-10	Very dark greyish brown massive coarse sandy loam with 2-10% quartzite gravel. Clear to:
10-20	Pale brown massive light sandy clay loam with 20-50% quartzite gravel. Abrupt to:
20-45	Red, brown and orange mottled medium heavy clay with strong coarse blocky structure. Gradual to:
45-65	Olive brown, red and grey brown mottled weakly structured sandy medium clay with 20% sandstone fragments. Clear to:
65-70	Sandstone.

Management

- Sodic clay subsoil perches water and restricts root growth. Causes temporary waterlogging at shallow depth (i.e. within 30 cm of surface), and reduces readily available water (RAW) capacity. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.
- Mulching, minimal till, and contour planting for erosion control.

Key properties

Drainage — The soil is moderately well to imperfectly drained. The clayey subsoil is dispersive and has low permeability, so perched water tables may form on it, saturating the soil for a week to several weeks.

Potential root zone — 65 cm in sampling pit.

Barriers to root growth

Physical: Basement rock limits root growth, depending on its depth and degree of weathering. The tight dispersive clay may also restrict root penetration.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 70 mm
Readily available: 40 mm

Fertility — Surface soil nutrient retention capacity is moderately low. Satisfactory organic matter levels needed to provide capacity. The subsoil clay has a high capacity, but exchangeable calcium percent is low. Phosphorus, nitrogen and possibly molybdenum required regularly. These soils are susceptible to acidification.

Erosion potential — Moderately high potential for water erosion on slopes due to the high erodibility of poorly structured texture contrast soils. Maintenance of protective vegetative cover essential, especially on steeper slopes.

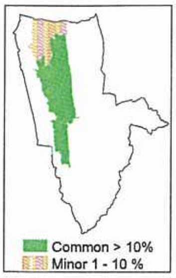
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	5.9	5.6	0	0.38	15	20	0.6	23	378	1.9	6.32	2.12	0.18	0.32
10-20	5.8	5.2	0	0.22	6	4.5	0.4	11	372	0.7	2.97	1.36	0.17	0.22
20-45	6.0	5.4	0	0.40	43	7.3	1.3	5	585	0.7	8.62	12.6	1.70	0.95
45-65	6.0	5.4	0	0.71	78	11	1.2	<4	515	0.5	7.78	12.8	2.23	0.89
65-70	6.1	5.6	0	1.20	79	21	0.8	4	302	0.2	2.97	4.69	0.99	0.34

Explanation of highlighted data

Exchangeable sodium (Na) values should be less than 6% of the sum [Ca+Mg+Na+K].
Calcium:magnesium ratio ideally more than 3.5

Sandy loam over brown clay on rock



Landscape: Hillslopes on quartzite or quartzitic shale bedrock. Surface soil is hard setting with variable amounts of quartzite fragments.

Profile: Up to 60 cm grey brown gravelly sandy loam over a coarse blocky brown, red and grey mottled clay grading to rock within 150 cm.

Depth (cm)	*Description*
0-15	Dark greyish brown massive sandy loam. Clear to:
15-30	Greyish brown massive light sandy clay loam with 2-10% quartzite stones. Clear to:
30-45	Pale massive light sandy clay loam with 10-20% quartzite stones. Clear to:
45-65	As above, with 20-50% quartzite stones. Clear to:
65-90	Brown, red and grey mottled heavy clay with strong angular blocky structure. Gradual to:
90-120	Olive, brown and red mottled heavy clay with strong angular blocky structure. Gradual to:
120-	Weathering quartzitic siltstone.

Management

- Tight clay subsoil perches water and may restrict root growth. Causes temporary waterlogging at moderate depth and reduces readily available water (RAW) capacity. Where shallower than 30 cm, rootzone is significantly reduced, and low water applications are essential to avoid drainage. Pre-plant ripping will help, but gypsum unlikely to have much effect. Note that this example has adequate depth of topsoil over clay.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.
- Mulching, minimal till, and contour planting for erosion control.

Key properties

Drainage: The soil is moderately well to imperfectly drained. The heavy clay subsoil restricts vertical movement of water, causing a perched water table to form. The upper profile may remain saturated for a week to several weeks.

Potential root zone: There are roots to 120 cm (weathering rock).

Barriers to root growth

Physical: The tight clay subsoil restricts root growth to some extent, as will bedrock when it occurs within a metre of the surface.

Chemical: There are no apparent chemical barriers apart from low nutrient status.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 120 mm
Readily available: 65 mm

Fertility: The upper soil layers have a low capacity to store nutrients; nutrient status relies on high organic matter levels. The clay subsoil has a high storage capacity. Phosphorus, nitrogen and possibly molybdenum required regularly. These soils are susceptible to acidification.

Erosion potential: Moderately high due to the slope and the high erodibility of poorly structured sandy loam texture contrast soils. Maintenance of protective vegetative cover essential, especially on steeper slopes.

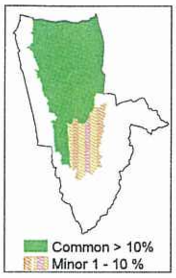
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-15	7.0	6.7	0	0.31	4	7.3	0.6	49	243	1.1	11.4	2.37	0.19	0.55
15-30	7.1	6.7	0	0.26	4	2.8	0.5	24	151	0.5	3.92	0.48	0.12	0.17
30-45	6.9	6.5	0	0.16	4	2.2	0.3	13	231	0.2	3.85	0.48	0.12	0.17
45-65	7.0	6.7	0	0.17	4	1.6	0.3	8	274	0.1	3.24	0.55	0.12	0.22
65-90	7.0	6.5	0	0.23	12	10	1.3	<4	413	0.2	16.9	10.9	0.53	1.07
90-120	7.2	6.8	0	0.32	11	14	1.5	<4	475	0.2	17.8	12.4	0.73	0.98

Explanation of data

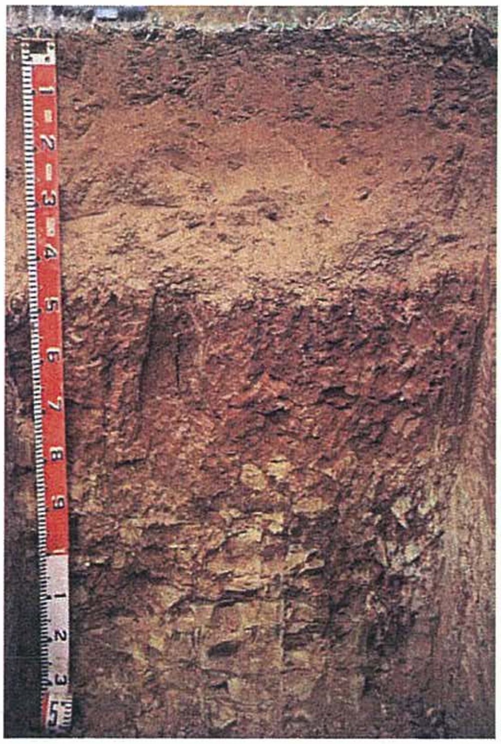
No problems, other than low nutrient retention capacity, are indicated by the chemical data. The tightness of the clay subsoil is not due to excessive exchangeable sodium.

Loam over red clay on rock



Landscape — Hillslopes on siltstone or slate bedrock. Surface soil is hard setting with variable amounts of rock fragments.

Profile — 20-50 cm hard loam over red clay grading to rock within 150 cm. Subsoil structure is variable.



Depth (cm)	*Description*
0-10	Dark reddish brown massive friable silty loam with 2-10% siltstone gravel. Gradual to:
10-25	Reddish brown firm massive silty loam with 2-10% siltstone gravel. Clear to:
25-45	Pink hard massive silty loam with 10-20% siltstone and quartz gravel. Abrupt to:
45-80	Dark reddish brown, grey and yellow mottled hard medium heavy clay with coarse prismatic structure. Diffuse to:
80-110	Reddish yellow, brown and red hard medium clay with strong blocky structure and 20-50% siltstone fragments. Diffuse to:
110-	Weathering siltstone.

Management

- Subsoil clay is variable. Where sodic (as at this site), subsoil perches water. This causes temporary waterlogging and restricts root growth to some extent, hence reducing RAW. Where subsoil is shallower than 30 cm, problem is more severe. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage. Where subsoil is non dispersive and friable, or deeper than 50 cm, the soil has no significant constraints.

- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.

- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.

- Mulching, minimal till, and contour planting for erosion control.

Key properties

Drainage — Moderately well drained. The subsoil clay restricts water movement to the extent that saturation of part of the profile is likely for periods of up to a week.

Potential root zone — 80 cm in sampling pit.

Barriers to root growth

Physical: The tight clayey subsoil restricts root growth to some extent. Pre-plant ripping with gypsum application will help. Where subsoil clay is more friable and non dispersive, as is common for this soil, there is no restriction on root growth.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 110 mm
Readily available: 55 mm

Fertility — Surface soil nutrient retention capacity is satisfactory due to high organic carbon levels, but subsurface layers (10-45 cm) have relatively poor capacity. This soil is not prone to any specific nutrient deficiencies, apart from nitrogen and phosphorus, but is susceptible to acidification.

Erosion potential — Moderate potential for water erosion due to ground slope and erodible nature of surface soil.

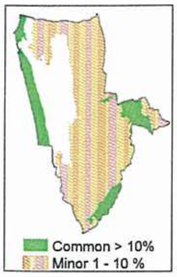
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	7.3	6.6	0	0.333	5	9.1	0.9	37	427	2.24	8.69	1.49	0.35	0.99
10-25	6.6	6.0	0	0.663	30	5.7	0.4	6	231	0.89	4.74	0.87	0.28	0.35
25-45	6.7	5.3	0	0.212	7	8.6	0.4	13	146	0.74	4.04	1.69	0.41	0.25
45-80	6.9	5.5	0	0.465	2	17	1.0	4	184	0.69	7.74	11.3	2.47	0.51
80-110	7.2	6.1	0	0.396	25	21	0.9	9	220	0.52	7.70	9.69	2.46	0.56
110-140	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Explanation of highlighted data

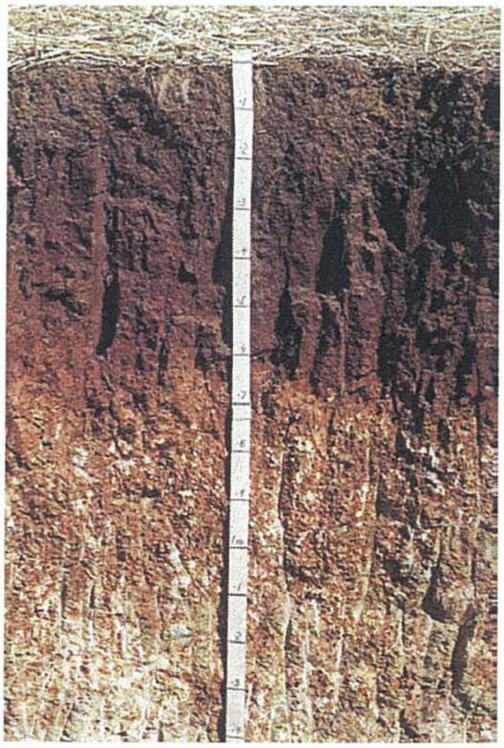
Exchangeable sodium (Na) values should be less than 6% of the sum [Ca+Mg+Na+K].

Gradational clay loam



Landscape — Undulating rises and gently sloping plains on deeply weathered rock or fine grained alluvium. Surface soil is firm with no stones.

Profile — Red brown loam to clay loam grading to a well structured red clay, highly calcareous with depth.



Depth (cm)	*Description*
0-18	Brown firm massive fine sandy clay loam. Clear to:
18-40	Dark reddish brown firm light clay with strong medium prismatic structure. Gradual to:
40-60	Dark reddish brown firm slightly calcareous light clay with strong medium prismatic structure. Gradual to:
60-80	Reddish brown firm highly calcareous medium clay with moderate medium prismatic structure. Gradual to:
80-	Red firm very highly calcareous weakly structured light clay with more than 50% fine carbonate segregations.

Management

- Sustainable irrigation on this soil is highly dependent on the permeability of the deep subsoil, which can be low. Unless there is capacity for salts to be leached, prospects are poor. Clays with coarse (bigger than 20 mm) aggregates, and dense massive sandy clays have low permeabilities and should be avoided where present within the upper 150 cm.
- Rip in gypsum pre-plant, or broadcast in established plantings to improve structure and permeability of subsoil clay. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Soil prone to acidification. Apply lime or dolomite, but where calcium:magnesium ratio is less than 3.5, avoid dolomite.

Key properties

Drainage — Moderately well drained. The soil may remain wet for up to a week following heavy or prolonged rainfall. These soils may be underlain (at depths of about 100 cm) by slowly permeable heavy clay. In these situations, deep drainage is impeded, waterlogging develops and salts accumulate into the root zone.

