5 PRODUCTIVITY AND LAND DEGRADATION HAZARDS

INTRODUCTION

One of the values of a statewide description of land types is the opportunity to examine the relative merits of the various types of land for productive purposes and the relative hazards of land degradation to each land type. This has application at a broad level in the examination of land use options and in the allocation of resources for the control of land degradation at both the state and regional level.

Clearly, because of the relatively coarse level of resolution offered by the dataset, each land system is treated essentially as a point entity with no limited variation. Nevertheless, the land systems do provide a useful first approximation for many purposes.

GENERAL CONCEPTS

The potential for producing plant biomass (production) and for deterioration of the land resource are determined by the interaction of many factors such as climate, landform, soils and vegetation. In the agricultural context, deterioration refers to changes in soil condition that reduce productivity.

Production and deterioration potential need to be assessed separately. Land capability estimates have tended to confound the two thereby putting estimates beyond scientific scrutiny, and reducing the information content.

The prediction of inherent production or deterioration potentials are used to assess the potential performance of different lands. Inherent potentials are independent of land use and management. With respect to deterioration, inherent potentials are analogous to susceptibilities or hazards.

The concept of applying inherent potentials to land systems is problematic given the heterogeneity of land within a land system, and is best applied at a land component level. In spite of this, the assessment of production and deterioration potentials provides the land manager with a useful tool for land assessment.

PRODUCTION POTENTIAL

The prediction of inherent production potential is based on identifying and assessing the characteristics of the land that are likely to be limiting to agricultural or horticultural production. The assessment is qualitative and provides a ranking of production potential of between 0 and 10 for each land system. Given that this prediction is of the inherent potential for plant biomass production, the impact of land management practices that improve production such as fertilizers, lime, gypsum or irrigation is not included.

This assessment is not intended to replace more detailed assessments of the productive capacity of the land based on more empirical evidence. However, such assessments are not currently available, and these production potential assessments may fill certain needs until such empirically based assessments do become available.

Method for Ranking

The limitations that have been considered are landform, soils and climate (Table 5.1). Each land system is assessed against the criteria and where no limitation is identified, a score of 10 is given to that land system (Productive Capacity Class). Where limitations are identified, ‘penalty points’ are summed and subtracted from 10 to assign the Productive Capacity Class.

Thus the best land in the state for agriculture or horticulture (land essentially without major physical or chemical limitations) is allotted the highest score of 10. Such land would have a relatively high rainfall, moderate temperatures, gentle slopes, fertile soils and good drainage. The score declines as the limitations become more severe, with the least productive land in the State having a score of 0.

Table 5.1 Description of limitations and penalty points used to rank land systems for inherent production potential.

Land Characteristic	Description	Penalty Points
Landform	Too steep for cultivation - Landform symbol; L,H and M where applicable. Formerly S.	3
	Too stony for cultivation - Geomorphic Unit 7.2 (Stony rises on the West Victorian Volcanic Plains).	3
	Poor site drainage indicated by the vegetation - vegetation types rushland, sedgeland, shrubland, or bare ground (**-**).	3
Soil physical condition *	Hard consistence in the A horizon; or low permeability of profile; or shallow stony loam profile (less than 0.2 m thick).	2
Soil chemical condition	Low nutrient status (sum of exchangeable calcium, magnesium and potassium less than 8 milliequivalents per 100 g within 1 m ≠ or High salinity (more than 0.2% total soluble salts within 1 m of the soil).	2
Climate+	200-300 mm (land system symbol; 2)	6
	300-400 mm (land system symbol; 3)	5
	400-500 mm (land system symbol; 4)	4
	500-600 mm (land system symbol; 5)	3
	600-700 mm (land system symbol; 6)	2
	>700 mm, temperate (land system symbol; 7)	1
	>700 mm, montane (land system symbol; 8)	2
	>700 mm, sub-alpine (land system symbol; 9)	3

* Soil conditions apply as interpreted from the soil classification from data in the original publications and from experience where data are not available.

\+ Climate penalties are based on both rainfall and temperature. Penalties for low temperatures apply in high country where the rainfall is high (more than 700 mm).

≠ Lorimer, M.S., and Schoknecht, N.R. (1987). **A Study of the Land in the Campaspe River Catchment.** Technical Communication No. 18. Land Protection Division, Department of Conservation, Forests and Lands.

Chapter 7 presents a consolidated picture of the assessed productive capacity of Victoria's land.

DETERIORATION POTENTIAL

Sustainable, efficient agriculture requires the maintenance and where possible the improvement of the land and soil resource. This can be achieved by designing management regimes that will reduce the risk of various land and soil deterioration processes to which a land type is known to be susceptible, or changing the land use to one that reduces or removes the risk.

