Land use potential for agricultural crops in southern South Australia: Summary of assessment and mapping methodology

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This document summarises *Land use potential* assessment and mapping methodologies that were largely developed during, and subsequent to, the State Land and Soil Mapping Program (1986-2001). Various organisational support and contributors to South Australia's strong legacy of soils information (which underpins the *Land use potential* modelling and mapping discussed here) are detailed in the reference text by Hall and colleagues (2009) *The Soils of Southern South Australia*.

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Summary

This document provides a summary of the methodology linking *Soil landscape mapping* (2009) to modelled *Land use potential* for various agricultural crops in southern South Australia.

The information provided here should be read in conjunction with *Land use potential* spatial datasets, available for download, from Data.SA, NatureMaps and Enviro Data SA

1 Introduction

1.1 Purpose of this document

This document provides background and overview information for the *Land use potential* spatial datasets, based on regional-scale soil and land mapping undertaken by the South Australian Government. This information is provided to raise awareness of the methodology and limitations associated with *Soil and land attribute* mapping and subsequent modelling of *Land use potential*. For example, key considerations discussed in this document include:

(a) The *Land use potential* models discussed here **should be considered preliminary**, are based on limited data, and have not been subject to field validation.

(b) **Scale of use:** These *Land use potential* models are intended for use at the regional, district, and at best property overview scale, but not paddock scale.

(c) **Other critical data to determine suitability**, for example climate, are not considered (i.e. *Land use potential* models are based on soil and landscape properties alone).

(d) The distinction between ***Analysis data*** and ***Mapping data***. Both *Soil and land attributes* and *Land use potential* datasets are underpinned by detailed estimates of the quantity and quality of landscapes [*Analysis data*] which can be used for calculating *Spatial data statistics*, but only a simplified version of this information can be presented in a map [*Mapping data*].

1.2 Soil landscape mapping framework

Between 1986 and 2001, Government of South Australia land resource assessment specialists, working under the auspices of the State Land and Soil Mapping Program (Hall *et al.* 2009), compiled a *Soil landscape mapping* coverage of South Australia's agricultural districts. These data are now managed by the Department of Environment, Water and Natural Resources (DEWNR). The *Soil landscape mapping* integrated field descriptions (soil profiles, sites and land forms), laboratory analysis of characteristic soil samples, stereoscopic visualisation of landscapes using aerial photographs, existing soil and geological maps and data, and conceptual models of regional landscape processes and stratigraphy—to provide an assessment of *Soil and land attributes* using defined classification criteria (Maschmedt 2002).

The mapping covered all land south of the South Australia's pastoral rangelands at a default scale of 1:100,000, with finer resolution mapping (1:50,000) undertaken in higher rainfall and more intensively-used areas (refer to linked map). *Soil landscape map units* were drawn onto aerial photographs and then digitised into a GIS database. These polygon boundaries provide the basis for all mapping discussed here.

> ***Soil landscape map units*** are areas of land defined by recognisable topographic features, formed on specific geological materials (or sequences of materials) and with a limited number of soils occurring in known (estimated) proportions.

In the mapping coverage, each *Soil landscape map unit* (*LANSLU* code) has up to eight characters. The first three characters define the *Land system* (i.e. abbreviation of the geographic name assigned to the *Land system*).

Land systems are broad and readily recognisable landscape areas defined by particular and distinctive patterns of geology, topography, soils and vegetation within a limited climatic range. Each *Land system* comprises one or more *Soil landscape units*.

The second three (or four) characters define the *Soil landscape unit*.

Soil landscape units have characteristic *Soil and land attribute* features.

Soil landscape units (*SLU*) can occur in different parts of the State, however it is the unique combination of *Land system* and *Soil landscape unit* codes that define each *Soil landscape map unit* (*LANSLU* code).

The *Soil and land attributes* recorded for each *Soil landscape map unit* have been used to create the *Land use potential* models.

1.3 What is land use potential?

Here we define ***Land use potential*** as the potential of soil and land to sustain a specific crop type.

The *Land use potential* modelling approach described in this report deals only with the *Soil and land attributes* which impact on the productivity and management requirements of different crops. This type of assessment describes the *capability* of land for a specific use.

We consider land *capability* differently to the assessment of land *suitability* for a particular use. Land *suitability* (not discussed further in this document) should consider dynamic and background influences such as economics, climate, landscape, soil type, pest and disease incidence, water availability (for irrigated crops), social considerations and regulations. For example, infertile land in a low rainfall area may have low production potential, but if the returns from a particular crop are sufficiently high, it may be a better option than another crop with higher productive potential. *Suitability* assessments often require a complex and multi-disciplinary approach, and can vary over time (e.g. year by year) for some crops.

2 Soil and land attributes

Soil and land attributes describe inherent (i.e. characteristic or natural) soil and land surface features that affect plant growth, land use and management and agricultural productivity. *Soil and land attributes* represent interpreted information and knowledge from land resource assessment specialists, designed to highlight key issues, limitations, opportunities, and potential impacts that can arise from the use and management of land.

As the diversity of soils and landscapes generally cannot be displayed at the scale of mapping, the surveyors developed a mapping system that captured underpinning comprehensive detail (in table format), together with rules to summarise useful or important features for map display.

2.1 How were soil and land attributes captured?

The main steps undertaken to capture *Soil and land attributes* were:

1. Developing standardised assessment methods

An assessment scheme was developed for each *Soil and land attribute* as described in *Assessing Agricultural Land* (Maschmedt 2002). Each *Soil and land attribute* has classes ranging from 1 to up to 8, as a means to highlight increasing limitation or susceptibility to degradation issues. Class 1 land represents no limitation with respect to the particular attribute, while the higher classes indicate more limiting or severe conditions.

2. Defining particular soil and landscape elements (components)

Field surveyors visualised the landscape in distinct elements (or components) based on recognisable features (for example dunes, swales, rises) in order to make separate assessments on each component of the landscape.

3. Capturing underlying complexity in linked data tables

At the scale of mapping, *Soil landscape map units* often comprise a number of landscape components (with a limited range of associated soils) which cannot be spatially defined.

For each landscape component, *Soil and land attribute* data have been captured and stored in a large table (*Soil landscape component table*), which has between one and five components for each map unit (one landscape component corresponds to one row in the table). Each component has an estimated proportion recorded, and these total to 100% for each map unit. Components belonging to a particular *Soil landscape map unit* will have the same *LANSLU* code, which provides a link between the detailed information in the *Soil landscape component table* and the GIS spatial data (mapping polygons). [To date, the *Soil landscape component table* has not been made publicly available, rather DEWNR staff use it to generate publicly available datasets.]

Because *Land use potential* models combine multiple *Soil and land attributes* to infer whether soil and land conditions support or inhibit growth of a particular plant, this is done at the component level (e.g. treating dunes separately from swales). This means each component is assessed separately when developing a *Land use potential* rating (discussed later) based on data stored in the *Soil landscape component table*.

[Available *Soil and land attribute* spatial datasets are also derived from the *Soil landscape component table*, by summing the component area proportions within each attribute class for each *Soil landscape map unit*. This is referred to as *Soil and land attribute Analysis data,* and can be used for calculating how much of each land class exists within a study area (this is also termed *Spatial data statistics*).]

4. Developing simplified Soil and land attribute mapping categories

To provide a useful visual summary, rules have been developed to convert the *Soil and land attribute Analysis data* into *Mapping data* (or map legend categories). Each *Soil and land attribute* dataset contains both *Mapping data* and *Analysis data*. Please see *Soil and land attribute* data descriptions for further information.

2.2 Soil and land attributes considered in land use potential models

In the *Soil landscape component table*, 36 *Soil and land attributes* (see Table 1 for list) are recorded for each *Soil landscape map unit*. For the purpose of assessing *Land use potential*, the *Soil and land attributes* are considered:

(a) separately, with regard to how each individual attribute may influence or limit potential crop growth, and

(b) in combination, in the context of eight groups or themes (see Table 1).

Soil and land attributes, and the role of groups, in relation to *Land use potential* assessment criteria and the development of modelling rules are discussed further in Section 5.

Not all *Soil and land attributes* are relevant to every crop and consequently they are not all used in every *Land use potential* model. Furthermore, some of the *Soil and land attributes* are closely linked to and overlap others (for example *Alkalinity* and *Sodium toxicity*). *Soil and land attributes* and guidelines for their assessment are described in *Assessing Agricultural Land* (Maschmedt 2002).

Table 1. ***Soil and land attribute* groups used in *Land use potential* modelling**

Soil and land attribute groups (with code letter) #		*Soil and land attribute* and code ^ (used in *Land use potential* rules)	
Soil type	-	Soils (soil type)	-
Topography	T	Steepness (as indicated by Water erosion potential) *	6e, 7e
		Surface rockiness	r
		Exposure	y
		Flooding susceptibility	f
Waterlogging / salinity / drainage	W	Waterlogging susceptibility	w
		Depth to watertable	o
		Salinity - watertable induced	s
		Deep drainage	b
		Recharge potential	q
Chemical barriers to root growth	B	Alkalinity	i
		Salinity - non-watertable (dry saline land)	v
		Boron toxicity	tb
		Sodium toxicity (sodicity)	ts
		Aluminium toxicity	ta
		Acid sulfate soil potential	j
Soil depth / water storage	D	Available waterholding capacity	m
		Depth to hard rock	xr
		Depth to hardpan	xp
		Potential rootzone depth:	
		Sensitive perennial horticultural crops (e.g. cirtus, avocado)	da
		Intermediate sensitivity perennial horticultural crops (e.g. stone fruits, almonds, pome fruits)	db
		Hardy perennial horticultural crops (e.g. grape vines, olives)	dc
		Annual root crops (e.g. potatoes, carrots, onions)	dd
		Above ground annual horticultural crops (e.g. brassicas)	de
Soil fertility	F	Inherent fertility	n
		Acidity	h
		Surface carbonate	ka
		Subsoil carbonate	kb
Soil physical conditions	S	Physical condition of surface soil	c
		Surface texture	-
		Structure of subsoil	p
		Water repellence	u
Erosion potential	E	Water erosion potential *	2e-5e
		Wind erosion potential	a
		Scalding	z
		Gully erosion	g
		Mass movement (landslip)	l

Soil and land attributes are grouped into related themes which are important for *Land use potential* assessment criteria.