Potential root zone — 80 cm in sampling pit.

Barriers to root growth

Physical: There are no significant physical barriers.

Chemical: The highly calcareous clay from 80 cm prevents deeper root growth. Growth is sub-optimal in the 60-80 cm layer.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 100 mm
Readily available: 45 mm

Fertility — Inherent fertility is high, due to high surface clay content and organic carbon concentration. However, increasing acidity will reduce nutrient retention capacity.

Erosion potential — Moderately low potential for water erosion on slopes due to stability of the clay loamy surface. Potential for wind erosion is low.

Laboratory data

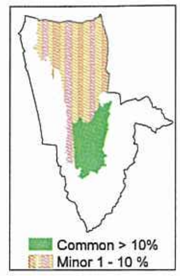
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe* dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-18	5.2	4.8	0	0.6	-	-	1.5	28	-	2.27	-	-	-	-
18-40	5.7	5.1	0	0.2	-	-	1.4	7	-	0.95	-	-	-	-
40-60	6.5	5.8	3	0.2	-	-	2.1	2	-	0.57	-	-	-	-
60-80	7.5	7.1	6	0.7	-	-	1.5	3	-	0.61	-	-	-	-
80-100	8.3	7.7	42	0.5	-	-	1.5	2	-	0.42	-	-	-	-

Incomplete data set at this site — * Estimated from EC1:5

Explanation of highlighted data

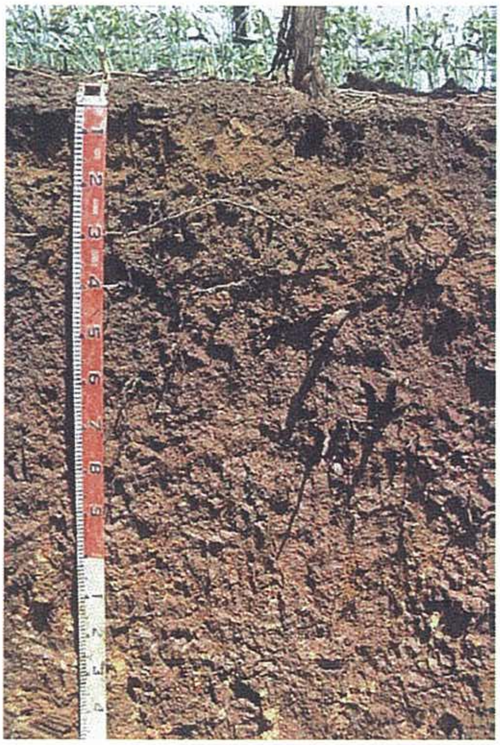
Root growth of most horticultural crops restricted in clays with more than 20% carbonate.
Exchangeable sodium probably high in 80-100 cm layer (estimated from data describing similar soils elsewhere in the northern districts.

Deep gradational red clay loam



<u>Landscape</u> Lower slopes of undulating to rolling low hills. Surface soil is firm and usually free of stones.

<u>Profile</u> Well structured red brown loam to clay loam overlying a thick well structured red brown clay, weakly calcareous with depth.



Depth (cm)	*Description*
0-11	Dark reddish brown granular clay loam. Abrupt to:
11-25	Dark reddish brown well structured light clay. Clear to:
25-40	Dark reddish brown well structured medium clay. Gradual to:
40-65	Dark reddish brown well structured heavy clay. Gradual to:
65-95	Dark reddish brown coarsely structured heavy clay. Clear to:
95-150	Dark red coarsely structured and moderately calcareous heavy clay with 10-20% soft carbonate segregations.

Management

- There are no significant management issues with this soil, other than possibly excessive vegetative vigour caused by high available water capacity of rootzone.

Key properties

Drainage: The soil is moderately well drained and is unlikely to remain wet for more than a week.

Potential root zone: 100 cm in sampling pit.

Barriers to root growth

Physical: There are no physical barriers to root growth above 65 cm. From this depth, the coarsely structured clay impedes root growth to some extent, but at the sampling site, there is strong root growth to 100 cm.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 180 mm
Readily available: 70 mm

Fertility: The surface soil has a high capacity to store and supply nutrients, despite a relatively low organic matter content. Similarly, the subsoil holds ample reserves of major cation elements. Apart from nitrogen and phosphorus, this soil is not prone to specific nutrient deficiencies. The soil is well buffered against acidification.

Erosion potential: Moderate potential for water erosion, due to the 5% slope. However, this soil has a relatively high resistance to erosion, due to its high clay content and strong structure.

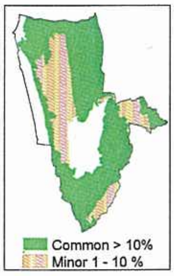
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-11	8.0	7.7	0.7	0.33	3	5.4	1.8	26	752	1.3	13.2	2.23	0.08	1.30
11-25	7.6	7.3	0	0.22	3	5.5	1.3	6	664	0.8	10.5	1.53	0.07	1.04
25-40	7.1	6.7	0	0.25	7	13	2.0	<4	545	0.8	18.2	9.01	0.29	1.50
40-65	6.6	6.2	0	0.27	8	22	2.8	<4	614	0.7	16.3	12.6	0.35	1.56
65-95	6.7	6.4	0	0.39	11	36	3.9	<4	499	0.6	16.8	13.1	0.42	1.48
95-150	8.1	7.8	11.8	0.44	8	33	3.3	<4	409	0.1	13.8	9.83	0.42	1.04

Explanation of data

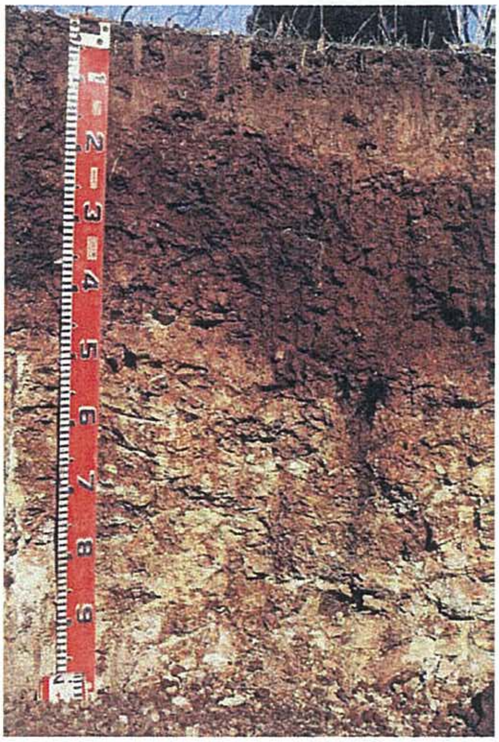
The chemical data above do not indicate any problems, apart from marginally elevated boron concentrations below 65 cm. American literature suggests more than 3 mg/kg is toxic to some horticultural crops, including grape vines.

Loam over hard red clay on limy rock



Landscape — Hillslopes on quartzitic siltstone or sandstone. Surface soil is hard setting with up to 10% quartzite fragments.

Profile — Sandy loam to loam over coarsely structured red clay, calcareous with depth, on basement rock.



Depth (cm)	*Description*
0-8	Dark reddish brown firm massive loam. Clear to:
8-14	Pink (bleached) firm massive loam with 2-10% sandstone fragments. Abrupt to:
14-35	Dark reddish brown very hard medium clay with strong medium prismatic structure. Clear to:
35-75	Red very hard very highly calcareous medium clay with strong subangular blocky structure and 10-20% siltstone fragments. Gradual to:
75-100	Weathering siltstone with 10-20% fine carbonate segregations and minor clay pockets in fissures.

Management

- Sodic clay subsoil perches water and restricts root growth. Causes temporary waterlogging at shallow depth (i.e. within 20 cm of surface), and reduces readily available water (RAW) capacity. Rip in gypsum pre-plant, or broadcast in established plantings. If untreated, water applications per irrigation must be kept low to avoid drainage.
- Hard surface will benefit from mulching to help stabilize soil aggregates and conserve moisture.
- Subsoil salt should be leachable, but where low volumes of irrigation water are available, this could be a problem.

Key properties

Drainage: The soil is moderately well to imperfectly drained. The clayey subsoil is dispersive and has low permeability, so perched water tables may form on it, saturating the soil for a week to several weeks.

Potential root zone: 55 cm in sampling pit.

Barriers to root growth

Physical: Basement rock limits root growth, depending on its depth and degree of weathering. The tight dispersive clay may also restrict root penetration.

Chemical: There are no apparent chemical barriers to root growth (refer note on salinity at Table below).

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 70 mm
Readily available: 35 mm

Fertility: Surface soil nutrient retention capacity is moderately low. Satisfactory organic matter levels needed to provide capacity. The subsoil clay has a high capacity, but exchangeable calcium percent is low. Phosphorus, nitrogen and possibly molybdenum required regularly. These soils are susceptible to acidification.

Erosion potential: Moderately high potential for water erosion on slopes due to the high erodibility of poorly structured texture contrast soils. Maintenance of protective vegetative cover essential, especially on steeper slopes.

Laboratory data

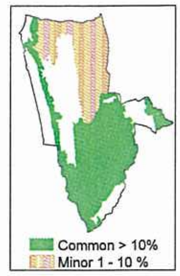
Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-8	7.8	7.0	0	0.994	56	24	0.9	14	471	3.03	14.8	3.62	0.36	0.94
8-14	8.2	7.3	0	0.749	66	24	0.9	4	290	1.11	11.3	3.95	0.66	0.60
14-35	8.6	7.6	1.4	2.03	371	46	2.2	3	641	0.73	17.6	11.0	3.33	1.62
35-75	8.8	7.9	11.7	6.96	1332	119	3.0	6	813	0.56	15.4	10.9	6.46	1.56
75-100	9.2	8.1	11.2	6.22	1027	101	2.2	5	909	0.76	10.7	7.76	6.74	1.10

Explanation of highlighted data

ECe exceeding 2dS/m and chloride exceeding 350 mg/kg can reduce yields of many horticultural crops. These ECe and Cl values are unusually high for this soil, but highlight need to check salinity levels down the profile, even where high values are not expected.

Exchangeable sodium (Na) values should be less than 6% of the sum [Ca+Mg+Na+K].

Loam over red clay on calcareous rock



Landscape: Hillslopes on fine grained bedrock mantled by fine carbonate. Surface soil is firm to hard with variable amounts of stone.

Profile: Medium thickness loamy surface soil over a well structured red clay, calcareous at moderately shallow depth over basement rock within 100 cm.

Depth (cm)	*Description*
0-12	Dark reddish brown firm loam with moderate granular structure. Clear to:
12-30	Dark reddish brown firm medium clay with strong fine polyhedral structure. Gradual to:
30-45	Dark reddish brown firm medium clay with strong fine polyhedral structure. Gradual to:
45-75	Weathering siltstone with 20-50% fine calcareous segregations in cleavage planes.

Management

- Except for shallow variations of this soil, it has no significant problems. Depth to underlying rock is variable and often shallow. It may be capped by a thin calcrete (limestone) pan. Generally ripping will be required to increase and "even out" effective soil depth.

Key properties

Drainage — Well drained. The soil is unlikely to remain saturated form more than a day or so following heavy or prolonged rainfall.

Potential root zone — 45 cm plus a variable depth of weathering rock, depending on its fracturing and bedding plane orientation.

Barriers to root growth

Physical: Underlying basement rock is the only physical barrier.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 80 mm
Readily available: 40 mm

Fertility — Inherent fertility is moderately high, as indicated by the exchangeable cation data. Note that the high exchangeable cation value for the surface layer is largely attributable to its very high organic carbon level, rather than clay content. Apart from nitrogen and phosphorus, these soils are not prone to specific nutrient deficiencies.

Erosion potential — Moderate water erosion potential due to ground slope. Wind erosion potential is low.