The deterioration potentials predicted for each land system provide a level of knowledge to assist the land manager in identifying inherent land deterioration (or degradation) hazards.

Susceptibility to degradation refers to the inherent potential for deterioration by a natural process (as distinct from other processes, for example the accumulation of artificial compounds or the development of hardpans at the depth of cultivation). Susceptibility is independent of the type of land use and of managerial inputs, these are considered to affect the extent of the deterioration realised rather than the susceptibility of the land to degradation. Generally, those lands with moderate to high degradation susceptibilities will show accelerated deterioration if inappropriate land uses or land management practices are applied.

In the context of the Statewide Land Systems, the concept of susceptibility is pursued further and a method of prediction is proposed, based on the condition of soil characteristics affected by each process.

In general usage, susceptibility refers to the ratio of deterioration to causal force. In organisms and ecosystems, however, the concept includes the effects of restorative processes. This 'resilience' is poorly understood, even in soil conservation technology. For example, the Universal Soil Loss Equation purports to predict soil loss from a slope, but it ignores the geomorphic reality that gains as well as losses may occur. In fact, on lower slopes, gains usually exceed losses.

Further, deterioration is generally episodic, caused by catastrophic disturbances such as fire under natural conditions, and frequent cultivation or overgrazing on farmland or rangeland. Subsequently vegetative growth in the intervening periods stimulates restorative processes and restoring (at least temporarily) some of the productive capacity of the land. These factors combine to frustrate many attempts at assessing relative productive potential of land without a substantial research base.

The balance between deterioration and restoration is reflected by the condition of the soil with respect to each process (the soil's 'status'). The criterion for water erosion, for example, is soil depth. Status under natural conditions can be used as a measure of susceptibility because it reflects the balance of forces over recent millennia.

Thus, degrees of susceptibility can be predicted by various criteria - soil depth for water erosion, texture for wind erosion on dry aeolian landforms, salt content for salination, soil reaction (pH) for acidification, consistence for compaction, and mottling for waterlogging. Exceptions are processes that remove soils completely, such as gullying and mass movement.

Land Degradation Susceptibilities

The land systems were assessed for susceptibility to seven forms of land deterioration:

I. water erosion (sheet, gully, tunnel, deposition)

II. wind erosion (sheet, deposition)

III. salting (salt seep, saltpan, scalding)

IV. leaching of nutrients (chemical decline and acidification)

V. compaction (physical decline through surface pressure and oxidation of organic matter)

VI. waterlogging

VII. mass movement (landslides)

Four classes for susceptibility to degradation are identified; nil, low, moderate and high. A class of nil indicates that the susceptibility is predicted to be generally below the limits of detection, and thus comparable to degradation under pre-European conditions.

Measurement and description of relevant parameters follows McDonald *et al.* (1990). Data on diagnostic characteristics in Victorian lands are generally sufficient for broad predictions of susceptibility. Predictions based on chemical data are less reliable than physical data, and are tentative in areas without laboratory data for soils. Data on soil mottling are also unreliable.

i) Water erosion

The criterion for predicting the susceptibility to water erosion is soil depth (the average depth to solid rock).

Score	Rating	Soil depth (m)
1	Nil	-
2	Low	> 2
3	Moderate	1 - 2
4	High	< 1

The three ratings are based on observations in hilly sub-humid areas where water erosion is relatively severe. Average soil depth is less than 1 metre on upper steeper slopes where soil lost by sheet/rill erosion is replaced only by extremely slow rock weathering. Mid slopes also lose soil but the soils are deeper because losses are counteracted by gains from upslope. Receipt of materials from upslope is dominant on lower slopes and intervening alluviated valleys with soil depth typically more than 2 metres.

Gullying is a linear phenomenon found typically in alluviated valleys. It occurs mainly in the drier hills severely affected by sheet/rill erosion. Thus susceptibility to water erosion as a whole is gauged, including sheeting, rilling and gullying on a land system basis. Tunnelling is also included, being regarded as a sub-process of gullying. Streambank erosion is listed in floodplains abutting streams.

A nil rating would only be merited where there was absolute protection from run-on water and insufficient slope on the land to generate moving run-off. These conditions would occur very rarely.

ii) Wind erosion

The criterion for predicting the susceptibility to wind erosion is based on Lorimer, (1985), and uses surface texture in semi-arid to sub-humid areas and exposure to particularly strong winds in humid areas.

Semi-arid areas

The criterion for susceptibility to wind erosion in semi-arid areas is surface soil texture.

