Office of Environment & Heritage

The land and soil capability assessment scheme

Second approximation

A general rural land evaluation system for New South Wales

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Cover photo: F Townsend/OEH

A typically mixed landscape in NSW showing a variety of LSC classes – Class 2 on the gently sloping farmland in the foreground, Class 4 on the moderately hilly grazing land in the mid-distance and Class 7 on the steep, rocky forested hills in the background.

Summary

A new land and soil capability (LSC) assessment scheme has been developed for NSW. Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources. Failure to manage land in accordance with its capability risks degradation of resources both on- and off-site, leading to a decline in natural ecosystem values, agricultural productivity and infrastructure functionality. Knowledge of land capability in NSW is of great use in ensuring the maintenance and conservation of the land, soil and environmental resources.

The new scheme builds on the rural land capability mapping developed in 1986 for NSW. It was initially developed for the NSW property vegetation planning program under the *Native Vegetation Act 2003* and further upgraded for the NSW Natural Resources Monitoring, Evaluation and Reporting program. It retains the eight classes of the earlier system but places additional emphasis on specific soil limitations and their management.

The LSC assessment scheme uses the biophysical features of the land and soil including landform position, slope gradient, drainage, climate, soil type and soil characteristics to derive detailed rating tables for a range of land and soil hazards. These hazards include water erosion, wind erosion, soil structure decline, soil acidification, salinity, waterlogging, shallow soils and mass movement. Each hazard is given a rating between 1 (best, highest capability land) and 8 (worst, lowest capability land). The final LSC class of the land is based on the most limiting hazard.

The LSC assessment scheme is most suitable for broad-scale assessment of land capability, particularly for assessment of lower intensity, dry-land agricultural land use. It is less applicable for high intensity land use or for irrigation.

The LSC class gives an indication of the land management practices that can be applied to a parcel of land without causing degradation to the land and soil at the site and to the off-site environment. High impact practices require good quality, high capability land, such as LSC classes 1 to 3, while low impact practices can be sustainable on poorer quality, lower capability land, such as LSC classes 5 to 8. As land capability decreases, the management of hazards requires an increase in knowledge, expertise and investment. In lands with lower capability, the hazards cannot be managed effectively for some land uses. These concepts form the basis of land management within capability, a theme under the NSW Natural Resources Monitoring, Evaluation and Reporting Strategy.

Knowledge of LSC throughout NSW, together with the principles of land management within capability, provide valuable tools for the sustainable use and management of the State’s land and soil resources.

Contents

Figures

Tables

Photographs

1 Introduction

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources (see Dent and Young 1981; Emery 1986; Sonter and Lawrie 2007). It is a function of landscape features and processes and is influenced by terrain, soil and climatic attributes and their interactions. Failure to manage land in accordance with its capability risks degradation of resources both on- and off-site, leading to a decline in natural ecosystem values, agricultural productivity and infrastructure functionality.

Land capability is based on an assessment of the biophysical characteristics of the land, the extent to which this will limit a particular type of land use, and the current technology that is available for the management of the land (Emery 1986). It provides information on the broad agricultural land uses most physically suited to an area, that is, the uses with the best match between the physical requirements of the use and the physical qualities of the land, and the potential hazards and limitations associated with specific uses over a site. It can provide guidance on the inputs and management requirements associated with different intensities of agricultural land use.

Using land beyond its capability may have serious consequences for the land and soil resources of the State as well as broader environmental impacts on water, air and biodiversity. Impacts can include loss of valuable soils on agricultural land, soil acidification, structure decline, soil carbon decline and wind erosion leading to poor air quality. All these are general indications of land degradation.

The threat of land degradation and the need to manage land within its capability has been recognised at the federal level (for example McKenzie et al. 2002; Campbell 2008; Dixon et al. 2007) and at the State level by the NSW Natural Resources Commission. Land management within capability is listed as one of 13 key natural resource management targets for NSW (NRC 2005):

> *By 2015, there will be an increase in the area of land being managed within its capability.*

The more land that is used within its capability in NSW, the more sustainable will be our land management practices and the more our soil and land resources will be protected.