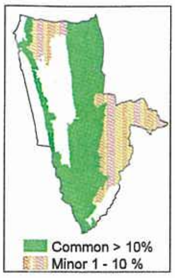
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-12	7.7	7.1	0	0.621	19	24	0.9	8	689	2.78	19.5	4.59	0.15	1.18
12-30	7.9	7.1	0.7	0.304	13	27	0.7	5	451	1.22	20.8	4.01	0.17	0.76
30-45	8.2	7.4	2.7	0.251	13	18	0.7	5	437	1.19	21.8	4.07	0.20	0.72
45-75	8.8	7.7	53.3	0.303	15	20	0.5	7	300	0.60	12.9	4.39	0.24	0.33

Explanation of data

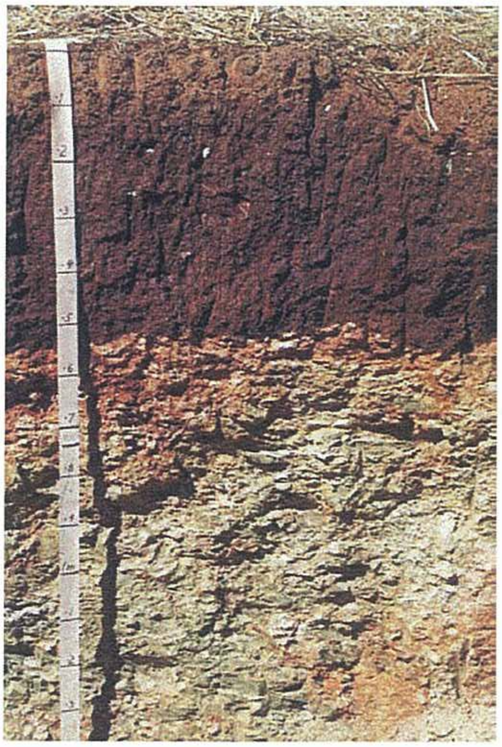
No problems are indicated by the chemical data. The surface phosphorus level is low because the sampling site was in an un-used part of the paddock.

Gradational clay loam over limy rock



Landscape: Slopes of rises and low hills formed on fine grained basement rocks mantled by fine carbonates. Surface soil is firm with minor stone.

Profile: Friable clay loam overlying a reddish brown well structured clay formed on calcified fine grained rock.



Depth (cm)	Description
0-10	Dark reddish brown clay loam with strong granular structure. Abrupt to:
10-20	Dark reddish brown light medium clay with strong polyhedral structure. Clear to:
20-40	Dark reddish brown light medium clay with strong angular blocky structure. Gradual to:
40-55	Dark reddish brown medium clay with strong prismatic structure. Abrupt to:
55-90	Soft carbonate with more than 50% weathered slate fragments. Gradual to:
90-150	Weathering slate with up to 10% soft carbonate in pockets and rock cleavages.

Management

- Except for shallow variations of this soil, it has no significant problems. Depth to underlying rock is variable and often shallow. It may be capped by a thin calcrete (limestone) pan. Generally ripping will be required to increase and "even out" effective soil depth.

Key properties

Drainage — The soil is well drained due to its fine open structure, and is unlikely to remain wet for more than a few days at a time.

Potential root zone — 55 cm in sampling pit.

Barriers to root growth

Physical: There are no barriers above the weathering rock and carbonate layer. Root growth in these materials depends on the hardness of the carbonate and the inclination of the layers in the rock (i.e. deeper root growth in vertical fissures compared with horizontal ones).

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 100 mm
Readily available: 40 mm

Fertility — The soil has a high inherent level of fertility as indicated by the moderately high exchangeable cation values and high proportions of exchangeable calcium. Apart from nitrogen and phosphorus, this soil has no susceptibility to specific nutrient deficiencies.

Erosion potential — Moderately low to moderate water erosion potential, due to the slope. The well structured clay loam surface has a high natural resistance to erosion.

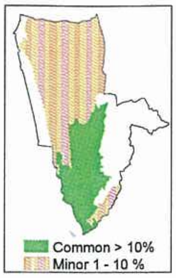
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-10	7.8	7.6	3.4	0.4	8	10	1.4	21	364	1.70	15.5	2.3	0.19	0.71
10-20	6.6	6.1	0	0.2	5	6.0	1.5	15	353	1.18	12.3	3.4	0.15	0.83
20-40	6.6	6.0	0	0.1	3	3.1	1.9	4	237	0.92	14.7	4.0	0.57	0.62
40-55	7.2	6.6	0	0.1	3	3.3	2.3	<4	162	0.73	15.5	4.9	0.43	0.50
55-90	8.9	8.2	39.1	0.3	5	3.3	0.4	<4	60	0.13	13.1	2.3	0.28	0.07

Explanation of highlighted data

Elevated surface pH and carbonate due to road dust.

Clay loam over limy rock (terra rossa)



Landscape: Hillslopes over highly calcareous (limy) rock. Surface soil is firm, with variable amounts of siltstone and calcrete fragments.

Profile: Red friable loam to clay loam, between 10 and 50 cm deep, over calcareous rock, usually with a hard calcrete capping.

Depth (cm)	*Description*
0-9	Dark reddish brown clay loam with strong granular structure. Abrupt to:
9-34	Dark reddish brown light clay with strong polyhedral structure and up to 10% calcrete fragments. Sharp to:
34-36	Moderately strong calcrete pan. Sharp to:
36-120	Soft weathering siltstone with 75% soft fine carbonate distributed throughout.

Management

- Depth to hard calcrete pan (cap) is variable, and can be very shallow. Ripping the cap to allow roots to penetrate the softer calcareous weathering rock below will usually be necessary, especially where water is limiting.

Key properties

<u>Drainage</u> The soil is well drained and no part of the profile is likely to remain wet for more than a day or so.

<u>Potential root zone</u> 36 cm in sampling pit. Some root growth to 120 cm after ripping.

<u>Barriers to root growth</u>

<u>Physical</u>: The thin calcrete pan restricts root growth into the underlying softer rock – ripping required.

<u>Chemical</u>: There are no apparent chemical barriers to root growth.

<u>Water holding capacity</u> (Estimates for potential root zone of grape vines)

Total available: 50 mm
Readily available: 25 mm

<u>Fertility</u> Inherent fertility is moderate. High calcium saturation. Provided ripping does not bring calcareous material to the surface, the soil is not predisposed to any nutrient deficiencies other than nitrogen and phosphorus.

<u>Erosion potential</u> Moderate potential for water erosion on slopes. Maintenance of protective vegetative cover essential, especially on steeper slopes.

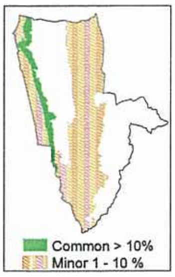
Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg			
											Ca	Mg	Na	K
0-9	7.6	7.4	0.7	0.44	8	9.6	2.1	100	769	1.7	11.7	2.69	0.09	1.22
9-34	7.7	7.5	0.9	0.31	8	5.2	1.3	18	437	0.8	11.2	2.24	0.09	0.55
34-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36-120	8.7	7.8	74.9	0.29	12	7.1	0.4	4	354	0.7	3.33	0.54	0.19	0.08

Explanation of data

No problems are indicated by the chemical data.

Shallow calcareous loam on rock



Landscape: Upper slopes of rises on fine grained limy rocks. Surface soil is firm, characteristically greyish in colour, and with up to 20% cover of calcrete and siltstone fragments.

Profile: Stony calcareous loam overlying fine grained calcareous basement rock at shallow depth.

Depth (cm)	*Description*
0-12	Dark brown friable highly calcareous loam with strong fine granular structure and minor siltstone gravel. Clear to:
12-30	Dark brown friable very highly calcareous loam with strong fine polyhedral structure, and 20-50% calcrete and siltstone fragments. Sharp to:
30-32	Strongly cemented but discontinuous laminar calcareous pan. Sharp to:
32-70	Weathering highly calcareous siltstone with 20-50% fine carbonate segregations.

Management

- Pre-plant ripping is essential to disrupt the calcrete cap and the underlying rock. Variable soil depth will make optimum water applications difficult.
- Specialized nutrition management is needed on calcareous soils.

Key properties

Drainage — The soil is rapidly drained and rarely likely to remain saturated for more than a few hours at a time.

Potential root zone — 30 cm in sampling pit.

Barriers to root growth

Physical: Basement rock at shallow depth is the over-riding restriction to root growth. Where the rock bedding planes are more or less vertically dipping, some root growth occurs into the rock layer. Thin calcrete pans which intermittently cap the rock are disrupted by normal pre-plant ripping.

Chemical: There are no apparent chemical barriers to root growth.

Water holding capacity (Estimates for potential root zone of grape vines)

Total available: 40 mm
Readily available: 20 mm

Fertility — Inherent fertility is moderate. Highly calcareous surface soils ('grey ground') tend to tie up phosphorus, manganese and zinc. Fertilizer programs need to be adjusted accordingly. Foliar applications of trace elements are needed in some situations Note that very high exchangeable calcium values reflect high organic matter concentrations.

Erosion potential — Moderately low. Surface soil is well aggregated and resistant to erosion.

Laboratory data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	ECe dS/m	Cl mg/kg	SO_4 mg/kg	B mg/kg	Ext P mg/kg	Ext K mg/kg	Org C %	Exch cations cmol(+)/kg Ca	Mg	Na	K
0-12	8.4	7.7	11.3	1.070	17	75	1.1	22	1202	3.94	27.6	3.40	0.27	1.72
12-30	8.4	7.7	15.4	0.652	36	119	1.0	9	291	3.18	30.8	3.82	0.33	0.71
30-32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32-70	9.1	8.0	29.8	0.481	41	72	0.4	4	166	0.63	12.3	6.10	0.77	0.24

Explanation of highlighted data

Carbonate concentrations exceeding 8% (i.e. very highly calcareous soil), indicate potential for tie-up of phosphorus, manganese, zinc and iron.

Management indicators from soil data

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Clear indicators for vineyard management are provided by David Maschmedt in the preceding chapter. However, as consultants with extensive experience in the Clare Valley we were asked to look at the data and comment under the headings of general vine management, irrigation practices, nutrition and vineyard floor management.

Our comments are not detailed as the interactions at each site will vary. Vineyard background (including whether dry grown or irrigated) as well as target markets for the crop will also be influences. The following notes are consequently not rigid pieces of advice but general management considerations.

Soil 1 Deep sandy loam over red and brown clay

Vine development

This soil type is likely to limit the available rooting zone to about 60 cm for vines, leading to low to moderate vigour.
This is due to the shallow topsoil which overlies dense clay subsoil and the limited rooting zone. The clay may cause waterlogging and has a relatively low level of fertility. Canopy growth could be affected by potential waterlogging and a sodic subsoil. This may be expressed in poor growth in spring and generally lower vigour.
A simple trellis system like sprawl or vertical shoot positioning (VSP) using a single cordon and spur pruning should be suitable.

Irrigation practices

The readily available water (RAW) is low to moderate.
Judicious irrigation is necessary, particularly if the watertable is shallower than 2 m. Where irrigation is applied, periods should be relatively short and frequent to ensure drainage does not exacerbate effects of a high water table.
Leaching of salts from the root zone is important but care must be taken to avoid a rising water table. Soil moisture monitoring devices are important management aids.

Nutrition and soil amendments

Nutrient status in the topsoil is poor. It may be advisable to deep rip gypsum, lime and organic matter before planting to combat limitations. Regular monitoring of mature vineyard soils is recommended and if required alternate rows could be ripped and ameliorated with gypsum when needed. This will assist in reducing sodicity in the subsoil and may extend the potential root zone while preventing soil acidification. As this soil type is prone to acidification nitrate-based fertilisers should be used rather than ammonium-based fertilisers that can contribute to acidification.

Vineyard floor management

Deep-rooted cover crops are usually considered for this soil type. Oats and other cereals as well as ryegrass have been found to provide high levels of biomass when slashed while annual ryegrass has the added benefit, according to some growers, of improving soil structure. Cover crops that compete too strongly with the vines for limited water should be slashed or sprayed out when necessary.
Undervine mulching can be useful for reducing soil moisture loss and to prevent hard-setting of the topsoil. The biomass produced by an oat or ryegrass cover crop at sowing rates of 100 kg/ha and 25 kg/ha respectively may provide sufficient mulch.
If the soil is prone to hard-setting then cultivation should be limited, especially when soils are wet. If wet weather vineyard access is a problem, consider using a perennial sward like ryegrass, tall fescue or chicory to improve traction. Once established these cover crops may compete strongly with vines for moisture, which means soil moisture monitoring will be an important management tool.

Soil 2 Hard loam over dispersive clay

Vine development

Vine vigour on this soil type is likely to be low to moderate. The sub surface soil layers are generally hard and tight clays which are prone to acidification and easily become sodic. Some limitations occur with these subsoil clays, including a perched water table and restricted root growth. Poorly drained and sodic subsoils can be indicated by restricted or poor shoot growth in spring and generally lower vigour.
A simple trellis system such as sprawl or VSP with a single cordon that is spur-pruned will provide suitable training.

Irrigation practices

The RAW of this soil is low so if irrigation is used then periods of watering should be short and frequent to ensure drainage from irrigation events does not add to the relatively high water table. Leaching of salts from the root zone is important but care must be taken to avoid creating problems with a rising water table. Soil moisture monitoring devices are essential to manage irrigation effectively in this soil.