^ *Soil and land attribute* codes from the *Soil landscape component table* (these are referred to in the example *Land use potential for wheat* rules).

* Note that *Water erosion potential* is present in two groups.

3 Land use potential crop types

3.1 Land use potential categories

Land use potential spatial datasets and maps have been developed for 45 crops and pasture types. These are grouped into seven broad categories as shown in Table 2.

3.2 Definition of land use potential assessment criteria

For all crops, the assessment criteria should be considered preliminary (draft). For some irrigated horticultural crops, criteria developed for the Murraylands Region of South Australia (Wilson and West 1998) were adapted. For other crops, information was provided by relevant industry consultants from Primary Industries and Regions, South Australia (PIRSA). It should be noted that during the development of assessment criteria there was a general lack of knowledge of subsoil requirements / tolerances of most crops. As a result, much of the criteria development relating to subsoil conditions was based on observations, and general understanding of the limitations imposed by the range of subsoil conditions encountered across South Australia's agricultural land.

3.3 Variations within a crop type

No account is taken of particular varietal or cultivar differences which may affect sensitivity to a particular attribute, i.e., the approach is generalized. For example, certain lucerne cultivars may have improved tolerance of acidic soils, but as a general rule, lucerne is sensitive to acidity, so acid soils are classified accordingly. [Note: *Land use potential for dryland lucerne (acid soil tolerant)* has been created and is available.]

3.4 Management considerations

A common observation relating to this type of generalised land classification is that a good manager can achieve equivalent or better production and resource protection outcomes from "low grade" land than a poor manager on "higher quality" land. This is undoubtedly true, but the purpose of this exercise is not to identify where certain activities should or should not occur, or how land should be managed, but rather to provide regional level information on the potential for specific crops managed according to accepted and recommended industry practices.

For example, wheat could be successfully grown on very poorly drained land if elaborate drainage systems were installed. However, this is not standard practice for wheat or any other field crop, so land subject to severe waterlogging is *Class 5** (low potential). Also, wheat production cannot be sustained on moderate slopes if seed bed preparation involves multiple destructive tillage passes and / or erosion control structures such as contour banks are not installed. Accepted practice specifies certain types of conservation tillage and use of engineered works to control erosion, so moderately sloping land is *Class 2** (moderately high potential). [*The *Land use potential* class rating system is discussed in Section 5.]

Table 2. Available *Land use potential* spatial data and map download links

Category	Crop	MAP *	SPATIAL DATA #
Field crops	Barley	MAP	DATA
	Canola	MAP	DATA
	Chickpeas	MAP	DATA
	Faba beans	MAP	DATA
	Field peas	MAP	DATA
	Lentils	MAP	DATA
	Lupins	MAP	DATA
	Oats	MAP	DATA
	Irrigated summer fodder (maize, millet and sorghum)	MAP	DATA
	Triticale	MAP	DATA
	Wheat	MAP	DATA
	Durum wheat	MAP	DATA
Perennial horticultural crops	Almonds	MAP	DATA
	Apples	MAP	DATA
	Cherries	MAP	DATA
	Chestnuts	MAP	DATA
	Citrus	MAP	DATA
	Grape vines	MAP	DATA
	Grape vines (mechanically harvested)	MAP	DATA
	Hazelnuts	MAP	DATA
	Olives	MAP	DATA
	Pears	MAP	DATA
Annual horticultural crops	Brassicas	MAP	DATA
	Carrots	MAP	DATA
	Onions	MAP	DATA
	Potatoes	MAP	DATA
Irrigated pastures	Irrigated pasture (best rating of irrigated: lucerne, high value perennial ryegrass, perennial ryegrass and white clover)	MAP	DATA
	Irrigated lucerne	MAP	DATA
	Irrigated perennial ryegrass (high value e.g. dairies)	MAP	DATA
	Irrigated perennial ryegrass	MAP	DATA
	Irrigated white clover	MAP	DATA
Dryland pastures	Dryland pasture (best rating of dryland: lucerne, phalaris, strawberry clover, subterranean clover and perennial ryegrass)	MAP	DATA
	Dryland lucerne	MAP	DATA
	Dryland lucerne (acid soil tolerant)	MAP	DATA
	Dryland phalaris	MAP	DATA
	Dryland strawberry clover	MAP	DATA
	Dryland subterranean clover	MAP	DATA
	Dryland perennial ryegrass	MAP	DATA
Native fodder	Mallee Saltbush (*Rhagodia preissii*)	MAP	DATA
	Mealy Saltbush (*Rhagodia parabolica*)	MAP	DATA
	Old-man Saltbush (*Atriplex nummularia*)	MAP	DATA
	Tall Scurf-pea (*Cullen australasicum*)	MAP	DATA
	Tar Bush (*Eremophila glabra*)	MAP	DATA
Alternative crops	Lavender	MAP	DATA
	Pyrethrum	MAP	DATA

* *Land use potential* maps are available for download from Enviro Data SA >Maps folder

Land use potential spatial data can be downloaded from Data.SA

4 Land use potential assessment criteria

The discussion of *Land use potential* assessment criteria in this chapter is provided for overview purposes only. Comprehensive and specific modelling rules have been developed on a crop-by-crop basis. By way of example, the assessment criteria (or rules) for wheat are provided in the Appendix.

Many of the *Soil and land attributes* listed in Table 1 are considered in the creation of *Land use potential* models. Following consultation with experts on each crop type, *Soil and land attribute* ratings are assigned to *Land use potential* classes (Table 3), to differentiate between land with high potential (*Class 1*) through to land with low potential (*Class 5*). This system is loosely based on the FAO classification (1976), and closely resembles the Western Australian system of van Gool and Moore (1999). Using the *Land use potential* assessment criteria discussed in this chapter, *Soil landscape map unit* components (i.e. landscape elements) are classified using the following class rating system.

Table 3. *Land use potential* class definitions

Land use potential class	Potential	Definition
Class 1	High	Land with high productive potential and requiring no more than standard management practices to sustain productivity.
Class 2	Moderately high	Land with moderately high productive potential and / or requiring specific, but widely accepted and used, management practices to sustain productivity.
Class 3	Moderate	Land with moderate productive potential and / or requiring specialized management practices to sustain productivity.
Class 4	Moderately low	Land with marginal productive potential and / or requiring very highly specialized management skills to sustain productivity.
Class 5	Low	Land with low productive potential and /or permanent limitations which effectively preclude its use.
Class X	Not applicable *	Urban, evaporation pans, quarry, water, rock, saline soil, reservoir, cliff, reef etc.

* Many *Soil landscape map unit components* are classed as 'X' for various *Soil and land attributes*. When any *Soil and land attribute*, considered in a *Land use potential* model, is classed as 'X' for a component, the resultant *Land use potential Class* for that component is '*X*'.

For example (see Appendix), *Soil landscape components* with a rating for waterlogging susceptibility ranging between 4-5 are considered to have a high degree of limitation (*Class 4*) for growing wheat. [Note that *Soil and land attribute* ratings shown in the example wheat rules reflect the raw detail, recorded by field surveyors, as listed in the *Soil landscape component table*.]

To reiterate in more detail, the development of *Land use potential* model rules involves the following steps:

(a) All relevant *Soil and land attributes* are considered, one attribute at a time, to assign every possible *Soil and land attribute* rating to a corresponding *Land use potential* class, based on the expected influence of that particular soil or land condition on the specific crop. It should be noted that the assignment of *Land use potential* classes corresponding to a *Soil and land attribute* rating can vary for different crops. For example, land with extensive surface stone and sheet rock can be ripped for grape vines, and presents only a moderate limitation (i.e. *Class 3*). However, for potatoes, extreme rockiness is a permanent and severe limitation, therefore the same land is rated *Class 5* for potatoes.

(b) Further downgrading may also occur due to interacting limitations, using additional assessment criteria taking account of the *Soil and land attribute* groups discussed previously (refer Table 1). For example, land which is rated *Class 3* due to waterlogging, inherent fertility and boron toxicity should not be in the same overall class as land which is *Class 3* due to inherent fertility alone. Where attributes from three or more attribute groups (refer Table 1) are jointly responsible for a particular ranking, the overall class for that land is downgraded by one category. In the preceding example, the land with three attributes contributing to a *Class 3* ranking is downgraded to *Class 4*. At the same time, care is taken not to double-count the influence of related *Soil and land attributes* in this downgrading process. For example, limitations due to waterlogging, salinity and depth to watertable occur within the same group (Table 1) and therefore would not by themselves prompt a downgrading. Also, by way of example, if watertable induced salinity and non-watertable salinity are the only limiting attributes, occurring in two groups ('W' and 'B' respectfully), then no further downgrading occurs.

(c) Within a particular *Soil landscape component*, the most limiting *Land use potential* class across all the attributes is ultimately assigned to that landscape component (i.e. 'most limiting factor' approach).

(d) The most limiting *Land use potential* classes, that are now ascribed to each and every landscape component, are subsequently summarised to list *Analysis data* classes for each map unit – this is described further in Section 5.

Soil and land attributes are discussed further below (grouped into themes) in the context of their effects on production potential for field crops, pastures and horticulture crops.

4.1 Topography

4.1.1 Steepness

In hilly country, slope gradient is a key determinant of defining water erosion classes. Slopes steeper than 30% cannot be negotiated safely by machinery other than straight up and down. Contour working is therefore not possible. Any uses involving cultivation are consequently not feasible on such slopes. In reality, slope limits for cultivated crops are significantly less than 30%, due to the potential for water erosion. Perennial crops and pastures can be managed on steeper slopes, however, because of erosion potential and practicability / safety issues, steep slopes are downgraded for all uses. Note: steepness is not recorded directly as a *Soil and land attribute*, however this is integrated into the assessment of water erosion potential, which is used as a surrogate.

4.1.2 Surface rockiness

Rock outcrop and surface stone affect productivity through interference and damage to equipment, the need to pick or roll stones, loss of arable area (where rocky outcrops occur), and harvesting/handling problems for root crops. Extensive outcrop renders land non-arable.

Field crops. Land which has sufficient surface stone to warrant picking and / or rolling is rated *Class 2* (due to the additional management input required). Land with 10-50% rocky reefs is rated *Class 3*. Class limits for rockiness are the same for all field crops except field peas where rocky land is ranked more severely due to the low growth habit of the plant and associated harvesting problems.