1.1 Development of the current land and soil capability assessment scheme

The land and soil capability (LSC) assessment scheme was initially developed by the then Department of Infrastructure, Planning and Natural Resources (now the Office of Environment and Heritage – OEH) to assist in assessing the environmental impact of clearing native vegetation under the *Native Vegetation Act 2003* (DNR 2005; DECCW 2011). The LSC module of the environmental outcomes assessment methodology used in the preparation of property vegetation plans under that Act was reviewed in July 2005 by an independent panel of internationally recognised experts. The panel found that the LSC assessment tool overall provided high quality decision support and was soundly based on good quality, practical applied science. That version of the LSC assessment scheme has proven to be a robust framework that has been routinely and very successfully applied in a regulatory framework for eight years.

To support a broader range of natural resource management issues beyond native vegetation, the scheme was subsequently modified to include two additional hazards (soil acidification and waterlogging). This assessment scheme is the second approximation of what was first applied in 2008 to support implementation of the NSW Natural Resources Monitoring, Evaluation and Reporting (MER) Strategy. The MER program included detailed site-specific LSC assessments to examine the extent to which land was being managed within its capability in NSW. The procedure used at the site scale is described in Bowman et al. (2009). The LSC assessment scheme was also applied at a broad scale and an interim land and soil capability map for NSW was developed. LSC mapping is discussed in section 4.

The Central West Catchment Management Authority (CMA) produced a summary of the LSC assessment scheme to support sustainable management of natural resources in their catchment (Central West CMA 2008). That document is consistent with the scheme presented here but did have several aspects that were specific to the Central West catchment. However, the definitions of individual classes and associated land management considerations presented in this current scheme follow closely those in the Central West CMA document.

The LSC assessment scheme as presented here is expected to continue to evolve and undergo further improvement in the light of ongoing review and user experience, changing climatic conditions and development of new agricultural technologies and practices. OEH encourages any users of the scheme to report any issues and more generally assist in the ongoing development of the scheme.

1.2 Aims

The LSC assessment scheme can make an important contribution to supporting the draft *NSW Soils Policy*, especially to its objectives of:

- improving community awareness and understanding of soils, to enhance commitment to better soil and land management
- providing a comprehensive, current and accessible soil knowledge base to inform strategic land use and catchment planning.

It is important to recognise that the scheme provides guidance only on the physical capability of the land to support different agricultural land uses. It does not address ecological or socio-economic issues that will influence the ultimate land-use decision over an area. In some cases conservation of natural ecosystems may be deemed the most desirable land use over high capability land.

This report describes the standard LSC assessment scheme. It represents the complete scheme for general purpose LSC assessment across NSW.

The aims of the report are to:

- present the methodology used in the LSC assessment scheme
- present definitions of the different capability classes used in the scheme
- identify the hazards and limitations used in the scheme
- present the logic tables that describe how the individual hazards and limitations are assessed for capability.

This report should enable a reliable assessment of the potential of the land to support a range of sustainable land uses and land management practices. It is directed at land managers and advisors in government, CMAs and landholders concerned with the protection of soil and land resources in NSW. It should also be of interest to all students of natural resource management.

2 Background

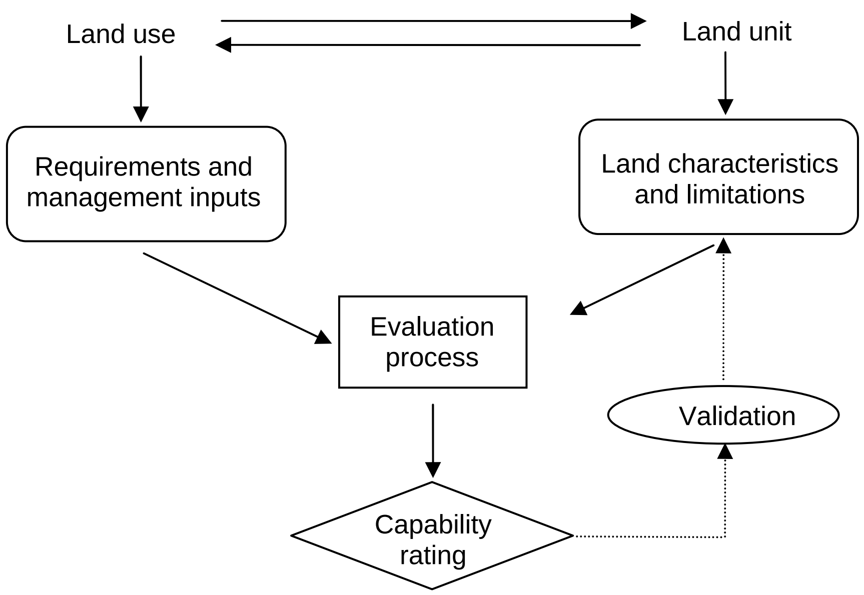
2.1 Development of land evaluation schemes in NSW