Nutrition and soil amendments

Nutrient status in the topsoil is moderate to low. Deep-ripping with gypsum is needed before planting, at which stage it may be beneficial to also apply lime and organic matter.
Regular soil monitoring in the mature vineyard is recommended and this may lead to such practices as ameliorating alternate rows with further gypsum, lime and organic matter. This will assist in building structure, possibly extending potential root zone depth. Reduction in sodicity and prevention of soil acidification are other possible benefits.
As this soil type is prone to acidification, particularly where ammonium based fertilisers are applied, nitrate based fertilisers should be used.
Boron toxicity may be a problem in some subsurface soils, which means regular soil tests down to at least 1 m are important.

Vineyard floor management

Deep-rooted cover crops are usually considered for this soil type. Oats and other cereals as well as ryegrass have been found to provide high levels of lasting biomass when slashed while annual ryegrass has the added benefit, some growers say, of improving soil structure. Cover crops that compete too strongly with vines for limited water should be slashed or sprayed out when necessary. It is necessary to keep subsurface cover to minimise erosion. Undervine mulching may be advisable to reduce soil moisture loss and to prevent hard-setting of the topsoil. The biomass produced by the oats or ryegrass cover crops at sowing rates of 100 kg/ha and 25 kg/ha respectively may provide sufficient mulch.

If the soil is prone to hard-setting then cultivation should be limited, especially when the soil is wet. If wet weather vineyard access is a problem, consider using a perennial sward like ryegrass, tall fescue or chicory which will take up winter rainfall and improve traction. Once established these cover crops may compete with vines for moisture so soil moisture should be monitored.

Vine development

Vine vigour on this soil type is likely to be moderate to high due to potentially deep rooting zones. Sub surface layers, however, are generally hard, tight, clays with poor structure occurring throughout the profile. Soils require appropriate amendment prior to planting tom maximise the potential root zone and to reduce the likelihood of a perched water table. The effect of the poorly structured clays may be expressed later in the season with poor response to moisture stress.

A simple trellis system like sprawl or VSP with a single cordon and spur pruning is probably the most suitable form of vine training although with proper amelioration of the soils higher capacity vines with more highly developed training may be considered.

Irrigation practices

The RAW of this soil is moderate to high. Where shallow water tables exist (such as river flats) it is important that irrigation is limited. If irrigation is used, shifts should be short and frequent to ensure drainage from irrigation does not add to the relatively high water table.

Leaching of salts from the root zone is important but care must be taken to avoid increasing the problems at depths greater than 80 cm. Soil moisture monitoring devices are essential.

Nutrition and soil amendments

Nutrient status in the topsoil is moderate to high. It may be beneficial to deep rip gypsum and organic matter before planting to combat poorly structured soil. Regular monitoring of mature vineyards is recommended and if required the occasional ripping of alternate rows may be advisable (some growers have done this every five years). Regular amelioration with gypsum will assist in maintaining friable subsoils and increasing the potential root zone.

Vineyard floor management

Deep-rooted cover crops are usually considered for this soil type. Oats and other cereals as well as ryegrass are capable of providing high levels of biomass when slashed while annual ryegrass has the added possible benefit of improving soil structure. Cover crops that compete too strongly with the vines for limited water should be slashed or sprayed out when necessary.

Undervine mulching can be useful for reducing soil moisture loss and for preventing hard-setting of the topsoil. The biomass produced by an oat or ryegrass cover crop at sowing rates of 100 kg/ha and 25 kg/ha respectively may provide sufficient mulch.

If the soil is prone to hard-setting then cultivation should be limited, especially when soils are wet. If wet weather vineyard access is a problem consider using a perennial sward like ryegrass, tall fescue o chicory to improve traction.

Once established these cover crops may compete strongly with vines for moisture, which means soil moisture monitoring is important.

Soil 4 Sandy loam over poorly structured clay

Vine development
Vine vigour on this soil type is likely to be moderate to high due to potentially deep rooting zones. Subsurface layers, however, are generally hard, tight, clays with poor structure occurring throughout the profile. Soils require appropriate amendment prior to planting to maximise the root zone and reduce the likelihood of a perched water table within the top 20 to 40 cm. The effect of the poorly structured clays may be expressed later in the season when vines do not respond well to moisture stress.
A simple trellis system such as sprawl or VSP with a single cordon and spur pruning is probably the most suitable form of training although with amelioration of the soils and higher capacity vines more developed training systems may be considered.
In some situations vine rows could be mounded to increase the favourable soil volume to which the vines have access, increasing the depth of soil above the poorly structured clay layer.

Irrigation practices
The RAW of this soil is low to moderate and it is important that limited irrigation be used. Irrigation periods should be short and frequent to ensure drainage from irrigation does not create a perched water table close to the vine roots.

Nutrition and soil amendments
Frequent fertiliser applications are likely to be required to correct the generally low fertility of this soil and to maintain productivity. Lime should be added before planting and broadcast when required (dictated by results of soil tests) to combat low pH. Application of gypsum is likely to show only marginal improvements to soil structure as sodicity is not of concern.
Organic matter incorporated into the rip line before planting and at five year intervals in alternate rows will improve soil friability and the potential soil volume to which the roots have access.

Vineyard floor management
It is recommended that deep-rooted cover crops be used. Cereals such as oats as well as ryegrass provide lasting quantities of biomass and there can be benefits from the capacity of annual ryegrass to absorb moisture. Mid rows can be sprayed or slashed when necessary to limit moisture competition.
Undervine mulching can be useful in reducing soil moisture loss and preventing hard-setting of the topsoil. The biomass produced by the oats or ryegrass cover crops at sowing rates of approximately 100 kg/ha and 25 kg/ha respectively may provide sufficient mulch.
If the soil is prone to hard-setting then cultivation should be limited, especially when soils are wet. If wet weather vineyard access is an issue, perennial swards with species like ryegrass, tall fescue and chicory can be considered. Once established these cover crops may compete too much with vines for moisture and the situation should be monitored through soil moisture measurement.

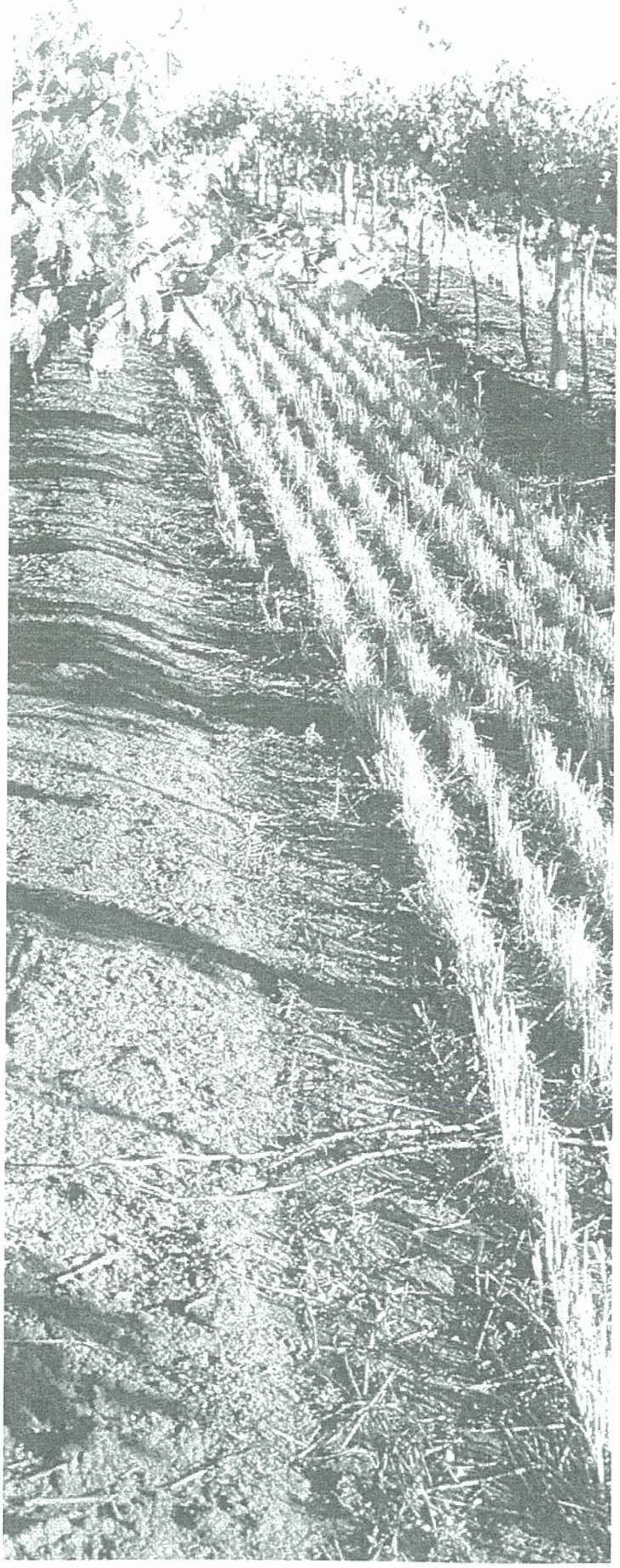
Soil 5 Hard loam over dispersive red clay

Vine development
This is a less than ideal soil to develop for any horticultural use. Poor vine growth and health will be evident on this soil due to its hard-setting surface, poorly structured and sodic subsoil and high salinity levels in the soil. The poorly drained and sodic subsoils are likely to restrict growth in spring.
A simple trellis system (sprawl or VSP) with a single cordon and spur pruning is a suitable.

Irrigation practices
The RAW of this soil is low. There is potential for water-logging at very shallow depths and a risk of salt build-up in the root zone. If irrigation is to be used the emphasis must be on short supplementary irrigations using good quality water with a low level of salinity.

Nutrition and soil amendments
Nutrient status in the topsoil is moderately low. It is imperative to deep rip gypsum into this soil before planting to improve nutrient retention in the clay subsoils. It may be beneficial to apply both lime and organic matter as well. Regular soil monitoring in mature vineyards is recommended. Ripping every few years will increase the potential root zone. This hard-setting soil will benefit from maintenance broadcast applications of 1 to 2 t/ha of gypsum each year.
As this soil is prone to acidification nitrate-based fertilisers rather than ammonium-based fertilisers are recommended.
Boron toxicity may be a problem in some subsurface soils, requiring regular soil tests. These soils may be predisposed to zinc deficiency which will be highlighted in regular soil and vine petiole testing.

Vineyard floor management
The hard-setting nature of this soil suggests minimal tillage practices are in order. It may be beneficial to plant a perennial ryegrass to stabilise the soil structure and reduce tillage requirements in the mid row. The biomass produced from the ryegrass will only be moderate but will contribute to organic matter in the soil, thereby improving soil stability.
Undervine mulching is recommended to reduce soil moisture loss and to prevent hard-setting of the topsoil. Mulch will improve the soil structure by creating a cover, improving infiltration and increasing soil stability by increasing organic carbon levels.



Vine development
The topsoil is a light clay but the subsoil clays are tightly structured and likely to limit root growth to between 15 cm and 40 cm, meaning vine vigour will be generally low despite the relatively high fertility. Vine vigour can be increased, however, by improving the subsoil layer and reducing the likelihood of perched water tables. A simple trellis system (such as sprawl or VSP) with a single cordon and spur pruning is probably the most suitable form of vine training although with soil improvement a two wire vertical trellis or Scott Henry system could be used.

Irrigation practices
The RAW of this soil is low, indicating that short and frequent irrigations are appropriate. Careful management is essential because a limited root depth is being managed and when very dry the soil will crack and become difficult to rewet.

Nutrition and soil amendments
This soil will benefit greatly from deep-ripping with a winged tine plough before planting to break through hard clay layers. Amelioration with gypsum may overcome the low permeability while incorporation of organic matter will improve soil structure. Regular soil monitoring in established vineyards is recommended and occasional ripping of alternate rows may be helpful.
Although the soil is relatively fertile soil testing may reveal nitrogen, phosphorus and in some cases zinc, are in short supply and need to be provided to maintain productivity.
If vineyard access is a problem during periods of wet weather, broadcasting gypsum will reduce stickiness of the clay topsoil and improve vehicle traction.

Vineyard floor management
Deep-rooted cover crops can be considered. Oats and other cereals as well as ryegrass can provide high levels of biomass when slashed while annual ryegrass is believed to have some benefit in improving soil structure. Cover crops that compete too strongly with the vines for limited water should be slashed or sprayed out when necessary. Undervine mulching can be useful for reducing soil moisture loss and to prevent hard-setting of the topsoil. The biomass produced by an oat or ryegrass cover crop at sowing rates of 100 kg/ha and 25 kg/ha respectively may provide sufficient mulch.
If the soil is prone to hard-setting then cultivation should be limited, especially when soils are wet. If wet weather vineyard access is a problem, perennial swards using ryegrass, chicory or tall fescue can be considered. In this shallow soil it is important of course to ensure the drain on moisture reserves is not excessive.