Pastures. The degree to which rockiness affects pasture potential depends on whether the pasture is only grazed (in which case even significant rockiness is not a major problem), or whether the pasture is to be mown for hay (in which case rockiness is a considerable limitation). Additional complications are caused by the type of rock. The relatively soft calcarenites and limestones of the South East do not present the same level of limitation as hard basement rocks or mallee calcretes. These South East landscapes are not ranked as severely as land with similar amounts of rock elsewhere.

Horticultural crops. For most perennial horticultural crops, land which has sufficient surface stone to warrant picking and / or rolling is rated *Class 2* (due to the additional management input required). Land with 10-50% rocky reefs is rated *Class 3*. For almonds, where harvesting may involve knocking, surface stone presents a more significant problem and rocky land is downgraded. Rocks and stone is a limitation for most annual crops, but root crops are more severely affected. Land requiring rock picking or stone crushing is rated *Class 4* for root crops.

4.1.3 Exposure

Exposure to wind reduces productivity through desiccation, foliar damage and root disturbance. Coastal exposure is a greater limitation than inland exposure because of the additional problem of salt spray.

Field crops. Land with inland exposure is rated *Class 2*, and with coastal exposure, *Class 3*.

Pastures. Exposure is less of a limitation for pastures. Only land with coastal exposure is downgraded to *Class 2*.

Horticultural crops. Land with inland exposure is rated *Class 2*, and with coastal exposure, *Class 3*.

4.2 Waterlogging / salinity / drainage

4.2.1 Waterlogging susceptibility

Waterlogging affects most plants by reducing or eliminating oxygen supply to the root system, creating favourable conditions for root-rotting anaerobic micro-organisms, and contributing to nitrogen loss. The assessment of waterlogging susceptibility is made on land under natural rainfall conditions (i.e. it is not necessarily an indicator of soil permeability). For example, a slowly permeable soil in a dry location may be assessed as well drained because rainfall is insufficient to saturate the soil in most seasons. The same soil under irrigation may be susceptible to waterlogging. In these situations, other attributes such as structure of subsoil and deep drainage potential are used to predict this limitation. Generally however, the assessment of waterlogging susceptibility provides a reasonable indication of the degree of limitation for various crops.

Field crops and pastures. No field crops and few pasture species can survive saturated conditions in the rootzone for more than three months, and most suffer losses after a few days to a week of waterlogging. Waterlogging resulting from rainfall is most likely to occur during winter / early spring when field crops and pasture plants are actively growing, so productivity on susceptible soils can be significantly affected, particularly in wet seasons. Oats and faba beans are the most tolerant of waterlogging. Chickpeas and lentils are the least tolerant. Field peas and barley are sensitive, but to a lesser extent. Wheat, triticale and canola are similar, with sensitivities between barley and oats. Productivity is seriously affected after several weeks of waterlogging, especially early in the season.

Perennial ryegrass (PRG), white clover and subterranean clover are relatively tolerant of waterlogging (PRG and white clover more so than subterranean clover), but lucerne is sensitive (similar to barley).

Horticultural crops. Most perennial horticultural crops have limited tolerance to waterlogging during their active growth periods. As this is usually summer, plants can tolerate some degree of winter waterlogging. However, there is always the risk of heavy rains in spring or summer, the effects of which can be significant if they follow irrigation events. Waterlogging susceptibility is an indicator of soil drainage under irrigation - a soil prone to winter waterlogging under natural rainfall is more likely to suffer wetness under irrigation than a soil which is naturally well drained. Note however the exception of dry climate soils mentioned in the introductory paragraph above.

Of the perennial crops assessed, pears are the most tolerant of waterlogging, followed by grape vines, almonds, apples and cherries are least tolerant.

Annual horticultural crops overall are less sensitive, as they have shallower roots. Waterlogging has an effect on the timing of crop production – i.e. establishment in wet locations will be delayed relative to better drained areas.

4.2.2 Depth to watertable

Depth to watertable is estimated as the shallowest depth maintained for at least two weeks in most years. In broadscale mapping, this assessment is generally an estimate, and as such can only be used as an indication of a possible limitation in crop potential interpretations. A watertable within the potential rootzone affects plant productivity in the same way as waterlogging. Saline watertables are clearly a more severe limitation than those which are non-saline.

Field crops. Non saline watertables deeper than 100 cm are not considered a limitation for field crops, and a minor limitation where depth is 50-100 cm. Where shallower than 50 cm, *Land use potential* is marginal to low. Where salinity occurs in the landscape, even as sporadic seepages, watertables become more restrictive. For example, a watertable at 50-100 cm is a moderate limitation.

Pastures. Perennial ryegrass and white clover are more tolerant of shallow watertables than are lucerne and subterranean clover, the latter two being ranked similarly to field crops.

Horticultural crops. Shallow watertables can impede drainage of irrigation water and prevent adequate flushing of salts, so irrigated crops are ranked more severely than rainfed crops. Watertables within 200 cm of the surface downgrade potential to moderate at best, for all horticultural crops, because of the associated risk of a rise in the watertable level and the accumulation of salts.

4.2.3 Salinity - watertable induced

Salinity affects plants by inhibiting their capacity to absorb water from the soil, i.e., salt affected plants are moisture stressed. Salinity also affects some plants through the toxic effects of sodium and / or chloride. Saline watertables affecting the potential rootzone may be natural or may result from European induced changes to hydrological equilibria. Except where drainage is an option, salinity is effectively unmanageable in the short term, except through the use of salt tolerant species. This severely restricts cropping options. Irrigated land uses have the potential to exacerbate salinity problems by increasing water accession to shallow groundwater tables. On the other hand, withdrawal of groundwater may have a net positive impact on watertable levels depending on local hydrogeological conditions.

Field crops and pastures. Barley is the most salt tolerant of the field crops. Wheat, triticale, oats and canola are somewhat less tolerant. Faba beans, chickpeas, field peas and lupins are more sensitive again, while lentils stand alone in being most susceptible to salinity. Of the pasture species assessed, white clover is most susceptible to salinity (similar to lentils), while lucerne, perennial ryegrass and subterranean clover have tolerances similar to that of wheat.

Ratings attributable to salinity for most crop and pasture species are downgraded where soil drainage is imperfect or worse. Similarly, ratings are downgraded if there is patchy salinity in the landscape. Patchy salinity indicates that saline watertables are present, albeit at variable depths, and that there is potential for rising watertables to cause problems.

Horticultural crops. All horticultural crops are sensitive to salinity. Even moderately low salinity levels downgrade land for almonds, apples, cherries and pears to *Class 3*. Olives and grape vines are more tolerant. Brassicas and potatoes are similarly relatively tolerant, compared with carrots and onions which have high susceptibility to salt.

Rankings for all horticultural crops are downgraded where deep drainage potential and / or depth to watertable are anything other than optimal. As for field crops and pastures, patchy salinity in the landscape downgrades the ranking attributable to salinity.

4.2.4 Deep drainage potential

Deep drainage potential is the capacity of the deep subsoil and the material immediately underlying the soil profile to transmit water away from the rootzone. Tight clays, notably the Blanchetown and Hindmarsh Clays, or their equivalents, in the 50-200 cm depth range, are the main impediment to deep drainage in South Australia. The situation is complicated where shallow watertables occur, as these also restrict downward water movement. Restricted deep drainage prevents leaching of salts, and can therefore have an indirect effect on dryland crops and pastures. However, the main impact of deep drainage limitation is on irrigated land where the hydrology of the soil profile is significantly altered.

Field crops and pastures. Deep drainage potential is not considered when assessing potential for field crops and pastures under dryland conditions, as any effects that it has on water movement are allowed for in the assessment of waterlogging susceptibility. The indirect effects on subsoil accumulations of salt, boron and sodicity are dealt with elsewhere (see Chemical barriers to root growth). Deep drainage potential is considered in the assessments for irrigated pastures, as a deep drainage barrier, shallower than 50 cm can cause watertables and salinity to build up in the potential rootzone.

Horticultural crops. Deep drainage restriction is a major threat to the sustainability of horticultural plantings, the majority of which are irrigated. The impact of substantial increases in water flow through soils must be considered. Deep drainage conditions determine the fate of any water applications in excess of crop requirements. Heavy rain following irrigation can upset even the most carefully scheduled irrigation plan, although even these usually include a leaching component which entails water percolating below the rootzone. Shallow rooted annual crops are less sensitive to drainage impediments than deeper rooted perennial crops. For most perennial crops, drainage restriction within 100 cm is likely to lead to problems of salt accumulation and shallow watertable development in the medium to long term at least. For annual crops, the critical depth is around 50 cm.

4.3 Soil depth / water storage

4.3.1 Available waterholding capacity

The amount of water stored in the rootzone determines the length of time that a plant can survive between rain events. In South Australia where rainfall, especially at the opening and the close of the growing season is erratic, available waterholding capacity is critical for the success of dryland crops and pastures. On irrigated land, irrigation scheduling largely overcomes any limitation.

Field crops and pastures. Most crop species will not persist on soils with less than 20 mm of plant available moisture in the rootzone. Barley, field peas, lupins and triticale are the most hardy on soils with limited moisture storage capacity. Faba beans are least likely to perform where limited moisture is available. Early maturing species and cultivars are at an advantage on soils with limited capacity. Of the pastures, deeper rooted species such as lucerne are most susceptible to soils with limited waterholding capacity, while shallow rooted plants like clovers are better suited to such conditions. For irrigated pastures, low available waterholding capacity is not a serious limitation.

Horticultural crops. Available waterholding capacity is not used in the assessment of horticultural crops (assuming that they are irrigated). Potential rootzone depth is used to determine the capacity of the soil to support plant growth.

4.3.2 Depth to hard rock or hardpan

Hard basement rock underlies most hillslopes in the Northern Agricultural Districts, Mount Lofty Ranges, Lower and Eastern Eyre Peninsula and parts of Kangaroo Island. Hardpan, predominantly calcrete, underlies the soils in parts of the Murray Mallee, Eyre and Yorke Peninsulas, and the Gulf Plains. Calcrete capped clays, limestones and dune sands are common in the South East of the State. These materials are defined as not penetrable with hand tools, and as such support little if any root growth.