Score	Rating	Surface soil texture
1	Nil	-
2	Low	clays
3	Moderate	loams
4	High	sands

In the drier areas, fine pieces of soil made up largely of clay, silt and very fine sand particles tend to be removed in dust storms, leaving medium to coarse sand particles behind. In much of the Mallee, clayey fluviatile deposits have been winnowed to produce sand hills alternating with loamy flats, or loamy hummocks alternating with clay plains. In the Big Desert, Sunset Country and Little Desert, the original materials were more sandy, and winnowing has produced surfaces that are virtually all sand.

Sand surfaces in semi-arid areas are weakly coherent, and particularly unstable when weakly vegetated. However, the main process is surface saltation and creep, with very little dust production.

Sub humid areas

Significant wind erosion in the drier parts of Victoria is usually confined to cropping areas in the Mallee and northern Wimmera. However, in the 1982-83 drought, instability extended to sub-humid areas with up to 600 mm mean annual rainfall and included traditional grazing areas with little history of cultivation. Sandy and loamy surfaces are affected. Erosion may be severe during droughts, but susceptibility is rated as low because of their intermittent occurrence.

Humid areas

In humid areas, soil binding by roots and humus appears to be sufficient to hold the soils together during the occasional periods when vegetative cover is weak. However, particularly strong winds cause erosion in two main situations; on coastal sands and in disturbed alpine to sub-alpine areas.

Barrier Complexes (Geomorphic Unit 8.5) facing the coast or lakes have high susceptibility to wind erosion but are not often used for agriculture. Slopes facing the sea or lakes are particularly sensitive in contrast to the swales and slopes facing inland which tend to be far more stable. Inland Barrier Complexes are well vegetated and thus have low susceptibility.

In the high country with alpine to sub-alpine climate, loam soils with high humus contents have strong small light aggregates which move readily without being broken down into their ultimate particles of sand, silt and clay. The susceptibility of these soils to wind erosion is regarded as low.

iii) Salting

Salting refers to an increase in salinity, not to high inherent contents as in most clay soils of the Wimmera and Mallee. These high inherent contents may reduce productivity, but the inherent contents will not increase unless watertables rise beneath them, or unless the surface horizons are removed by erosion.

Most soils are considered to be saline when total soluble salt contents exceed 0.2% at the surface and 0.3% in subsoils.

Salting has been episodic over the last million years or so in many parts of Victoria, and areas most likely to become saline today are those affected in the past. Past episodes of salting are reflected in relatively high subsoil salt concentrations, the presence of gypsum crystals, and the occurrence of indigenous halophytes.

In theory, the criterion for susceptibility is the maximal soluble salt content in subsoils. However, laboratory data are insufficient for this criterion to be used on a State basis. Because of this, a system based on incidence is used:

Score	Rating	Conditions
1	Nil	Mountainous areas are included here because there is virtually no evidence of salinity problems in these areas.
2	Low	Areas with yellow clayey soils but in which salt seeps have not been recorded.
3	Moderate	Areas with salt seeps in many parts of the State. The seeps may be associated with regional or local groundwater systems and are generally confined to the lower parts of the land systems. Affected areas usually occupy less than 5% of the landscape.
4	High	Regional groundwater discharge areas on plains with indigenous halophytes, for example at Kerang, in the Mallee and Wimmera and beside the Gippsland Lakes. Semi arid plains with duplex soils; e.g. older riverine plains in the Mallee. The loamy topsoils tend to be removed by erosion, exposing saline clays.

iv) Leaching of nutrients (chemical decline, acidification)

The balance between accession and leaching of anions (e.g. nitrate, sulphate, chloride) and cations (e.g. calcium, potassium) determines the reaction (pH) of soils. Many factors are involved; soil age, climate, lithology, landform and soil permeability. The pH tends to decline (become more acidic) with increasing rainfall and elevation, decreasing temperature, acidic parent materials, and increasing permeability. Thus the nutrient status of alkaline soils in the Mallee and Wimmera is generally higher than that in acidic soils of the south and east.

An arbitrary susceptibility scale based on surface pH can be made:

Score	Susceptibility rating	Soil pH
1	Nil	-
2	Low	> 6.5
3	Moderate	5.5 - 6.5
4	High	< 5.5

It is acknowledged that some nutrients may not be leached readily from soils; e.g. phosphorus applied in superphosphate tends to be adsorbed in the surface horizons of many soils.

v) Compaction (structure decline)

The criterion for the susceptibility to structure decline is dry consistence of the surface soil:

Score	Susceptibility rating	Breaking force*	Class
1	Nil	-+	-
2	Low	loose, very weak	<2
3	Moderate	moderately weak	2
4	High	moderately firm , very firm, moderately strong, strong, rigid	>2

Note:
* Taken from McDonald *et al*. (1984)
+ All land systems/soils are considered to be susceptible to structure decline.