Vine development

This soil type has very high natural fertility which means potentially high vine vigour. As there are few limiting factors the root zone can be extensive.
The only obvious limiting factor is that deep black gradational clays are found in lower lying positions where waterlogging can be common.
Training a balanced vine is made easier with good spacing and a two wire vertical system enabling an increase in the node number per metre of row.

Irrigation practices

The RAW value is high and due to the potential for spring water-logging early season irrigation may not be necessary. Vigilant monitoring is required, however, to ensure that adequate water remains available as the high clay content of the topsoil means that water becomes more difficult to extract in very dry conditions.
The potential root zone of this soil type is greater than 1 m, without any obvious restricting layers, resulting in a high water holding capacity. It is important to know this area of roots and not irrigate beyond it.

Nutrition and soil amendments

Due to the inherent fertility and potential for excessive vigour, nitrogen inputs should be monitored frequently and adjusted accordingly. On established sites where vines are too vigorous it can be beneficial to implement a limited nutritional program to reduce vigour.
Pre-planting soil amendments are most probably not necessary because the soil is friable and well-structured. Deep ripping may aid preliminary preparation but is unlikely to be required in established vineyards.

Vineyard floor management

High vine vigour means a competitive deep-rooted early season cover crop is best. Perennial ryegrass or fescue should be suitable and also will aid vehicle access.
Broadcasting gypsum at 1 to 2 t/ha per year can help overcome surface stickiness.
In low lying wet areas mounding may have some benefit while mulching has value in minimising seasonal shrinking and cracking.

Soil 11 Sandy loam over red clay on rock

Vine development
Vine vigour on this soil type is likely to be low to moderate. The subsurface soil layers are generally tight clays with rock fragments present from 20 cm in the profile.
Sandy loam over red clay on rock will be prone to acidification and can easily become sodic. Where poorly drained and the subsoil is sodic, growth in spring will be poor and vines will generally have a low vigour appearance. Similar observations are made in some situations where subsoil clays below 25 cm cause perched water tables and restrict root growth to within 30 cm of the surface. Despite these difficulties, several good vineyards are on this soil type, where most vines are trained bilaterally on a single cordon wire with VSP and lifting wires.

Irrigation practices
The RAW value of this soil is moderate. It is important that limited irrigation be applied with short and frequent sequences guided by soil moisture monitoring devices. It is important that irrigation events do not contribute to the relatively high water table.

Nutrition and soil amendments
Nutrient status in the topsoil is moderate to low so regular monitoring is advised. Prior to planting it is common practice to deep rip with gypsum, with additions of lime and organic matter including animal manure. These ameliorants are often applied in established vineyards too, with ripping of alternate rows every few years. Such practices are believed to assist in reducing sodicity of the subsoil and minimising acidification. Nitrate based rather than ammonium based fertilisers are recommended because of the potential for acidification.

Vineyard floor management
It is recommended that deep-rooted perennial cover crops such as ryegrass and legume blends are planted. Ryegrass provides high levels of biomass which lasts when slashed and thrown into the vine row. If water is limited during the season highly competitive cover crops should be either sprayed out or slashed low to reduce competition with the vine.
Mulching will reduce soil moisture loss and prevent hard-setting of the topsoil. A bulky stand of cover crop, particularly where a cereal is included in the mix, will normally provide sufficient mulch to be effective.
If the soil is prone to hard-setting working should be limited to the sowing of the cover crop. A few growers have adopted permanent swards as a means of protecting the soil and improving access.

Soil 12 Sandy loam over brown clay on rock

Vine development
Vine vigour on this soil type will be moderate to high as a result of fairly deep topsoil. Although the subsurface layers are generally tight heavy clays present from 65 cm in the profile, the potential root zone is more than 1 m.
Some limitations may occur due to subsoil clays which may cause perched water tables and restrict root growth to within 30 cm of the surface but this is not typical of the soil type. Poorly drained and sodic subsoils, however, may cause restricted or poor growth in spring and generally lower vigour vines.
As with Soil 11, a simple trellis system is normally suitable for vine training although slightly more vigour can be expected with Soil 12.

Irrigation practices
The RAW value of this soil is high. It is important that limited irrigation be applied with short and frequent sequences guided by soil moisture monitoring devices. It is important that drainage from irrigation events does not contribute to the relatively high water table.

Nutrition and soil amendments
Ripping before planting is likely to be beneficial and as the nutrient status in the topsoil is moderate to low inclusion of organic matter will be useful. Addition of gypsum before planting is not likely to be useful but it may be beneficial to add lime with the organic matter. As this soil type is prone to acidification, nitrate based fertilisers should be used as ammonium based fertilisers can cause acidification.

Vineyard floor management
Options for the vineyard floor include grasses, legumes as well as cereals. Deep-rooted perennial cover crops have been successful but as described for other soil types the competition between cover crops and vines must be managed.
Choices for cover crop will be influenced by advantages for vineyard vehicle access, the need to compete in vigorous situations, and the amount of bulk needed for soil improvement and undervine mulch.

Soil 13 Loam over red clay on rock

Vine development

Vine vigour on this soil type is likely to be moderate as a result of relatively deep topsoil. The subsurface soil layers are generally tight heavy clays present from 65 cm in the profile but the potential root zone may still be greater than 1 m.

These soils are prone to acidification and easily become sodic. Some limitations occur with subsoil clays which may cause perched water tables and restrict root growth to within 30 cm of the surface at some sites. This may be expressed as poor growth in spring and generally lower vigour vines although this problem is not widely typical of the soil type.

A simple trellis system such as sprawl or VSP with a single cordon and spur pruning is a suitable form of vine training.

Irrigation

The RAW value of this soil is moderate to high and it is normal for short frequent irrigations to be applied when moisture monitoring indicates the necessity.

Nutrition and soil amendments

Ripping before planting is beneficial as this gives the opportunity to break up compacted clay and improve structure with gypsum placed along the rip line. As the nutrient status of the topsoil is moderate to low, organic matter is often included.

As this soil type is prone to acidification nitrate based rather than ammonium based fertilisers are recommended.

Vineyard floor management

Deep-rooted perennial cover crops are recommended although annuals have also been used. If water is limited highly competitive cover crops should be sprayed out or slashed low when vine requirements are the priority.

Often the cover crop will be a suitable source of mulch to be slashed and thrown under the vine rows. For example sufficient biomass can be achieved for mulching from oat and ryegrass sown at approximately 100 kg/ha and 25 kg/ha respectively. Mulch will reduce soil moisture loss and help prevent hard-setting.

Soil 14 Gradational clay loam

Vine development

Vine vigour has the potential to be high if correct amelioration of the soil is carried out before planting. Due to the imperfectly drained subsoils and low pH levels, however, the capacity of vines on gradational clay loam can be limited.

The subsurface soil layers are generally medium to heavy clays with a carbonate layer from 60 cm. These clays are prone to acidification and easily become sodic. They may also cause perched water tables. Poorly drained and sodic subsoils may cause poor growth in spring and generally lower vigour vines.

A simple trellis system as described with Soil 11 will be adequate if vigour is in check.

Irrigation practices

The RAW level of this soil is moderate. As outlined by David Maschmedt, ripping and gypsum application before planting and broadcasting of gypsum in established vineyards will improve structure and permeability of subsoil clay. Such improvement will aid the effectiveness of irrigations which should be scheduled so that only the active root zone is serviced. Excessive irrigation is likely to build up salts in the deeper parts of the profile.

Nutrition and soil amendments

In addition to gypsum treatments liming will often be undertaken to optimise nutrient availability. Organic carbon levels are relatively low so incorporation of organic matter prior to planting can be useful. As the soil is prone to acidification nitrate based rather than ammonium based fertilisers are recommended.

Vineyard floor management

This type of soil would benefit most from an annual cereal cover crop like oats or triticale as long as lower lying subsoil clays do not cause problems with deep drainage. If the site is prone to waterlogging at depth it may be advisable to plant a deep-rooted species like lucerne.

It is important that the water status of the soil is carefully monitored to avoid competition between vines and cover crop.

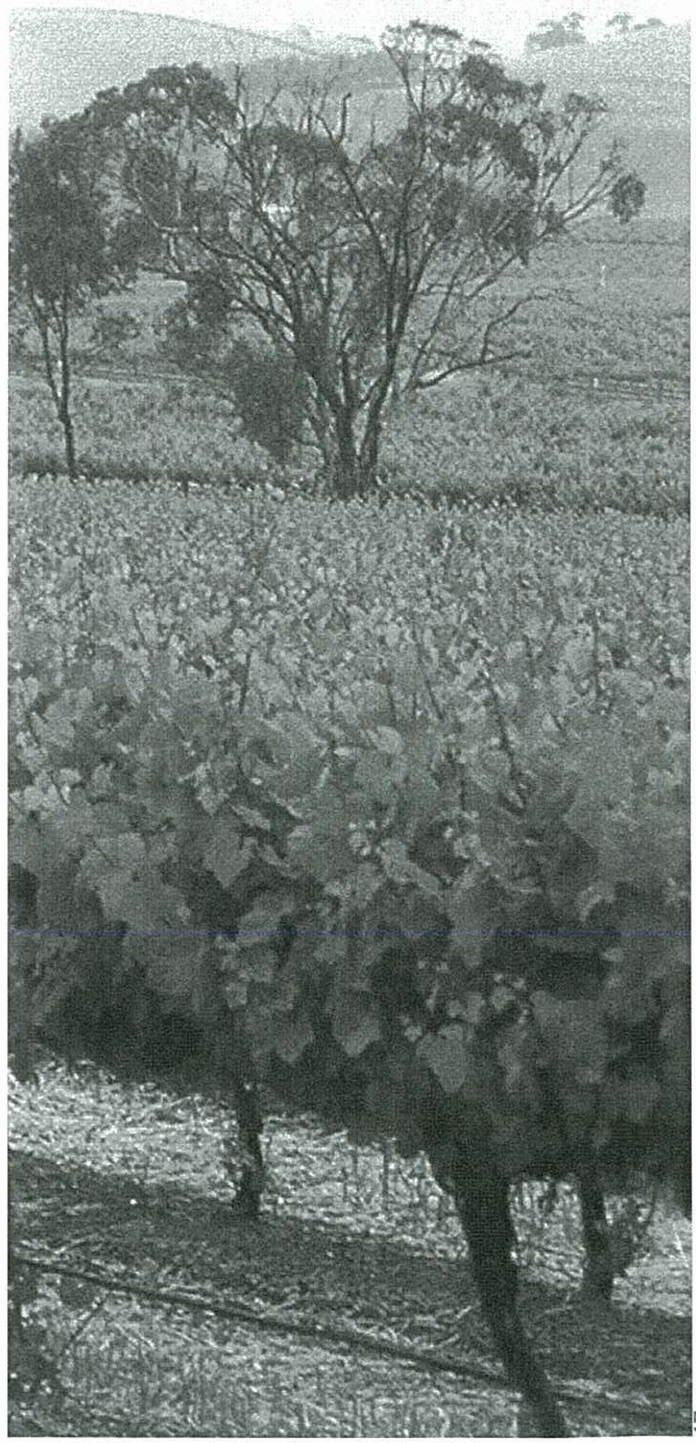
Mulching on this soil type is important for retaining soil moisture and increasing the organic carbon levels in the soil over time. Sufficient mulch may be achieved by slashing the cover crop through the season.

Vine development
While Soil 15, Soil 17 and Soil 19 have their differences (e.g. Soil 17 has more stone near the surface and both Soil 17 and Soil 19 have a defined rock base while Soil 15 on lower slopes generally has a broken base), they share such features as good drainage and well-structured clay loam. These attracted vine plantings particularly jn the Auburn to Watervale part of the region.
As the potential root zone of this soil type is relatively deep but variable, vine vigour can mean consideration of trellising systems ranging from the simple (e.g. sprawl or VSP) to elaborate (e.g. two wire vertical or Smart Dyson). Knowledge of the variations gained through soil surveys coupled with use of irrigation as a management tool will, however, help control vigour.

Irrigation practices
The RAW value is high and the nature of this soil means production without irrigation is possible. Even where the modern vineyard has required irrigation for early production and as a 'safety net' in periods of drought, the modest amount of water applied is carefully managed.

Nutrition and soil amendments
Good vine development and productivity can be expected as soil fertility is high and there are no physical or chemical barriers to root growth. Plantings in the last 20 years that have used deep ripping prior to planting with incorporation of gypsum and use of irrigation have done so for uniform young vine development and not because of significant soil problems

Vineyard floor management
For non-irrigated vineyards cover crops should be limited to annual cereal crops which can be easily knocked down to eliminate competition with the vine while providing organic matter or undervine mulch. Sites using irrigation could be sown with a perennial sward of ryegrass and clover to control early season vigour.