Depth to hard rock or depth to hardpan are not used as stand-alone criteria in these classifications, but are incorporated into available waterholding capacity and potential rootzone depth. Many shallow soils are further downgraded due to rockiness (above)

4.3.3 Potential rootzone depth

Potential rootzone depth indicates the "irrigable depth" of the soil profile. It is determined by the depth to restrictive layers such as poorly structured clays, carbonate accumulations and hard rock or pans. Potential rootzone depth varies between species, depending on their capacity to penetrate various materials.

Field crops and pastures. Potential rootzone depth is not used in assessments for dryland crops and pastures.

Horticultural crops. The roots of grape vines and olives can penetrate further into poorly structured clays and carbonate layers than can the roots of most other horticultural crops. For a given *Soil landscape component*, potential root depth therefore varies, depending on the crop. Potential rootzone depth is assessed for each of five crop type categories, and the most appropriate category is used in the assessment of a specific crop.

Potential rootzone depth categories are:

A. Sensitive perennial horticultural crops (e.g. citrus, avocado)
B. Intermediate sensitivity perennial horticultural crops (e.g. stone fruits, almonds, pome fruits)
C. Hardy perennial horticultural crops (e.g. grape vines, olives)
D. Annual root crops (e.g. potatoes, carrots, onions)
E. Above ground annual horticultural crops (e.g. brassicas)

The depth requirements for shallower rooted annual crops are less than for perennial crops. For crops where mounding is standard practice (e.g. potatoes), there must be sufficient depth in which to form the mounds. Root crops need sufficient depth to prevent deformities of the product. Annual crops need 20-30 cm of root depth, while perennial crops need 40-50 cm.

4.4 Chemical barriers to root growth

4.4.1 Alkalinity

Like acidity (refer to Soil fertility section), alkalinity affects nutrient availability and uptake. Unlike acidity, alkalinity cannot be corrected in a commercial or broadacre situation.

Field crops and pastures. Root growth of most field crops is very poor to non-existent where pH (water) exceeds 9.2 (i.e. soil is strongly alkaline). Barley, field peas and lentils are the most tolerant to alkaline soils, and can maintain productivity when soils are strongly alkaline within 30 cm of the surface. Triticale and wheat are the next most tolerant, followed by faba beans and chickpeas. Canola, lupins and oats are the most susceptible to soil alkalinity. Perennial ryegrass and the clovers are highly sensitive to alkalinity, with lucerne more tolerant.

Horticultural crops. Most horticultural crops are intolerant of strongly alkaline soils. Strong alkalinity downgrades land to *Class 3* for most perennial crops and *Class 4* for annual crops.

4.4.2 Non-watertable salinity (dry saline land)

Salts which have accumulated in the soil in the absence of watertables have the potential to restrict root growth and hence water use efficiency. In irrigated situations, initial water applications may be used to flush salts out of the potential rootzone, but this can only occur if deep drainage is not restricted.

Field crops and pastures. Whilst the effects of watertable induced salinity, and extreme cases of non-watertable induced salinity (magnesia ground) are well known, the impact on productivity of moderately low to moderate levels of subsoil salinity, where there are no surface expressions, are not well understood but are potentially significant. Barley is the most salt tolerant of the field crops, followed by wheat, triticale, oats and canola. Faba beans, chickpeas, field peas and lupins are more sensitive, while lentils have very low salt tolerance. Lucerne, perennial ryegrass, subterranean clover and white clover are all moderately tolerant of soil salinity. Land with magnesia patches is downgraded by up to three classes depending on the severity of the problem.

Horticultural crops. Where there is capacity for leaching, non-watertable salinity is not a significant limitation. Where leaching capacity is restricted, salt sensitivities as discussed previously apply. Of the perennial crops for which assessments have been developed, cherries and almonds are the most susceptible to damage by salt. Annual crops, with shallower root systems, are generally moderately tolerant. Land with magnesia patches is downgraded by up to four classes, depending on the severity of the problem.

4.4.3 Toxic elements

Toxic elements in the potential rootzone effectively limit the depth to which plants can extract moisture and nutrients. In SA's agricultural districts, boron and sodium toxicity are widespread, while aluminium toxicity can be a problem in acidic soils (invariably in higher rainfall areas). Data on critical concentrations of boron and sodium for crops (other than boron in cereals) is sparse. Boron toxicity is determined by the depth to concentrations exceeding 15 mg/kg, while sodium toxicity is determined by the depth to exchangeable sodium percentages (ESP) exceeding 25. Aluminium toxicity is determined by the concentration of extractable aluminium in the potential rootzone.

Field crops and pastures. For cereals, boron concentrations of 15 mg/kg are critical. In the absence of data for other crop types, the same limits are used for all crops – i.e. no differentiation has been made between crops with regard to susceptibility to boron toxicity. Some evidence suggests that barley, canola and triticale have better tolerance of sodicity than other crops, and that oats are less tolerant. Aluminium toxicity is generally not a limitation for field crops which are mostly grown in medium to low rainfall areas where the acidic soils associated with aluminium toxicity do not occur, or where acidity can be easily corrected. For those situations where acidic soils do occur, aluminium toxicity downgrades, due to acidity. Of the pasture species, lucerne is sensitive to aluminium, but perennial ryegrass, white clover and subterranean clover are tolerant.

Horticultural crops. Available data suggest that horticultural crops are more boron sensitive than field crops. Boron concentrations in excess of 15 mg/kg and shallower than 100 cm downgrade the potential of perennial crops to *Class 3* or worse. Shallower rooted annual crops are not affected by boron until high concentrations occur within 50 cm of the soil surface. In the absence of data on sodium toxicity, the critical limits used for intermediate sensitivity horticultural crops are used as an interim measure – e.g. exchangable sodium percentages (ESP) of more than 25 at depths of 25-50 cm ranks land for all horticultural crops as *Class 3*. Most horticultural crops are sensitive to aluminium, with high levels of aluminium downgrading potential to *Class 3*.

4.5 Soil fertility

4.5.1 Inherent fertility

Inherent fertility is a subjective assessment of the soil's capacity to store and release nutrients. It is judged by exchangeable cation characteristics, clay and organic matter content, leaching capacity, acidification potential, and carbonate and ironstone content. Different species vary in their nutrient requirements - those with lower requirements or more efficient uptake mechanisms perform better on soils of low inherently fertility.

Field crops. Barley, lupins and triticale seem to perform better on poor (low fertility) soils than other field crops. Faba beans, canola, wheat and oats prefer more fertile soils. Chickpeas, field peas and lentils are intermediate.

Pastures. Lucerne and white clover are more tolerant of low fertility than subterranean clover, while perennial ryegrass has high fertility requirements (similar to faba beans, canola and wheat).

Horticultural crops. Low fertility is generally less of a limitation for horticultural crops than for field crops because overcoming nutrition problems is easier (smaller areas, fertigation options, high value returns).

4.5.2 Acidity

Acidity affects the availability of nutrients in the soil, reduces the nutrient retention capacity of the soil, and inhibits the activity of some micro-organisms essential for healthy plant growth. The capacity of root hairs to take up nutrients may also be reduced in acidic soils, partly due to damage caused by aluminium, the solubility of which increases at lower pH (see toxic elements). Susceptibility to acidity is determined through a combination of actual measurements and extrapolation between similar soil landscape environments. All landscapes which are susceptible to acidity are classified accordingly, regardless of ameliorative measures which may have been implemented. Subsoil pH is considered as well as surface pH, as many South Australian cropping soils have a pH range of up to four units within the potential rootzone.

Field crops and pastures. Barley, canola, lupins, oats, triticale and wheat are all reasonably tolerant of acidic soils. Faba beans, chickpeas, field peas and lentils are intolerant. For example, a soil with an acidic surface and neutral subsoil is *Class 1* for barley and wheat, and *Class 2* for faba beans, while a soil with a strongly acidic surface and an acidic subsoil is *Class 3* for barley and wheat, and *Class 4* for faba beans. Lucerne is highly intolerant of acidic soils, while perennial ryegrass and the clovers are tolerant. Where a crop is sensitive to aluminium, and aluminium levels are elevated, the ranking due to acidity is downgraded.

Horticultural crops. Apples, grape vines and pears are more tolerant of acidity than almonds, cherries and olives. For example, soils which are acidic in both the surface and subsoil do not limit grape vines, but rank *Class 3* for almonds. For shallow rooted annual crops where acidity in the rootzone is easily ameliorated, acidity is not a significant limitation.

4.5.3 Soil carbonates

Fine earth carbonates at shallow depth in the soil affect nutrient availability and uptake. Carbonate effects become significant when concentrations exceed 8-10%. The effects of hard carbonates, pans and heavy rubble layers which affect root depth and moisture storage are accounted for under the headings of potential rootzone depth and available waterholding capacity.

Field crops and pastures. Chickpeas are the most tolerant of “limy” soils, followed by barley and triticale. Lupins are notorious for their intolerance of soil carbonate. They are substantially more sensitive than any other field crop. Lucerne and perennial ryegrass are tolerant of carbonates at shallow depth, but the clovers perform poorly on any soil with carbonates in the upper 30 cm.

Horticultural crops. Perennial horticultural crops with the exception of grape vines and olives, which are highly tolerant, prefer carbonate free conditions to 60 cm. Most annual crops prefer 30 cm of carbonate free soil, but potatoes are more sensitive.

4.6 Soil physical condition

4.6.1 Physical condition of surface soil

The condition or strength of the soil surface affects water infiltration, workability, seedling emergence and erodibility. Loose to friable surface soils present few problems for any crop. Hard setting soils are more susceptible to problems, while dispersive soils are highly susceptible to damage and restrict plant growth.

Field crops and pastures. The fibrous root systems of cereals are less affected by hard setting surface soils than are the roots of other crop plants. Land with hard setting surface soils is not downgraded for cereals, but is *Class 2* for other crop and pasture species. Dispersive soils are problems for all crops and are *Class 3* or *Class 4*.

Horticultural crops. Surface soils in orchards and vineyards are not usually worked post establishment, so hard setting surface soils are not a limitation. Where soils are regularly cultivated, hard setting surfaces present a slight limitation and the land is consequently downgraded for annual crops to *Class 2*. Dispersive soils are problems for all annual crops and downgrade land to *Class 3* or *Class 4*.