Dry surfaces tend to be hard in semi-arid to sub-humid climates where humus contents are low, where textures are loams or clays and where pH is neutral to acidic. Notable examples are sodic duplex soils in the following situations:

- in much of central Victoria, both on the plains and in the hills.
- on red Wimmera soils
- on older alluvial plains in the Mallee.

All these hardsetting soils are extremely sensitive to disturbance. The naturally weak structure rapidly declines, particularly under cultivation. Improvement is slow and difficult requiring conservation farming practices.

Surfaces of moderate susceptibility can be rendered hard by frequent cultivation, but restoration is less difficult, especially in humid areas. Examples are self-mulching clays in the Wimmera, calcareous earths in the Mallee and duplex soils in humid areas.

Surfaces of low susceptibility are easy to maintain in good condition, such as on the widespread sands, and on earths on humid mountain slopes. These earths can suffer quite large reductions in porosity before productivity declines.

vi) Waterlogging

Waterlogging refers to the build up of excess moisture in soils under conditions of low soil permeability and/or poor site drainage. Excess moisture results in poor aeration and hence reduced agricultural production. The incidence is increased by practices such as clearing of original vegetation, cultivation and overgrazing, all of which result in soil structure decline and reduce evapotranspiration.

The degree of mottling can be used as an estimate of susceptibility in young soils where mottling reflects current moisture regimes. However this is not practicable in Victoria where most soil materials, particularly subsoils, are of Pleistocene age. Thus mottling usually reflects previous drainage conditions.

In Victoria, low soil permeability occurs notably where there are sodic clay subsoils, and less often where there is impeding bedrock or hardpan in some heath areas.

Areas with poor site drainage have ingress of overland or underground water, notably on low-lying plains with modified indigenous vegetation such as rushlands, sedgelands and mossbeds. These occur mainly around coastal lakes and lagoons.

Susceptibility thus depends on two factors, internal soil permeability and site drainage. Using the six-class drainage scale of McDonald *et al*. (1990), classes 1 (very poorly drained), 2 (poorly drained) and 3 (imperfectly drained) are taken to be susceptible to waterlogging.

Score	Susceptibility rating	Drainage class
1	Nil	Moderately well drained. Well drained. Rapidly drained.
2	Low	Imperfectly drained e.g. gentle plains with slowly permeable soils in humid and sub-humid areas. Included are large parts of the West Victorian Volcanic Plains and the redgum plains on high terraces of riverine plains in Gippsland.
3	Moderate	Poorly drained; locally low sites in humid areas, e.g. drainage lines; these occur mainly as minor components not accounted for in evaluating land systems as a whole.
4	High	Very poorly drained, e.g. beside coastal lakes and in mossbeds of the high plains.

vii) Mass movement

Mass movement takes various forms such as landslides, slips, flows and soil creep. Stress failure in soils and rocks causes entire soils to collapse. Thus susceptibility is not reflected by a single soil characteristic.

There are several predisposing land characteristics; site steepness, differential permeability of upper and lower soil horizons and rocks, and the angle of dip in rock strata.

In soils, failure often occurs along the plane between highly permeable and slowly permeable horizons, as the zone just above the slowly permeable horizon becomes saturated, it loses strength and thus triggers the collapse. In Victoria, the slowly permeable horizon is often a strongly mottled clay, the remnant of a subsoil weathered in Tertiary times and subsequently buried by colluvium.

Estimates of susceptibility are difficult to make because several factors are involved and some of them (e.g. differential permeability of layers) are not easily observed. Thus susceptibility is expressed only in terms of known presence or absence for each land system. No doubt many other land systems are susceptible, particularly in steep mountainous areas on sedimentary rocks.

Mass movement usually has less effect on agricultural productivity than the other processes listed. However, there can be costly effects on infrtructures such as buildings and roads.

Score	**Susceptibility rating**	**Evidence of mass movement***
1	Nil	No evidence of movement apparent, particularly in cleared areas where it would normally be more apparent.
2	Susceptible	Clear evidence of past (or current) mass movement of soil materials through landslips, mud flows, debris avalanches, etc.

Note:
* This criterion does deviate somewhat from the basic premise that susceptibility should be determined without reference to land use to provide at least a common basis for comparisons between land systems. Evidence of susceptibility (presence of mass movement) will be clearer where native vegetation has been removed for farming and other uses, however this clearing alters the basic condition of the land making susceptible land more likely to move.