Soil 16 Loam over hard red clay on limy rock

Vine development

This soil type is common over a wide area of the Clare Valley hill slopes and normally promotes fairly low vigour in vines through a restricted root zone and low fertility. Clay subsoils are restrictive and may cause waterlogging which will result in poor spring growth.

In most cases a simple trellis system (e.g. sprawl or VSP) is appropriate due to the inherent low soil fertility and water holding capacity.

Irrigation practices

The RAW value is low to moderate and irrigation should be limited and carefully monitored to avoid perched water tables.

To minimise the level of irrigation required it is recommended that straw mulch be used under vines. While judicious use of applied water is important it may be necessary to apply a leaching fraction due to the potentially high salt levels within 15 cm of the surface. Use of high quality water is desirable due to the soil's naturally high salinity.

Nutrition and soil amendments

Pre-planting incorporation of gypsum and high levels of organic matter along the rip line will improve the soil and vine potential. Gypsum will go some way towards countering the sodic subsoil layer and reducing waterlogging although regular soil testing is needed to monitor salinity levels and to highlight any further requirements for gypsum in the sodic subsoil layer.

Vineyard floor management

This soil would benefit most from an annual cereal cover crop like oats or triticale if the subsoil clays do not cause problems with deep drainage. If the site is prone to severe waterlogging at depth, however, it may be advisable to plant a deep-rooted species (e.g. lucerne). Moisture monitoring will help manage competition between the cover crop and vines.

Mulching on this soil type is important both for soil moisture retention and increasing carbon levels over time. Sufficient mulch may be achieved from cover crop slashing if the stand has ample bulk.

Soil 17 Loam over red clay on calcareous rock

Vine development

This soil type has few physical or chemical barriers to vine growth apart from the variable depth fo topsoil to the underlying calcareous rock. Detailed soil surveys are critical for understanding the degree of topsoil variability.

A simple trellis system (e.g. sprawl or VSP) with bilateral training on a single cordon wire will usually be appropriate even on deeper soils if water and nutrients are carefully managed.

Irrigation practices

The RAW value is moderate. Irrigations should be short and frequent when required using soil moisture monitoring devices to manage the limited quantity applied through the season as there is generally limited root growth in the calcareous layers. Due to the moderate RAW it is possible for water stress to be seen in the later part of the season if vines are dry grown.

Nutrition and soil amendments

Soil fertility is moderate to high and there are no chemical or physical limitations in the soil, so good vine development and productivity can be expected.

The purpose of pre-planting ripping, incorporation of gypsum and irrigation is to promote uniform young vine development.

Vineyard floor management

For dry grown vineyards cover crops should be limited to cereals, which can be easily knocked down to eliminate competition with vines while returning organic matter to the soil. Irrigated vineyards have used perennial stands of ryegrass and clovers to control early season vigour.

Soil 18 Gradational clay loam over limy rock

Vine development

There are few physical or chemical limitations to vine growth apart from the variable depth of topsoil to the underlying calcareous rock which will cause unevenness of vine vigour. Site selection using detailed soil surveys is critical to gain an understanding of topsoil variability.

A simple trellis system such as sprawl or VSP is appropriate for the level of vigour promoted by this soil type.

Irrigation practices

The RAW level of this soil is moderate, meaning that it is possible that effects of water stress will be seen at the end of the season where vines are not irrigated. With variable depth that can mean limited root extension in parts, well-placed soil moisture monitoring is essential in irrigated vineyards to guide the patterns of application.

Nutrition and soil amendments

With relatively high soil fertility and no major chemical or physical limitations good vine development and productivity can be achieved, particularly where variations are known and deep ripping with gypsum prior to planting has helped to open up the soil and further improve structure. The soil, however, is not poorly structured when compared with other viticultural soils and is naturally well-drained.

Vineyard floor management

Annual cereal crops that can be easily knocked down when competition with the vines or frost risk dictate will be suitable vineyard floor covers for non-irrigated vineyards. Irrigated sites have other options, including permanent swards of grass and legume mixtures.

Clay loam over limy rock (terra rossa)

Vine development

There are few physical or chemical limitations to vine growth although moderate changes in vigour across a vineyard on this soil may be observed due to variations in topsoil depth.

Although fairly easy to manage, soil surveys are valuable for mapping out differences and determining appropriate irrigation regimes. Normally bilateral training on a single cordon wire and use of foliage wires is sufficient for achieving balanced growth and exposure.

Irrigation practices

The RAW value of this soil is moderate and while vines have been grown without irrigation there has been greater control over the status of vines throughout the season when using small quantities of irrigation determined through moisture monitoring and vine inspections.

Nutrition and soil amendments

Soil fertility is moderate and, as there are no chemical barriers to roots, good productivity is expected. As described by David Maschmedt, a thin calcrete pan can restrict root growth into underlying softer rock and this physical barrier must be broken by ripping. In addition to extending root volume this will be advantageous where water is limited.

Other than nitrogen and phosphorus nutrient deficiencies are uncommon.

Vineyard floor management

Annual cereal crops that can be easily knocked down when competition with the vines or frost risk dictate will be suitable vineyard floor covers for non-irrigated vineyards. Irrigated sites have other options, including permanent swards of grass and legume mixtures although where soil is shallow and water limited such stands should not be too competitive.

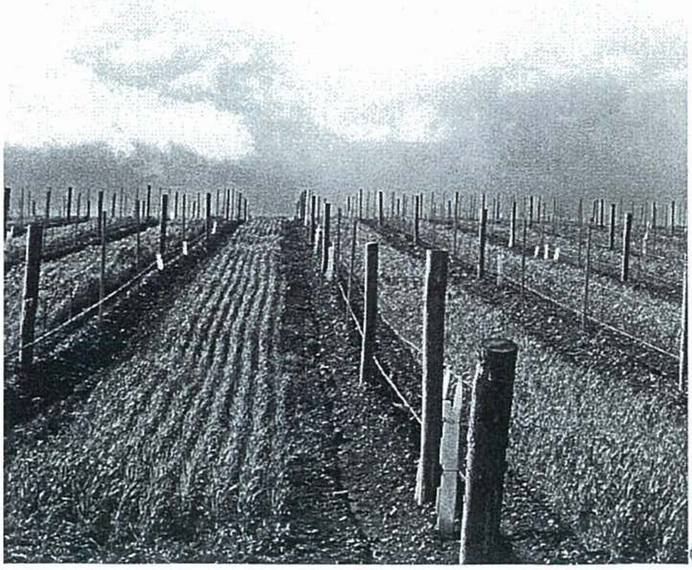
Soil 20 Shallow calcareous loam on rock

Vine development
This is a shallow soil with a limited root zone. It fosters only low to moderate vigour in grapevines, meaning that a simple trellis system (sprawl or VSP and a single bilateral cordon) will be adequate.

Irrigation practices
As the soil drains rapidly, the RAW value is low to moderate and there is limited root extension, soil moisture monitoring devices are essential for gaining a picture of moisture levels and the distribution pattern. This determines when and for how long to apply the water, with short and often rather than extended soaking being appropriate. For vine condition it is also critical that vine roots not be allowed to get too dry during extended hot periods.

Nutrition and soil amendments
Nutrient applications need to be determined from regular soil testing every two or three years and annual petiole analyses. This is because the high pH associated with calcareous soils tends to tie up such nutrients as phosphorus, manganese, zinc and iron, making them less available.

Vineyard floor management
Annual cereal cover crops that can be easily knocked down when competition with the vines is an issue may be suitable for non-irrigated vineyards. Irrigated sites have additional options including permanent swards of grass and legume mixtures, although there is a management balance of the need for a bulk of organic matter and the preservation of sufficient moisture in a limited soil depth to serve the vines.



Climatic factors

Di Davidson and Holly Jones
Viticultural Consultants
Davidson Viticultural Consulting Services

The Clare Valley is a moderately warm low rainfall region compared with other premium wine producing regions in Australia.

The table summarises available data but caution should be exercised due to the small number of recording sites and their relatively short history. A more comprehensive understanding of the regional climate requires a network of strategically-placed weather stations to record information in a standardised manner over the long term.

Climate Summary

	Clare High School	Clare Post Office	Sevenhill	Kirribilly	Polish Hill River
Elevation (m)	395	385	480	400	440
DD (standard)	1767	na	1891	1585	1465
DD (19/10)	1540	na	1646	1435	1342
DD (BEDD)	1513	na	1645	1331	1245
Mean January Temperature - MJT	22.1	21.6	22.4	20.81	20.46
Mean Ripening Month Temperature (March)	18.5	19.2	19	18.5	16.83
Mean Ripening Month Temperature (April)	14.8	15	16.2	14.15	12.44
Continentality Factor	14.5	13.4	13.8	12.99	13.49
Ave 9am RH (Oct-Apr)	60.1	55.7	na	61.6	na
Sunshine Hours (Oct –Apr)		na	na	na	na
Spring Frost Index	13.7	15.35	5.32	15.4	12.99
Mean Frost Incidence (Sept-Nov)	3.5	7.5	0.3	13.3	9.9
No days > 35°C (Oct - Apr)	17	16.1	13.75	16.7	14.1
No days < 0°C (Oct-Apr)	3	3	0	3.5	1
Annual Rainfall (mm)	554.7	632.1	568.6	565.5	667.3
Oct-Apr Rainfall (mm)	213.2	245.3	222.1	206.2	248.1
Ripening Month Rainfall (March)	16.9	25.4	26.7	15.96	21.8
Ripening Month Rainfall (April)	28.6	46.6	13.9	24.42	32.21
No of rain days (Oct-Apr)	42.5	44.3	na	45.85	Na

na	Unable to calculate index due to missing data

Weather station data

There is one registered Bureau of Meteorology (BOM) weather station currently recording in the Clare Valley. It has been operational for 11 years and is located at the Clare High School. Prior to this the Clare Post Office had been collecting data for 132 years. Several other private weather stations exist in the Clare Valley. The following table indicates the spread and duration of weather recording, including limitations on the data.

Location of weather stations

Site	Duration	Limitations to data
Clare Post Office (BOM)	132 years	Location in township not relevant to viticulture
Clare High School (BOM)	11 years	
Sevenhill	11 years	Daily measurements taken by a maximum/minimum thermometer
Watervale	2 years	Not a long term data set
Auburn	6 years	Many gaps in data set
Kirribilly	16 years	
Polish Hill River	10 years	Weather Station located in frosty hollow
Spring Farm Road	3 years	Not a long term data set

Elevation

Most of the Clare Valley's grapes are grown where the elevation ranges from 400 to 500 m. There are, however, places like Mount Horrocks (600 m), Rhynie (252 m) and White Hut (62 m) which are significantly different from this nominal elevation, and hence may vary greatly in mesoclimatic conditions. For example, it is estimated that there is a 3.2°C drop in mean temperature from Rhynie to Mt Horrocks.

Aspect

As the Clare Valley is located within and around a narrow mountain range, a wide variety of slopes and aspects exists. This makes each vineyard within the region unique, with often significant differences across hill slopes on the same property . Aspect influences the exposure of a vineyard to the sun and therefore its relative warmth in relation to the local climate. The warmest aspects are those facing north, north-east and east, while westerly aspects, which are cool in the morning but receive the harsh afternoon sun, are the next warmest aspects. Southerly aspects are the coolest.

Slope, along with aspect, also has an important impact on the mesoclimates in the Clare Valley, not necessarily determining the ability for fruit to ripen, but more the effect on fruit quality, and the exposure to climatic extremes. The following diagram explains the effect of slope, aspect and elevation on potential fruit quality and climatic extremes.

Effect of aspect, slope and elevation on vineyard mesoclimates (source Jackson and Spurling 1988).

(a) This warm site will intercept more sunlight due to the lie of the land and will miss late spring and early autumn frosts as the cold air can drain to lower lying areas.
(b) This site has counteracted the advantages seen in (a) due to its increase in altitude, decreasing temperatures.
(c) This site is cold and will accumulate less heat in summer due to its elevation, exposure to prevailing wind and poor exposure to the sun. It may however miss spring and autumn frosts.
(d) This site is very cold and susceptible to frosts as cold air will drain to this point from the surrounding region.
(e) This site is frost prone but less than (d). Prevailing winds should be decreased by the hill and dense tree plantation.
(f) The dense tree planting at the base of the hill prevents cold air from draining away from this site, and hence a frost- free site has been lost.
(g) This site is warmer than (e) but the prevailing wind and increase in altitude may hinder the accumulation of heat in summer.
(h) Cold, like (c) above.