4.6.2 Surface soil texture

Surface soil texture is used in some *Land use potential* assessments either as an additional means of downgrading low fertility sandy soils, or to downgrade clayey surfaces which are undesirable for root crops.

Field crops and pastures. Sandy surface soils are downgraded when assessing potential for faba beans and perennial ryegrass, because of their high fertility requirements.

Horticultural crops. Sandy soils are downgraded for brassicas because of their high fertility requirements. Clay loamy and clayey surface soils are downgraded for all annual crops because of their adverse effects on workability and trafficability, and on digging and cleaning of root crops.

4.6.3 Susceptibility to water repellence

Water repellence affects crop establishment and increases the risk of both wind and water erosion, and sand blasting. It is less of a limitation for irrigated crops than in rainfed situations because amelioration is simpler.

Field crops and pastures. Strong water repellence reduces crop and pasture potential to moderate at best. Although the problem can be managed, it is an expensive procedure on a broadacre scale, consistent with the definition of *Class 3* land. Water repellent soils are commonly associated with low fertility and high wind erosion potential, which both downgrade *Land use potential*. As a consequence, water repellence is rarely the principal limitation to crop production.

Horticultural crops. The impact of water repellence on horticultural crops can be as severe as on rainfed crops, but the problem is more readily managed on smaller area irrigation enterprises. Therefore land is never ranked lower than *Class 2* on account of water repellence.

4.6.4 Structure of subsoil

The nature of subsoil affects water movement and root growth. Structural characteristics, strength and depth are the determinants of the degree to which subsoil materials impact on root growth and permeability. The effects of unfavourable subsoil structure are reflected in other attributes, mainly waterlogging susceptibility, available waterholding capacity and potential rootzone depth. This apparent "doubling up" serves to reinforce the importance of adequate water movement through the soil, and of favourable subsoil physical conditions for root growth.

Field crops and pastures. Although tap-rooted species like lucerne may have some advantages, there is no conclusive evidence to indicate that any particular crop or pasture species has more or less capacity than any other to proliferate in poorly structured subsoils. Dispersive clay subsoils shallower than 10 cm prevent the development of adequate root systems and are *Class 4* for all field crops and pastures.

Horticultural crops. Because of the risk of rising watertables and salt accumulation under irrigated horticulture, poor subsoil structure is a potentially more serious problem in irrigated situations than on dryland, so land with dispersive clay subsoil within 60 cm, or non-dispersive clay within 30 cm is downgraded. Dispersive clay subsoils shallower than 10 cm are *Class 5*.

4.7 Erosion potential

4.7.1 Water erosion potential

In hilly country, slope gradient is a key determinant of land class. Any uses involving cultivation are not possible on slopes steeper than 30%. In reality, the risk of erosion generally determines an upper slope limit of 20% for cultivated land uses, but slopes steeper than 8-12% (depending on soil erodibility) require very high levels of conservation management. Perennial crops and pastures can be managed on steeper slopes, but erosion potential and practicability / safety issues cause steep slopes to be downgraded for all uses.

Unchecked erosion causes loss of nutrients and organic matter (which are concentrated in the upper few cm), and loss of soil depth and structure. Off-site consequences include damage to fences, siltation of culverts, waterways, dams and roads, pollution of water supplies, and weed seed dispersal. Land is ranked more severely for uses which entail regular cultivation. Consequently sloping land has a higher degree of limitation for annual crops than it does for perennial crops and pastures.

Field crops. Some degree of soil disturbance or at least cover reduction is an inevitable part of annual cropping, and erosion risk increases in the process. Land on which contour banks have traditionally been recommended is *Class 2*. Land with slopes greater than about 16-20% (depending on soil erodibility) is *Class 4*. Class limits for water erosion potential are the same for all field crops as they involve similar establishment techniques.

Pastures. Although soil disturbance occurs during establishment, over the long term erosion risk is lower on well managed perennial pastures than on cropped land. For example, slopes which rank *Class 4* for field crops are *Class 2* for perennial pastures.

Horticultural crops. Once established, there should be minimal risk of water erosion in perennial crops. Land with high erosion potential poses a minimal risk for well managed orchards or vineyards, so only steep slopes (greater than 30% gradient), is downgraded beyond water erosion potential Class 2. Annual crops are similar to field crops in that regular soil disturbance is required, and for root crops, this disturbance is more severe. Slopes which rank as *Class 2* for field crops (and *Class 1* for perennial horticultural crops and pastures) are *Class 3* for annual root crops.

4.7.2 Wind erosion potential

Wind erosion potential is a critical determinant of land class in sandy country. Wind erosion is responsible for substantial losses of nutrients and organic matter, and loss of soil depth. Drift on fencelines and roads is well-known, and dust storms create safety hazards (e.g. on roads), and cause incalculable damage to machinery and appliances. The greater the degree of disturbance, the greater the risk of wind erosion on any given area of land. Consequently, wind erosion-prone land has a higher degree of limitation for annual crops than it does for perennial crops and pastures.

Field crops. Because wind erosion is a function of soil type, topography, soil management practices and seasonal conditions, all crops are affected to similar degrees. The exception is field peas, the vines of which have little capacity to bind the soil after harvest. *Land use potential for field peas* on wind erosion-prone land is therefore less than for other crops. For example, a deep sand on a low sandhill in a medium rainfall area is *Class 3* for most crops, but *Class 4* for field peas.

Pastures. Once established, well managed perennial pastures should be at lower risk of wind erosion than cropped paddocks (with either crop, stubble or volunteer pasture). The deep sand on a low sandhill in a medium rainfall area (previous paragraph) is *Class 2* for perennial pastures.

Horticultural crops. Well managed orchards and vineyards are at a relatively low risk of wind erosion, once established. The deep sand on a low sandhill in the medium rainfall district (above) is *Class 2* for perennial horticultural crops. Annual crops with regular cultivation are at a higher risk – higher than field crops because of the additional surface disturbance that is usually involved. Irrigation systems can be used to stimulate surface cover, so this extra risk is partially offset. The low sandhill (above) is *Class 3* for annual horticultural crops.

4.7.3 Scalding

Scalds, resulting from the exposure of inhospitable subsoils by erosion in the past, reduces productive potential by reducing arable area. Land susceptible to scalding is fragile and requires conservative management.

Field crops and pastures. As a land surface feature, the impact of scalding is independent of crop type. Criteria for scalding is the same for all crop and pasture species. For example, land where 5-10% of the area is affected by scalding is *Class 3*.

Horticultural crops. As a land surface feature, the impact of scalding is independent of crop type. Criteria for scalding is the same for all horticultural crops. For example, land where 5-10% of the area is affected by scalding is *Class 3*.

4.7.4 Gully erosion

Apart from their land degradation aspects, erosion gullies affect accessibility and hinder the installation and use of irrigation systems. Land is assessed according to the proportion of land affected by gullying – all crop types are affected to a similar degree.

Field crops and pastures. Minor erosion gullies are not considered a problem, but where more than 5% of the land is affected, land is downgraded (non-irrigated perennial pastures are less affected than crops or irrigated pastures). Land where gully erosion accounts for 10-20% of the area is *Class 3* (*Class 2* for non-irrigated perennial pastures) due to the operational problems and risk of further degradation.

Horticultural crops. Gully erosion is considered to impose a similar level of restriction on land for horticulture as it does for field crops and irrigated pastures.

4.7.5 Mass movement (landslip)

Land affected by or prone to mass movement is usually too steep for cropping, but generally has some potential for grazing or perennial horticulture.

Field crops. Land at risk of mass movement (landslip) but presently unaffected does not present any particular limitation to cropping on its own, but because it is ranked *Class 3* or worse due to water erosion potential, it is similarly classified with respect to mass movement.

Pastures. The grazing potential of land at risk of, or affected by mass movement is only reduced by the loss of land which is either affected or is being revegetated for landslip control purposes. Affected land is downgraded by one or two classes depending on the severity of mass movement, and by two to four classes for irrigated pastures.

Horticultural crops. Land at risk of mass movement represents a moderate limitation for perennial horticulture (through the potential damage to investment), and is ranked *Class 3*. Affected land has little or no potential. In the case of annual crops, land at risk of mass movement is at least *Class 3* on account of its potential for water erosion, and is ranked accordingly.

4.8 Other important criteria (not included)

Land use potential assessments are based on soil and land properties, however assessment of the *suitability* of land for a particular use, should consider a range of other background and dynamic influences such as economics, climate, landscape, soil type, pest and disease incidence, water availability (for irrigated crops), social considerations and regulations. We do not attempt to provide a comprehensive discussion on other factors that should be considered in land suitability assessments.

The quality and quantity of water supplies are essential considerations when assessing land suitability for irrigated crops. Where available, water resource data should be incorporated into irrigation development assessments. Tolerance of salinity in applied water will vary by crop type.

5 Land use potential Analysis data

Analysis data refers to the estimated area proportions of each *Land use potential* attribute class.

Analysis data comes from the *Class* rating (*1-5*) given to each *Soil landscape map unit component*, as outlined in Section 4. Once the *Land use potential* class is determined for each *component* of each *Soil landscape map unit*, the proportions of each *Land use potential* class are summed for each map unit – to create summary tables of ***Land use potential Analysis data***. Similarly, *Analysis data* can be summarised and reported using larger spatial boundaries. *Land use potential Analysis data* classes mirror the *Land use potential* classes shown in Table 3 (Section 4).

5.1 Analysis data example

The concept of *Land use potential Analysis data* is illustrated in Figure 1, using an example view from NatureMaps which shows *Land use potential for wheat*. The "Point" selection tool (from the "Select Tools" tab) has been used to select one polygon and "View additional detail" of the *Soil landscape map unit* labelled *BOWUEF* (note that the sum of all the *Analysis data* class proportions = 100%).

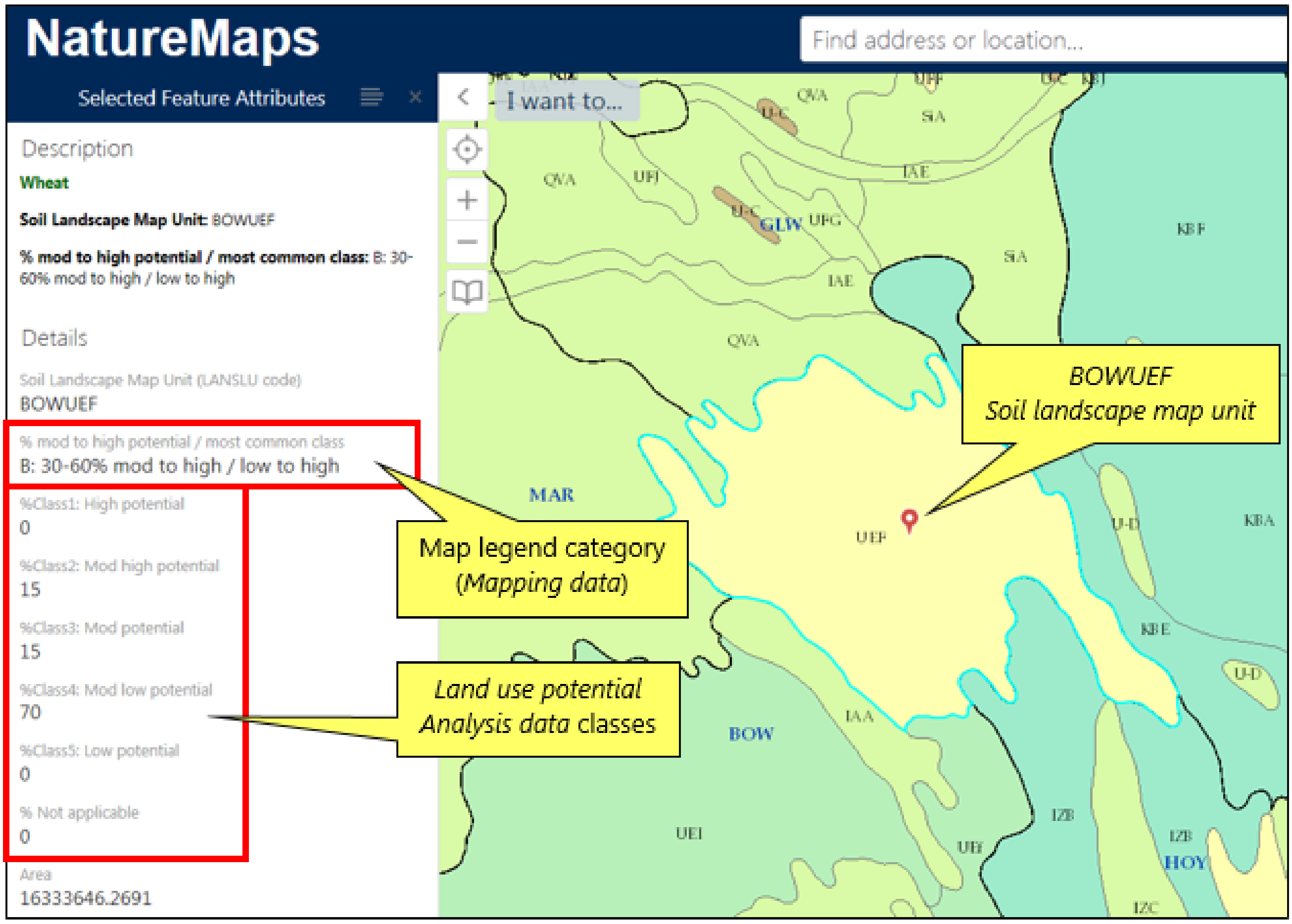

Figure 1. Example query from NatureMaps, highlighting *Soil landscape map unit BOWUEF* with a legend category "B" (*Mapping data*) and listing *Land use potential Analysis data*

5.2 Using Analysis data to create spatial data statistics

***Spatial data statistics* are derived from the detailed area estimates of *Analysis data*.**

Spatial data statistics, calculated from *Land use potential* spatial data, are displayed as a summary table of the area of each *Land use potential Analysis data* class.

To calculate *Land use potential Spatial data statistics* for a study area, proportions of each *Land use potential Analysis data class* within each *Soil landscape map unit* are multiplied by the area of each *Soil landscape map unit*, and then summed for the study area.

Using the example in Figure 1, above, the area proportions for each *Analysis data class* have been multiplied by the area (m^2) of the *Soil landscape map unit (BOWUEF)* to calculate *Spatial data statistics*, as displayed in Table 4, below.

Table 4. *Land use potential for wheat Spatial data statistics* calculated for *BOWUEF Soil landscape map unit* from *Land use potential Analysis data*

Land use potential Analysis data class	*Class 1*	*Class 2*	*Class 3*	*Class 4*	*Class 5*	*Class X*	TOTAL
Potential	High potential	Moderately high potential	Moderate potential	Moderately low potential	Low potential	Not applicable	
Proportion of *BOWUEF*	0%	15%	15%	70%	0%	0%	100%
Area (m^2)	0	2,450,046	2,450,047	11,433,552	0	0	16,333,645

Example across southern South Australia (i.e. full extent of soil mapping): summary *Spatial data statistics* for *Land use potential for wheat* tally as follows.

Table 5. Summary *Spatial data statistics* of southern South Australia for *Land use potential for wheat*

Analysis data class	Area (ha)	Potential	Description
Class 1	47,758	High potential	Land with high productive potential and requiring no more than standard management practices to sustain productivity.
Class 2	885,734	Moderately high potential	Land with moderately high productive potential and / or requiring specific, but widely accepted and used, management practices to sustain productivity.
Class 3	5,522,092	Moderate potential	Land with moderate productive potential and / or requiring specialized management practices to sustain productivity.
Class 4	5,034,590	Moderately low potential	Land with marginal productive potential and / or requiring very highly specialized management skills to sustain productivity.
Class 5	4,045,233	Low potential	Land with low productive potential and /or permanent limitations which effectively preclude its use.
Class X	230,052	Not applicable	Not applicable (urban, lakes, reservoirs, evaporation pans, quarry, etc.)
TOTAL	15,765,459		

Key message:

***Land use potential Analysis data* should be used to calculate summary *Spatial data statistics*.**

6 Land use potential Mapping data

Land use potential Mapping data has been simplified FROM _Analysis data_ for map display purposes.

6.1 Rules for determining Land use potential mapping categories

Pre-determined rules are applied to the *Analysis data* (*Classes 1, 2, 3, 4, 5* and *X*) to assign map legend categories (*Mapping data*). The rules have been designed to convey a practical summary of the information (see Table 6), which can be displayed visually, taking into account the variability of *Land use potential* within a map unit.

Map legend categories (or *Mapping data*) assigned to *Soil landscape map units* represent a summary of the *Analysis data*.

Table 6. Rules used to assign _Land use potential_ mapping categories to _Soil landscape map units_

Land use potential mapping categories	Rules to assign *Land use potential* mapping categories (*Mapping data*)	Order of assigning mapping categories
Aa	If *Class 1* ≥ 60%	2
Ab	If sum (*Classes 1+2*) ≥ 60% *(and mapping category not already assigned)*	3
Ac	If sum (*Classes 1+2+3*) ≥ 60% *(and mapping category not already assigned)*	5
Ad	*Class 3* ≥ 60% and (*Classes 1+2*) < 1% *(and mapping category not already assigned)*	4
B	If sum (*Classes 1+2+3*) ≥ 30-60% *(and mapping category not already assigned)*	6
C	If sum (*Classes 1+2+3*) ≥ 10-30% *(and mapping category not already assigned)*	7
D	If sum (*Classes 1+2+3*) ≥ 1-10% *(and mapping category not already assigned)*	8
Ea	If *Class 4* ≥ 50% *(and mapping category not already assigned)*	9
Eb	Any remaining map unit with mapping category not already assigned	10
X	If *Class X* ≥ 70%	1

Key message:

Mapping data should NOT be used to calculate summary _Spatial data statistics_.

6.2 Land use potential map legend category descriptions

For areas where *Soil landscape map units* have been mapped uniformly (i.e. there is only one component, within a *Soil landscape map unit*), the *Analysis data* have a uniform class rating for the entire (100%) *Soil landscape map unit*. This means *Land use potential* mapping categories can simply be drawn using five classes for the crop in question. This situation occurs, for example, across most of the Mount Lofty Ranges.

However, much of the land in South Australia's agricultural districts is complex, in that significant variations in soil type or land surface features occur over short distances (e.g. dune-swale systems, stony rises on sandy plains etc.). These variations cannot be differentiated in mapping at regional 1:100,000 or 1:50,000 scale assessments. Consequently, many map units comprise of two or more components with variable *Land use potential*. As discussed previously, a proportional mapping approach has been used to account for this variability. This introduces a degree of complexity into the mapping product, but for heterogeneous landscapes where relatively minor components are important for some crops, it is the best compromise.

A nine class map legend system is used to convey various proportions of *Land use potential* classes that can occur, as shown in Table 7. Note that in areas where *Soil landscape map units* consist of single components, only five of the nine classes are applicable (shown in bold).

Table 7. *Land use potential* mapping categories

Mapping category	Proportion of land with moderate to high potential	Most common potential class
Aa	More than 60%	High potential (**mostly *Class 1***)
Ab	More than 60%	Moderately high potential (**mostly *Class 2***)
Ac	More than 60%	Moderate to high (mixed)
Ad	More than 60%	Moderate potential (**mostly *Class 3***)
B	30-60%	Low to high potential (mixed)
C	10-30%	Moderately low to low potential (mixed)
D	1-10%	Moderately low to low potential (mixed)
Ea	Less than 1%	Moderately low potential (**mostly *Class 4***)
Eb	Less than 1%	Low potential (**mostly *Class 5***)
X	-	-

Using the NatureMaps example of *Land use potential for wheat* in Figure 1, *Soil landscape map unit, BOWUEF,* has been assigned a map legend category **B**.

Soil Landscape Map Unit (LANSLU code)
BOWUEF
% mod to high potential / most common class
B: 30-60% mod to high / low to high

6.3 Notes on the use of Land use potential maps

The following general principles need to be considered (and communicated) when creating and using *Land use potential* maps:

1 Potential based on *Land and soil attributes* only – no account has been taken of water quality or availability, climatic factors or existing land use.

2 Classes are based on interpretations of *Soil landscape map units*. The most limiting feature of a *Soil landscape map unit* determines the overall class of that unit. *Soil landscape map units* are not homogenous entities - the class is intended to reflect the most common characteristics of the landscape. Unspecified variations occur.