Temperature & degree days (DD)

Day degree

There are three methods of calculating Degree Days (DD): Standard Base 10°; 19/10; and Biologically Effective Day Degrees (BEDD).
Degree Days refers to the summation of the mean monthly temperature above 10°C. Degree Days is a temperature-time integration of growing season conditions.
Temperature related indices are commonly used for two reasons. Firstly temperature has a significant impact on plant growth, and secondly it is one of the easiest climatic indices to measure. Indices have been devised from heat summation factors to predict the suitability of districts for grape production.

Standard (Base 10)

Base 10 is calculated by the summation of the mean monthly temperature minus 10 and multiplied by the number of days in the month. 10°C is used as the base temperature on the assumption that little or no growth occurs below 10°C.
This index is calculated for the fixed period of October to April. This has been identified as the standard HDD summation.

The standard Day Degree Summation ranges from 1891 at Sevenhill to 1465 at Polish Hill River. The Clare High School site closely follows Sevenhill with 1767, while Kirribilly has a standard day degree summation of 1585.

The Clare Valley can be classified as Region III, having 1760. The data from the Kirribilly and Polish Hill River stations indicates that these areas of the Valley fit into Region II. It must be noted that the Polish Hill River weather station is located in a frosty hollow and this is most likely responsible for the lower day degree accumulation. Anecdotal evidence suggests that there has never been a problem with ripening of any variety at the site; indicating that there is in excess of 1350 BEDD which is more similar to the other sites

19/10

John Gladstones developed a different method whereby any month with a mean temperature greater than 19°C or higher is truncated at 19°C; i.e. a maximum day degree summation of 279 is the highest summation possible for any month. Thus the 19/10 DD is the mean temperature (truncated at 19°C) minus 10°C, multiplied by the number of days in that month, and summed over the growing season.
The 19/10 Day Degree summation ranges from 1646 at Sevenhill, 1540 at Clare High School, 1435 at Kirribilly and 1342 at Polish Hill River (but query implications of the low lying location).

Biologically effective day degrees (BEDD)

Biologically effective day degrees (BEDD) is a climatic index that has been derived from the HDD summation. It limits summation to between 10°C and 19°C and also adjusts for latitude and daily temperature range. This climatic index is the most common and comprehensive temperature-time measure used in the Australian viticultural industry, and hence will be the main Day Degree summation referred to in this report.

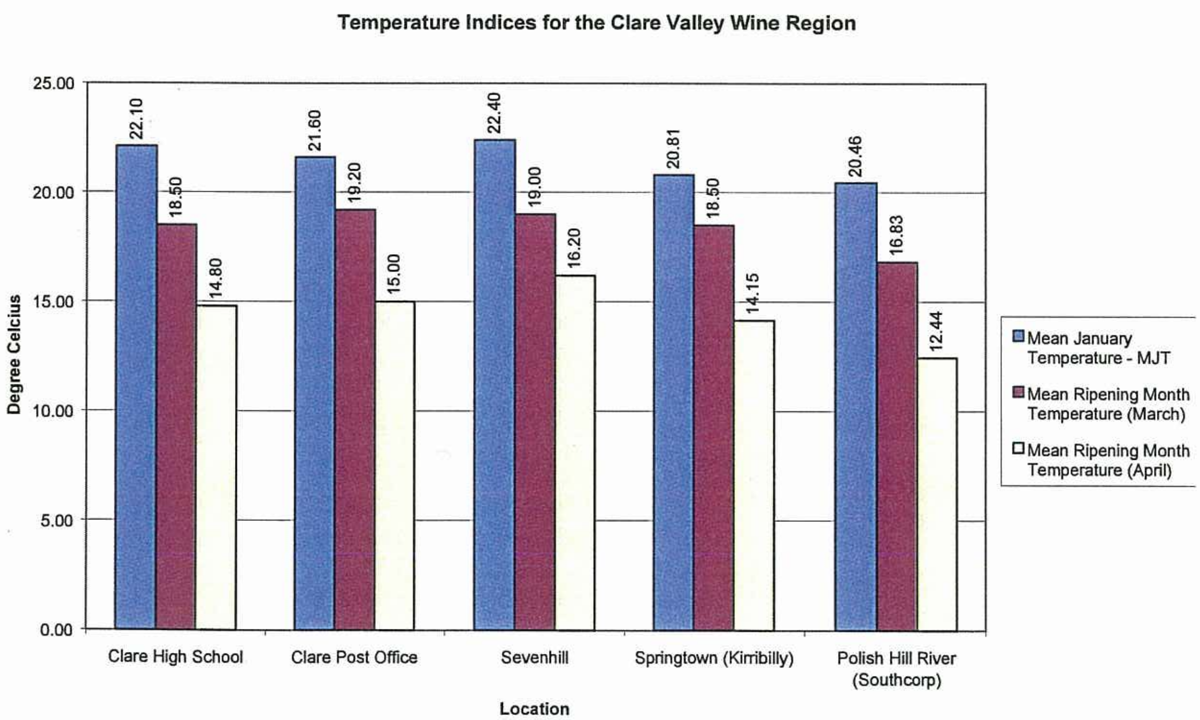
Table 3: Climatic regions as described by John Gladstones 1992

Region	Heat summation °F	Heat summation °C	Examples of Regions
I	less than 2500 DD	(less than 1371DD)	Coonawarra & Blenheim (NZ)
II	2501 → 3000 DD	(1372 → 1649 DD)	Barossa Valley and Auckland (NZ)
III	3001 → 3500 DD	(1650 → 1927 DD)	Bendigo & Lisbon (Portugal)
IV	3501 → 4000 DD	(1928 → 2204 DD)	McLaren Vale & Madeira (Portugal)
V	4001 DD or more	(2205 DD or more)	Hunter Valley and Fresno (USA)

Different varieties require different heat summations to ripen fruit fully. Examples given by Gladstones are:

Pinot Gris	1100 BEDD
Pinot Noir	1150 BEDD
Chardonnay	1150 BEDD
Sauvignon Blanc	1150 BEDD
Shiraz	1250 BEDD
Merlot	1250 BEDD
Cabernet Sauvignon	1300 BEDD
Grenache	1350 BEDD
Polish Hill River	1245 BEDD
Kirribilly	1331 BEDD
Clare High School	1531 BEDD
Sevenhill	1645 BEDD

The data suggests that Polish Hill River would be unable to ripen Cabernet Sauvignon and Grenache, and in some years may not be able to ripen Merlot. However, experience indicates that sites in this area do ripen Cabernet Sauvignon without any difficulty. Nonetheless there may be some cooler sites within the Polish Hill area which are unable to sufficiently ripen the later varieties in every year.



Mean January temperature (MJT)

MJT is a simple calculation of how warm a specific site or region is, and is the average of the monthly maximum and minimum temperatures.

Throughout the Clare Valley there appears to be a 1.94°C difference in MJT (limited data available). As would be expected from the rankings of day degree summation, Polish Hill River has the lowest MJT (20.46°C) and Sevenhill has the highest MJT (22.4°C). But the statistical significance of this cannot be tested due to the lack of data.

Mean ripening month temperature (March & April)

Mean Ripening Month Temperature is defined as the mean temperature of the 30 days prior to the expected harvest date for any variety. Gladstones suggests that there is a broad association between mean temperature of the ripening month and the styles of wine which can be produced.
Sites with ripening month average mean temperatures below 15°C may or may not allow full sugar ripeness. Ripening month average mean temperatures of between 15°C and 21°C will generally allow for well balanced wines for dry table wines. Comments from winemakers and grape growers confirm that wines which are made from grapes grown closer to 15°C tend to be lighter bodied, more fresh and delicate, while wines produced from grapes grown where the mean ripening month temperature is closer to 21°C are likely to be more full bodied.

Continentality

Continentality is an index which measures the difference between the mean temperature of the warmest and coolest months and is often used as a measure of the moderating influence of large water bodies. In the Clare Valley Region, the Clare High School site has the highest continentality measure (14.5), while Kirribilly has the lowest (12.99), but this is not likely to be statistically significant, merely a reflection of the limited years of recording. The Clare Post Office, Sevenhill and Polish Hill River are all relatively similar at 13.4, 13.8 and 13.49 respectively.

Average 9 am relative humidity (%RH)

Relative humidity is an important climatic index for determining disease risk, irrigation requirements and potential for heat damage due to persistence of hot dry winds. The 9am %RH of January is used as an index of relative humidity for the season (Gladstones 1992). There have been suggestions that superior wine quality is associated with greater continentality (Gladstones 1992), however this is controversial and not generally accepted in the international winemaking community.

For the purposes of this climatic summary the average 9am RH over the growing season has been used as the index as it accounts for more humid conditions experienced during flowering and harvest. There is little variation in humidity records between the sites, with 55.7% at Clare Post Office and 61.6% at Kirribilly.

According to Peter Dry and Richard Smart (1988) a moderate to high incidence of bunch rot can be expected when the following conditions occur in the ripening month:-

Rainfall exceeds 60mm
Rain days exceed 8
9am RH exceeds 60%
These conditions are likely to be of rare occurrence in the Clare Valley.

Dry & Smart (1988) also suggest that a moderate to high incidence of downy mildew can be expected when the following conditions occur throughout the season:
Rainfall (Oct – Mar) exceeds 200mm
Rainfall (Nov) exceeds 40mm
Rain days (Oct-Mar) exceed 40
9am RH (Nov) exceeds 60%

These conditions are not generally expected to occur in the Clare Valley, although in individual years a moderate to high incidence of downy mildew may occur.

Sunshine hours

The amount of sunshine at the time of flowering has a direct impact on fruit set via enhanced photosynthesis. Sunshine hours can be considered at specific times during the growing season, or over the seven month growing season period.

A figure of 1250 sunshine hours from October to April is a generalised requirement for viticulture according to Gladstones. This equates to approximately 5.9 hours per day during the growing season. The Clare Valley exceeds this requirement with an average of 1750 sunshine hours observed (Gladstones 1992) or 8.3 hours per day during the growing season. Within the Clare Valley there is no official measurement of sunshine hours. Some of the more sophisticated automatic weather stations measure day length by means of a global radiation sensor which measures watts/m2.

Spring frost index

Gladstones established an index known as Spring Frost Incidence (SFI). The SFI is calculated as the spring months' average mean temperature minus its average lowest minimum temperature, recorded between the months of October and November. Clare Post Office and Kirribilly have the lowest chance of frost, whilst Polish Hill River and the Clare High School have higher chances of frost.

The data suggests that Sevenhill has a SFI of 5.32. This result is questionable. The temperature data is collected by a maximum and minimum thermometer, and hence may not be as accurate as other measurements taken in the region.

When comparing this SFI data with that collected by Gladstones (1992), frost risk in the Clare Valley is similar to that experienced in other moderate frost risk areas such as Coonawarra, Adelaide Hills, Reims (France), Fresno (California) and Blenheim (NZ). SFIs in Australia range from 9.6 in Hobart, Tasmania to 15.8 in Cowra. Generally, the closer a region to a humid coastline environment, the lower the frost risk.

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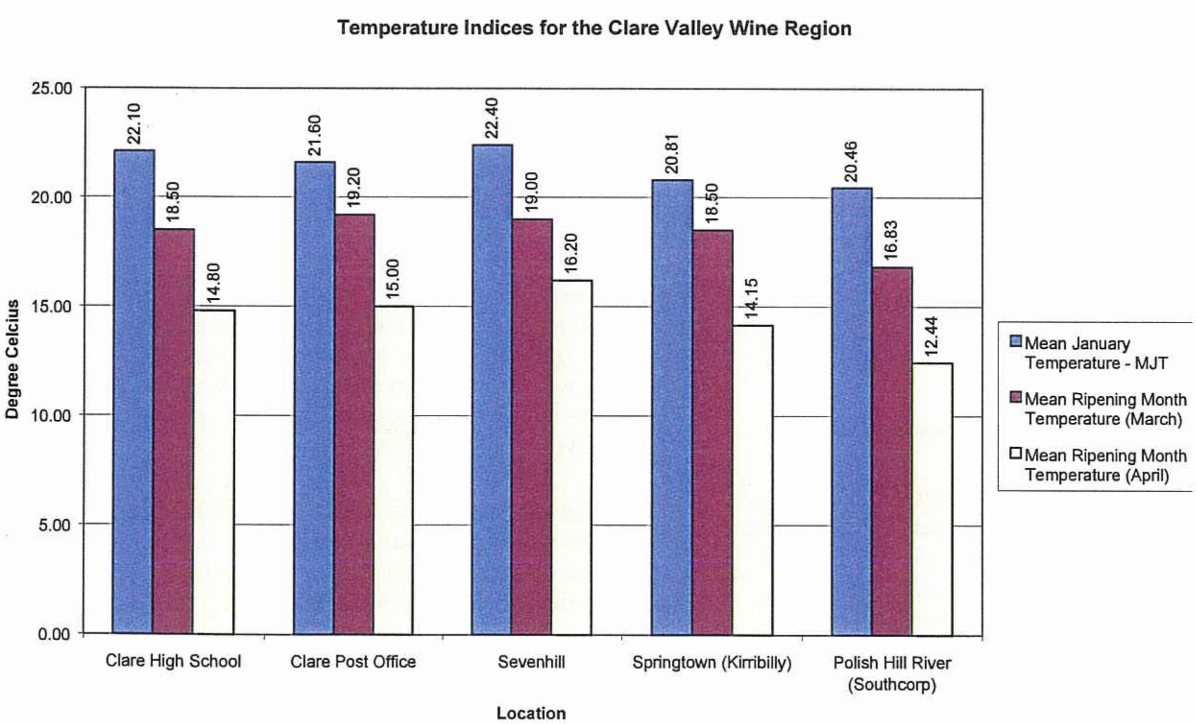

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Mean frost incidence

The mean frost incidence is the average number of times that the temperature will reach 2.2°C or below at the recording station in the months of September to November. The figure of 2.2°C is used by the Bureau of Meteorology as a measure of temperature in the Stephenson screen which reflects a ground temperature of 0°C.