3 Boundaries between mapping units should be treated as transition zones.
Soil landscape map unit boundaries are typically not as sharp as lines on maps imply. Changes may occur imperceptibly over a distance of a kilometre or more, so changes from one legend category to another can be assumed to be gradual.

4 This information is derived from limited field assessments and / or laboratory data, and estimates based on personal experience or judgement may be used where data are unavailable.

DEWNR Soil and Land Program will consider any feedback, comments, suggestions or data which can be used to improve the accuracy and utility of this mapping.

5 The interpretation methodologies are in developmental stage, and only limited verification has been undertaken. Mapping classes are subject to change without notice.

6 The maps are intended to provide a regional overview and should not be used to draw conclusions about conditions at specific locations.

Land use potential maps contain a significant level of generalisation. *Analysis data* accounts for the heterogeneity within map units. Simplified *Mapping data* with generalised map legend categories cannot depict spatial features at a paddock-scale. Maps are only intended to provide a visual representation of where particular conditions are likely to occur. At best, the mapping can be used to provide an overview of property-level conditions. Zooming in on specific areas and treating map units as homogeneous entities will be misleading. For site specific information, on-site inspection is recommended.

7 The scale of maps should not be enlarged beyond their scale of publication.

Mapping information is presented at a scale which reflects its reliability. Information presented at 1:100,000 scale, is based on relatively low density ground-truthing and is for regional, sub-regional and catchment-level applications only. Enlargement of a 1:100,000 scale map to 1:20,000 for example, is technically easy, but generates a misleading product in which the level of apparent precision cannot be justified.

8 Independent expert advice should be sought prior to using this information for commercial decision-making

The production of *Land use potential* maps involves a considerable degree of interpretation of a range of data compiled by land resource assessment specialists. Although every effort is made to document the processes underpinning these interpretations, there may be some situations in which a particular use of the information has not been considered. It is therefore essential that independent expert advice be sought before making any significant decisions based on this information.

9 To avoid inconsistencies and confusion, any updates to the *Land use potential* mapping are to be managed by DEWNR Soil and Land Program

To maintain consistency of the data, it is essential that all future updates are managed by DEWNR Soil and Land Program.

10 This data has been released under a Creative Commons licence. Where products are derived from this data, DEWNR should be acknowledged and any changes to original data should be indicated.

Creative Commons licensing allows data users to share and adapt data, within the terms of the licence. The notes provided here, particularly concerning the scale limitations, on use of these data should be carefully considered in the development of any products based on this data. If in doubt, advice should be sought from a qualified professional or DEWNR Soil and Land Program.

6.4 Example maps

The following pages display example A5 and A4 *Land use potential* maps.

Where space allows (e.g. A4 landscape map) more detailed information on the use and limitations of the *Land use potential* maps should be provided. However, where less room is available (e.g. A5 map below) it may be appropriate to provide a summary version of the notes related to mapping limitations.

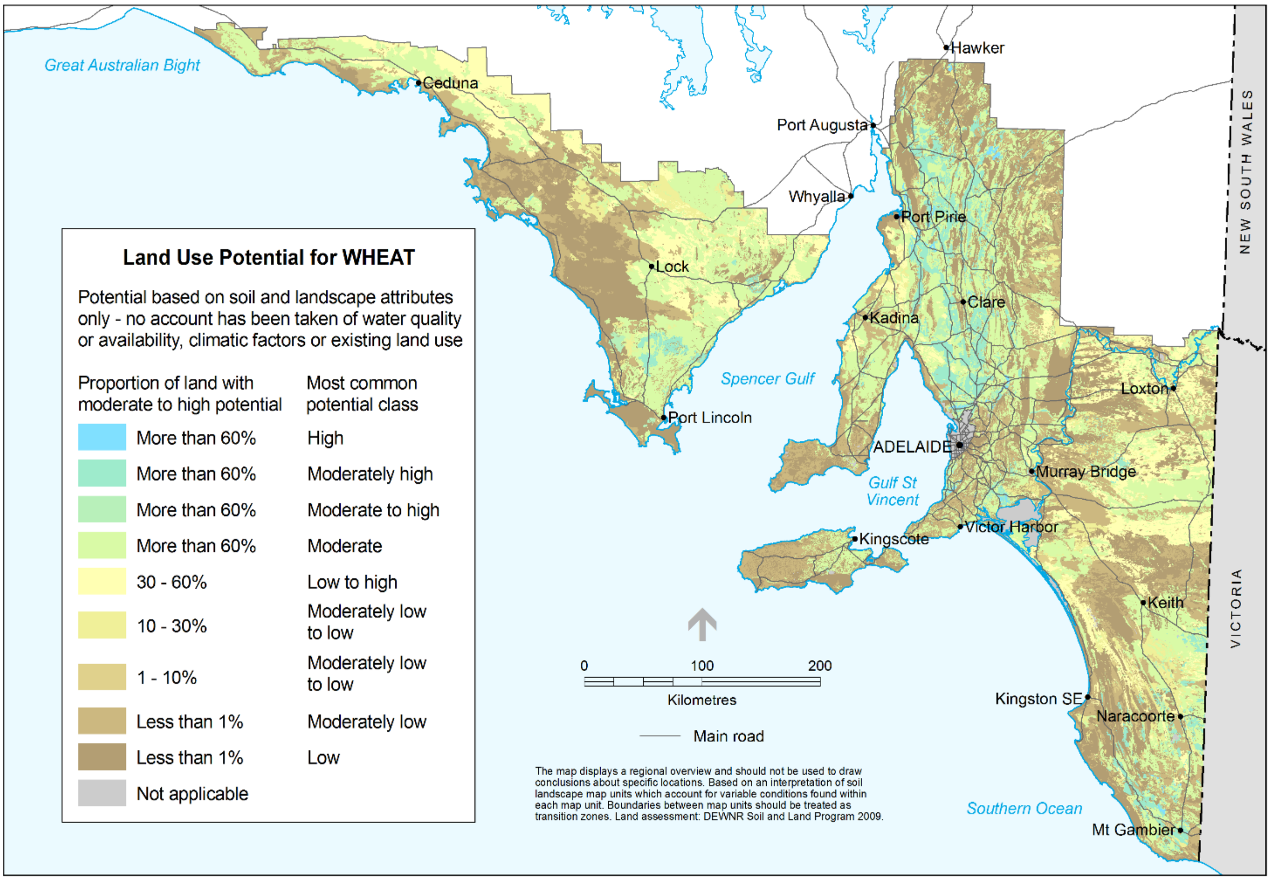

Figure 2. Example *Land use potential for wheat* map (A5 format)

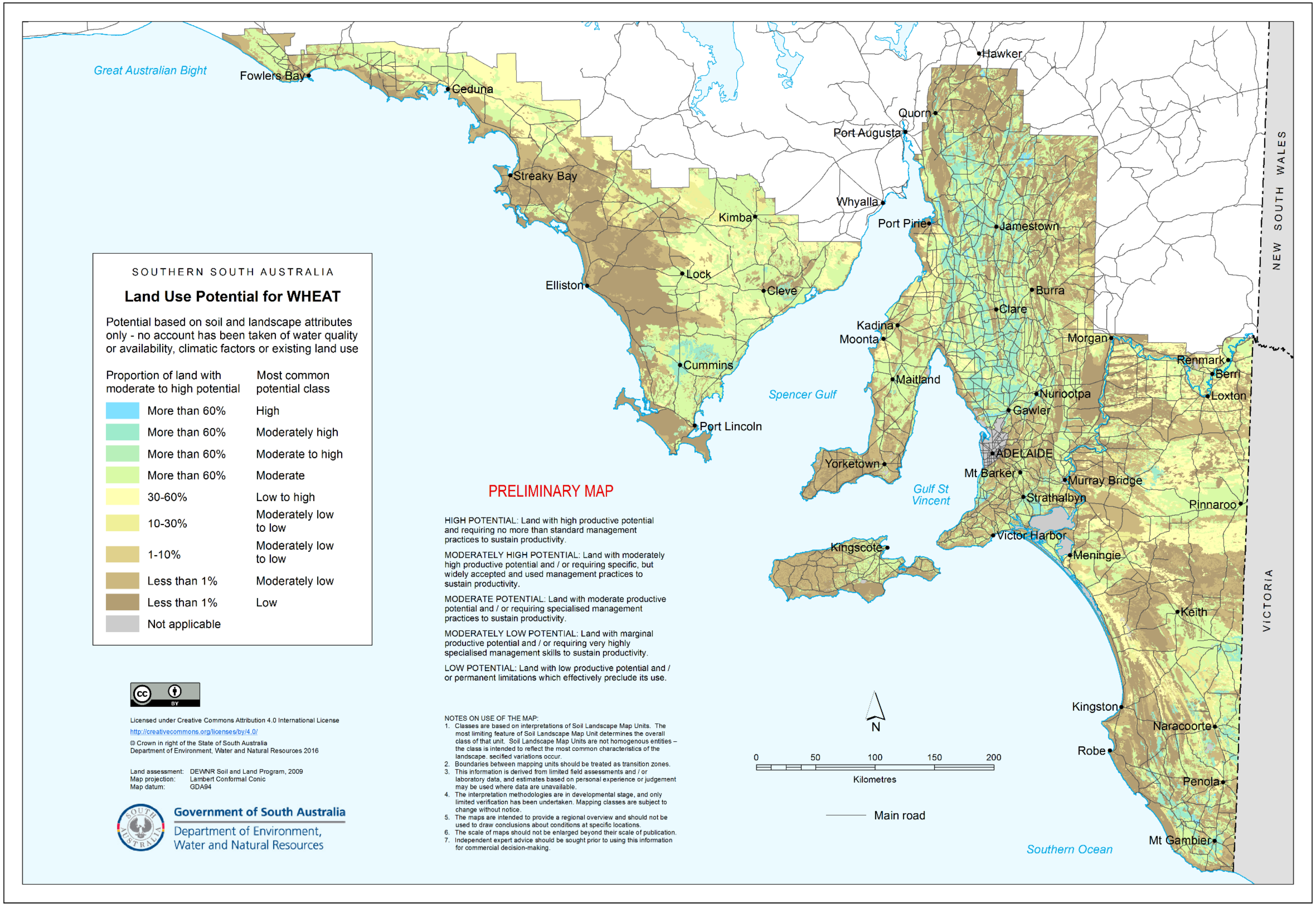

Figure 3. **Example *Land use potential for wheat* map (A4 format)**

7 Further information

Land use potential metadata

Land use potential spatial data downloads, available from Data.SA

Land use potential maps (pdf) available from Enviro Data SA > Maps folder

Soil and land attribute data descriptions (pdf)

Soil and land attribute fact sheets (pdf) available from Enviro Data SA > Fact Sheet

Soil and land attribute spatial data downloads, available from Data.SA

Soil and land attribute maps (pdf) available from Enviro Data SA > Maps folder

DEWNR Soil and land information

DEWNR Assessing *Land use potential*

NatureMaps is an interactive online mapping site supporting South Australia's natural resource management, which displays soil and land information, including the *Land use potential* and *Soil and land attribute* datasets, across southern South Australia. Spatial data can be viewed and downloaded from this site (see > Soils folder).

AgInsight South Australia is an interactive website that gives users comprehensive agricultural and economic data. AgInsight displays various *Land use potential* for agricultural crops datasets.

8 Appendix

Land use potential for WHEAT – Assessment criteria (rules)

Following consultation with crop experts, *Soil and land attribute* ratings are assigned to *Land use potential* classes. **For example**, landscape components with a rating for waterlogging ranging between **4-5** are considered to have a high degree of limitation (***Class 4***). The most limiting class across all *Soil and land attributes* is assigned to give an overall rating to each landscape component.

Soil and land attribute and code		What to measure or look for	Degree of limitation				
			Negligible *Class 1*	Slight *Class 2*	Moderate *Class 3*	High ***Class 4***	Severe *Class 5*
Waterlogging susceptibility	w	Length of time that any part of the profile is saturated following heavy rain	<1 week w = 1, 1-2, 1-3, 2-1, 2, 2-3	1-2 weeks (early) w = 1-4, 1-5, 2-4, 2-5, 3-1, 3-2, 3	Several weeks w = 3-4, 3-5, 3-7, 4-2, 4-3, 4	Several months w = **4-5**, 4-7, 4-8, 5-1, 5-2, 5-3, 5-4, 5	Most of year w = 5-7, 5-8, 7-*, 8-*
Depth to watertable	o	Estimate highest level maintained for at least two weeks per year					
		Where s = 1	>100 cm o = 1, 2	50-100 cm o = 3	-	0-50 cm o = 4	Above surf. o = 5, 7, 8
		Where s = other than 1 (includes 1o, 1+, 1*)	>200 cm o = 1	100-200 cm o = 2	50-100 cm o = 3	0-50 cm o = 4	Above surf. o = 5, 7, 8
Available waterholding capacity	m	Estimate mm total available water in rootzone	>100 mm m = 1	70-100 mm m = 2	40-70 mm m = 3	20-40 mm m = 4	<20 mm m = 5
Salinity watertable induced	s	Observe presence of halophytic plants (eg sea barley grass) **OR**	None present	None present but subsoil is mod. saline	Scattered halophytes	Halophytes common	Mostly halophytes
		Measure ECe (dS/m) in surface and subsoil	<2 (surface) <4 (subsoil) s = 1	2-4 (surface) 4-8 (subsoil) s = 2	4-8 (surface) 8-16 (subsoil) s = 3	8-16 (surface) 16-32 (subsoil) s = 4	>16 (surface) >32 (subsoil) s = 5, 7, 8
		If w = 4, 5, 7, 8	s = 1	-	s = 2	s = 3	s = 4, 5, 7, 8
Patchy salinity (associated with watertable)	s	Proportion of land affected by saline seepages	<2% s suffix = o **or** absent	2-10% s suffix = +	10-50% s suffix = x	-	-
Salinity – non-watertable (dry saline land)	v	Measure ECe(dS/m) in surface and subsoil.	<2 (surface) <4 (subsoil) v = 1	2-4 (surface) 4-8 (subsoil) v = 2	4-8 (surface) 8-16 (subsoil) v = 3	8-16 (surface) 16-32 (subsoil) v = 4	>16 (surface) >32 (subsoil) v = 7
Salinity – non-watertable (magnesia patches)	v	Proportion of land affected by dry saline (magnesia) patches	<2% v suffix = o **or** absent	2-10% v suffix = +	10-50% v suffix = x	-	-
Acidity	h	Measure pH ($CaCl_2$) at surface and deep subsoil:					
		Surface > Subsoil 1 = >5.4 1 = >6.9 2, 3 = 4.5-5.4 2 = 5.5-6.9 4, 5 = <4.5 3 = 4.5-5.4 4 = <4.5	h = 1>*, 2>1, 2>2	h = 2>3, 3>1, 3>2, 3>3	h = 2>4, 3>4, 4>2, 4>3, 5>3	h = 4>4, 5>4	-
		Downgrade if aluminium present (**ta** = 2 or 3):	h = 1>*	h = 2>1, 2>2	h = 2>3, 3>1, 3>2, 3>3	h = 2>4, 3>4, 4>2, 4>3, 4>4, 5>3, 5>4	-
Alkalinity	i	Measure pH (water) at surface and deep subsoil:					
		Surface > Subsoil 1 = < 8.0 1 = <8.0 2 = 8.0-9.2 2 = 8.0-9.2 3 = >9.2 (10-30) 3 = >9.2 4 = >9.2 (0-10)	i = 1>*, 2>1, 2>2	i = 2>3	i = 3>3, 4>3	-	-
Surface carbonate	ka	Reaction to 1M HCl	Nil to mod. ka = 1, 2	Strong ka = 3	-	-	-
Subsoil carbonate	kb	Depth to strong reaction to 1M HCl	>30 cm kb = 1, 2	< 30 cm kb = 3	-	-	-
Inherent fertility	n	Identify soil type	High, very high n = 1	Moderate n = 2	Moderately low n = 3	Low n = 4	Very low n = 5
Boron toxicity	tb	Determine depth to boron levels of > 15 mg/kg	>100 cm tb = 1	50-100 cm tb = 2	25-50 cm tb = 3	10-25 cm tb = 4	<10 cm tb = 5

Sodium toxicity	ts	Determine depth to exchangeable sodium percentage of >25%	>100 cm ts = 1	50-100 cm ts = 2	25-50 cm ts = 3	10-25 cm ts = 4	<10 cm ts = 5
Rockiness	r	Estimate proportion of surface rock and stone	Nil - slight r = 1, 2	Picking or rolling r = 3	Semi arable r = 4	-	Non arable r = 5, 6, 8
Physical condition of surface soil	c	Hardness / dispersiveness of surface soil	Loose, soft, friable, hard c = 1, 2	-	Dispersive c = 3	Str. dispersive c = 4	-
Structure of subsoil	p	Determine depth to and nature of subsoil. eg Depth to dispersive clay:					
		Where Soil % E1+E2+E3 = >30%	>30 cm p = 1, 2	20-30 cm p = 3	<20 cm p = 4, 5	-	-
		Other soils	>30 cm p = 1, 2	20-30 cm p = 3	10-20 cm p = 4	<10 cm p = 5	-
Scalding	z	Assess the percentage of land affected	None z = 1	Up to 5% z = 2	5-10% z = 4	10-50% z = 5	>50% z = 7
Water repellence	u	Measure time taken for drop of water to be absorbed into soil	Non repellent u = 1	Repellent u = 2	Strongly repellent u = 3	-	-
Water erosion potential	e	Refer handbook for water erosion classes	Low - moderately low e = 1, 2	Moderate e = 3	Moderately high e = 4	High e = 5	Very high - extreme e = 6, 7
Wind erosion potential	a	Refer handbook for wind erosion classes	Low - mod low a = 1, 2	Moderate a = 3	Mod high a = 4	High a = 5	Extreme a = 7
Gully erosion	g	Assess percentage of land affected	<5% g = 1, 2	5-10% g = 3	10-20% g = 4	-	>20% g = 7, 5x, 7x
Mass movement (landslip)	l	Estimate area affected or at risk	None present l = 1	-	None present (but potential) l = 4	Up to 5% of land affected l = 5	>5% of land affected l = 7
Exposure	y	Estimate degree of wind exposure	Nil y = 1	Moderate y = 2	High (coast) y = 3	-	-

Soil and land attribute groups for wheat are:

Soil and land attribute group code	*Soil and land attribute* group #	Attribute code *
T	Topography	r, y, 6e, 7e
W	Waterlogging / salinity / drainage	w, s, o
B	Chemical barriers to root growth	i, v, tb, ts
D	Soil depth / water storage	m
F	Soil fertility	n, h, ka, kb
S	Soil physical conditions	c, p
E	Erosion potential	2e-5e, a, g, l, z, u

For a given *Soil landscape map unit component*, the *Land use potential* classification may be down-graded where attribute/s within multiple attribute groups are contributing equally to a particular rating. For example, land which is rated *Class 3* due to waterlogging, inherent fertility plus boron toxicity should not be in the same overall class as land which is *Class 3* due to inherent fertility alone.

See Table 1 for *Soil and land attribute* group details

* Note that not all *Soil and land attributes* in the rules are necessarily listed in this table for downgrading purposes.

If most severe ranking = *Class **2***, and this ranking is due to attributes from any three attribute groups then downgrade to *Class **3***.

If most severe ranking = *Class **3***, and this ranking is due to attributes from any three attribute groups then downgrade to *Class **4***.

If most severe ranking = *Class **4***, and this ranking is due to attributes from any three attribute groups then downgrade to *Class **5***.

Note that where 's' and 'v' are equally limiting, special rules apply:

Where '**s**' and '**v**' are the only limiting attributes in groups '**W**' and '**B**' respectively, '**s**' is not taken into account for downgrading or for determination of attribute ranking.

Where other attribute(s) as well as '**s**' and '**v**' occur in either or both of groups '**W**' or '**B**', both '**W**' and '**B**' are retained in the downgrade assessment, but where '**s**' is the only '**W**' group attribute, it is not taken into account for determination of attribute ranking.

9 References

Food and Agriculture Organization (FAO) of the United Nations (1976). *A Framework for Land Evaluation*. FAO Soils Bulletin 32, Rome.

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