Kirribilly has the highest incidence of frost in the region, experiencing an average of 13.3 frosts in the September to November period. Polish Hill River has a mean frost incidence of 9.9 days. The Clare Post Office has on average 7.5 days of frost in the specified period. The incidence at the Clare High School site is much lower (3.5 days), most probably due to slightly higher elevation. The data suggests that Sevenhill has only 0.3 days of frost during September to November and anecdotal evidence confirms this. Sevenhill experiences easterly winds which will generally disturb any pooling of cold air. The weather recording site is nearly 100m higher in elevation than the Clare Post Office which would also be responsible for the reduction of frost incidence at Sevenhill.

Unfortunately the data from Auburn and Watervale cannot be used in this project due to significant gaps in the data or lack of long term data. However more data would be interesting and of value to growers in assessing frost risk through the valley. Until more accurate and detailed data is collected this cannot be achieved.

Number of days > 35°C

The number of days above 35°C is an important measure to enable grape growers to determine, on average, the number of times that the vines' physiological function may be reduced in the growing season

This will occur on average 16 to17 times per year in the Clare Valley Region. January and February are the times when this is most likely to happen as these are the warmest months of the year. The result of this can be devastating, especially if irrigation is supplementary and the water status of the soils is low (as generally is the case for most Clare vineyards). Depending on the prior level of water stress that the vine is experiencing, the result may range from complete defoliation to the loss of growing tips only.

Rainfall

Rainfall is an important factor to consider in the climatic evaluation of a viticultural region because of its impact on irrigation requirements and the potential disease risk associated with ripening month rainfall.

Rainfall data is collected by the Bureau of Meteorology at many more stations than are other climatic indices. Therefore a clearer map of rainfall distribution can be made. The annual rainfall for Clare is moderate for a premium wine producing area with an annual range of 465 mm to 650 mm. The comparison with other areas is made below:

Coonawarra	581mm
Barossa	500 mm
Mt Barker SA	766 mm
Yarra Valley	899 mm
Pyrenees	600 mm
McLaren Vale	522 mm

Annual rainfall

The annual rainfall in the Clare Valley ranges from 667.5 mm at Polish Hill River to 465.2 at White Hut, generally of winter incidence. Annual rainfall is a useful index in the Clare Valley in addition to growing season rainfall and ripening month rainfall as it gives an indication of the amount of soil water refill. Generally soils in the Clare Valley have a high water holding capacity and hence will retain relatively high volumes of winter rainfall which becomes available to the vines early in the season.

Rainfall (October – April)

Growing season rainfall is measured as the total rainfall for October to April, and is useful for the aridity index (irrigation requirements) and disease risk assessment.
The growing season rainfall in the Clare Valley ranges from 273.6 mm at Armagh to 152.4 mm at White Hut.

Ripening month rainfall (March & April)

The ripening month rainfall index is used mainly to predict the associated risk of such diseases as downy mildew and Botrytis. It is the summation of rainfall (mm) for the 30 days preceding the expected harvest date.
The March ripening month rainfall in the Clare Valley ranges from 16 mm at Kirribilly to 27.3 mm at Watervale. The April ripening month rainfall is higher, as expected, with Watervale (the wettest) having an average of 48.8 mm.
The table below is a summary of each site in the Clare Valley which measures rainfall and compares annual, growing season and ripening month values.

Comparison of rainfall categories and distribution in the Clare Valley

Site	Latitude ° ' S	Annual (mm)	Growing Season (mm)	Ripening Month - March (mm)	Ripening Month - April (mm)
White Hut	33 47	465.2	152.4	20.1	28.2
Hilltown	33 41	474.2	181.4	16.6	30.8
Farrell Flat	33 49	475	188.5	17.6	32.6
Manoora	34 00	485.8	196.2	19.9	33.8
Rhynie	34 11	505	208.7	22.6	33.5
Geralka	33 37	514.2	198.6	17.4	34.6
Kybunga	33 54	519.2	213.2	22.6	32.9
Neagles Rock	33 5	544.5	185.9	17.6	14.5
Calcannia/Barinia	33 44	544.6	210	17.5	34.9
Clare High School	33 49	554.7	213.2	16.9	28.6
Kirribilly	33 49	565.5	206.2	16	24.4
Sevenhill	33 52	568.6	222.1	26.7	13.9
Clare Caravan Park	33 51	573.9	230.8	19.1	28.1
Bungaree	33 44	580.2	227.5	23.1	42.1
Auburn	34 1	594.2	236.4	25.9	42.9
Mintaro	33 54	597.6	221.8	21.5	37.6
Hill River	33 5	629.2	238.9	23.6	45.8
Clare Post Office	33 5	632.1	245.3	25.4	46.6
Armagh	33 51	652.8	273.6	25	46.3
Watervale	33 57	653.9	257.5	27.3	48.8
Polish Hill River	33 53	667.5	248.1	21.8	31.9

References

Gladstones, John Viticulture and Environment (first published 1992, Winetitles).

Smart, Richard and Dry, Peter in Viticulture Volume One – Resources (ed. B.G.Coombe and P.R.Dry, first published 1988, Winetitles).

Current practices

Tony Clancy
Communication Manager
Grape and Wine Research and Development Corporation

Aspects of the Clare Valley's soil and climate that influence grapevine development and production are generally well understood and are reflected in current practices.

These practices revolve around natural constraints on vigour which are described in preceding sections by David Maschmedt, Di Davidson and Holly Jones.

While the environment works in favour of high quality grape production and demands relatively simple trellising and low inputs of water and nutrients, attentive management is essential for best results. This is illustrated in wide use of soil moisture monitoring, soil nutrient sampling and tissue testing to determine inputs.

Setting up the vineyard

With a series of undulations and ridges within the valley it is not surprising to find both east-west and north-south orientation of rows, although east-west is the most common.

Ripping the row line, plus cross-ripping in some cases, has been common practice to break up rocky or naturally compacted foundations of dense clay that are difficult for roots to penetrate. A vineyard established a few years ago near Mintaro left a few rows un-ripped to compare vine performance and the result confirmed the benefits of ripping to enable early root extension and to break down some of the variation along a planting line. On some soils with a clay base, such as that described as soil type 11, a few old dryland patches of vines have demonstrated that roots will eventually find their way through but delayed production in modern viticulture would be costly. Incorporation of gypsum and well-matured compost in the rip line often is undertaken to improve soil structure.

Although vine spacings as close as 1.5 m can be found, most are set 1.8 m to 2 m apart with 3 m row spacing. Young vines are typically trained on strings to reach a cordon wire at 1 m or higher, with the aim of establishing a single pair of sturdy arms from which foliage can be lifted for aeration. In some new plantings total trellis height is up to 1.8 m, with one or two pairs of lifting wires. As suggested by Di Davidson and Holly Jones, the relatively low vigour of the region makes vertical shoot positioning (VSP) a suitable training method.

Grapevine phenology

The season starts and finishes earliest in the southern part of the region, where white varieties usually have budburst by the end of the second week of September and an expected harvest date in early to mid March. In the later ripening sectors of the region, however, such varieties as Cabernet Sauvignon and Merlot are often not harvested until early April. At the centre of the region the pattern for Shiraz is budburst in late September, fruitset in mid November, veraison in early

February and harvest in March.

Where phenological records are taken for each site and variety it is possible to fairly accurately track growth for management purposes. For example, at a site north of Clare township, a Riesling block had the following dates recorded for early stages:

Year	Budburst	Full bloom	Set
2000-2001	Sept. 15 Nov. 14	Nov. 20	
2001-2002	Sept. 11 Dec. 16	Dec. 27	
2002-2003	Sept. 14 Nov. 15	Nov. 25	

Consistency is shown in the first and third years of recordings while the disruption in 2001-2002 was caused by very cold conditions in October and November which had an adverse effect on fruit set and yield.

Canopy manipulation

Compared with most other significant winegrape producing areas, the Clare Valley is not a major user of irrigation to control total vine growth and regulate the balance of fruitful and vegetative components of the canopy. It can be important, however, to maintain vine health and to help meet economic yields.

Two examples of growers linking irrigation to yield targets are: one who aims for 10 to 12 tonnes per hectare of white wine varieties and 'around 8' tonnes per hectare of red wine varieties using an average of 0.5 megalitres/ha/year; and another who applies an average of 0.8 megalitres of water/ha/year and has yield targets of 12 to 14 tonnes/ha for white varieties and 8 to 10 tonnes/ha for red wine varieties. Some sites are naturally more productive than others, while selected sites, most often with old dryland vines, have yields of 6 tonnes or fewer per hectare.

These are very broad illustrations, of course, and most growers see a combination of climatic factors, water and nutrient management, and pruning governing yield. Another influence is the target market. In general the soils and climate will not allow yields to get out of hand and experience shows that annual yields can fluctuate (within a reasonable range) without measurable change in quality.

The most common approach to pruning is to use mechanisation and to follow up with hand pruning to a range of bud numbers per metre. This figure varies from a rule of thumb of 30 to 35 per metre (some producers have a lower range of 20 to 25) to a more precise number determined by climatic records, bud dissection and consideration of the perennial nature of the vine. The precise method will also consider variety and site. To illustrate, at Dunn's block near Clare, Cabernet Sauvignon and Shiraz are all spur pruned and 18 buds per metre are left, Merlot is rod and spur pruned leaving 18 buds per metre and Malbec is rod and spur pruned leaving 30 buds per metre. In a few cases fruitfulness will determine targets.

Summer pruning is not common although there can be some light trimming to improve exposure. Bunch thinning is another practice this is rarely necessary.

Vineyard floor management and nutrition

Many soils have a relatively shallow depth that is easily penetrated by vine roots before reaching compacted or stony layers which, particularly if not initially ripped or regularly decompacted, presents a limited area for root growth. This has implications for irrigation as well as weed control and cover cropping as described earlier by Di Davidson and Holly Jones.

Problems can vary from having too much competition from weeds and sown pastures for limited water, to insufficient drainage in wet periods.

Clues for management, which will vary with site, are given in early sections of this publication. Interviews with growers have helped provide some 'ground truthing' of the situation, revealing that while there is wide use of moisture monitoring and interest in root distribution, there is much reliance placed on visual observation of canopy growth when deciding on management options. There is also less use of ryegrass mixes as permanent sods than might have been expected, the exception being steeper rises with trafficability and erosion issues.

Cereal crops are dominated by triticale, followed by oats, which are most common on land that is less prone to erosion and where spraying out just prior to budburst will halt competition for water in soil that is shallow and/or supports dryland vines. Another common practice is to plant legumes (medics, clovers or beans) with cereals and to either slash or turn in. Many growers choose to rotate cover crop treatments.

Slashing and throwing of what is cut under vines is fairly common, along with use of cereal straw mulching, although the need for building soil structure needs to be weighed up with the frost risk in certain tracts of the valley.

Working of soil in vineyards is limited due to the threat of erosion and need to conserve moisture. Practices include sowing cover crops, slashing, spreading of soil ameliorants, and occasional ripping of wheel track lines to relieve compaction. A minor practice used on cracking black clays is light harrowing to fill the cracks and reduce moisture loss.

Production of organic matter through cover cropping and mulching, plus generation of nitrogen where legumes are used, contributes to nutrient requirements. The chemical analyses charts in this publication highlight likely deficiencies for each major soil category. In general, however, a broad application of fertilisers dominated by phosphorus and nitrogen and potassium is made in establishment years. For mature vines nitrogen and phosphorus fertilisers are broadcast or applied with the cover crop. Based on soil and petiole test results, foliar sprays of such elements as manganese have been applied, while fertigation is a growing practice for application of such compounds as calcium nitrate.

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