The first formal land capability rating system was devised in the early 1950s by the Soil Conservation Service of the US Department of Agriculture (USDA). It was mainly intended for farm planning and led to the publishing of the handbook *Land capability classification* (Klingebiel and Montgomery 1961). This scheme focused on the potential of the land for broad agricultural use, with or without specified soil conservation practices. It allocated land into one of eight classes based on the severity of various limitations, assuming a moderately high level of management. The scheme has been criticised for being too generalised and subjective (Johnson and Cramb 1992). The USDA later developed other capability assessment schemes for non-agricultural uses (USDA 1971, 1983).

Land evaluation processes were further developed by the United Nations Food and Agriculture Organization (FAO) in the early 1970s. This led to the publication of *A framework for land evaluation* (FAO 1976) which formed the basis of several more specific schemes such as those relating to rain-fed agriculture (FAO 1983) and forestry (FAO 1984). These schemes were particularly intended for use in developing countries and they also considered economic factors.

In Australia, different approaches to land evaluation are adopted in each state, but most systems in frequent use are based significantly on the USDA capability scheme. They generally all contain the key components as shown in Figure 1. A discussion of land evaluation schemes used in Australia is provided by McKenzie et al. (2008).

In NSW, two broad systems have been widely used to evaluate the agricultural potential of land: the rural land capability system developed by the former NSW Soil Conservation Service (SCS) (Emery 1986), and the agriculture suitability system (NSW Department of



Source: Modified from Baja et al. (2001).

Figure 1. Main components of land capability assessment

Agriculture 1983). The SCS capability system has eight classes and is similar to the original USDA system. It is empirical and qualitative in nature, emphasising soil conservation aspects and the ease of maintaining the stability of land under cropping, grazing and timber. Most of eastern and central NSW has been mapped using the scheme at a scale of 1:100 000. The NSW Department of Agriculture suitability system has five classes and identifies the agricultural productivity of the land (from better quality cropping land to poorer quality grazing land), mainly through qualitative descriptions. Unlike the SCS system it also considers social and economic parameters.

The SCS rural capability system forms the basis of the LSC assessment scheme presented here. The new scheme was initially developed for the NSW property vegetation planning program under the Native Vegetation Act (DNR 2005; DECCW 2011) and modified for the MER Strategy (Bowman et al. 2009). It retains the eight classes of the earlier rural capability system but places additional emphasis on specific soil limitations and their management. Rather than the single all-encompassing rating table, this new scheme comprises separate detailed rating tables for a range of soil and land hazards, such as water erosion, wind erosion, structure decline and acidification.

2.2 Data requirements

The LSC assessment scheme uses a range of data covering the biophysical characteristics of the landscape to establish the limitations to the land and the likelihood of degradation under a number of hazards. Included are land features such as slope, exposure to wind, drainage, groundwater recharge and discharge, cliffs, wetlands and rock outcrop, soil features such as texture, pH, structure and erodibility, and climate features such as average annual rainfall and wind erosive power. This data is used in a series of logic or decision tables to establish the degree of limitations associated with each hazard and the LSC class for each hazard. A detailed description of the data requirements and the logic or decision tables is presented in section 5.

2.3 Context and application of the land and soil capability assessment scheme

The context and application of the LSC assessment scheme is largely for:

- regional assessment of land capability
- the assessment of land capability for broad-scale, dry-land agricultural land use.

A conceptual framework of the LSC assessment scheme and two other land assessment schemes is shown in Figure 2 and Table 1. They show the relationship between the scale of the assessments being made and the intensity of the land uses. Essentially the LSC assessment scheme is a broad-scale scheme for low intensity agricultural land use. It emphasises risks and hazards rather than productivity. The lack of specific detail for particular land uses can limit its application for detailed planning for specific land uses outside of broad agricultural types such as cropping, grazing, forestry and conservation. Schemes such as SOILpak (McKenzie 1998, 2001) are for detailed assessments and are used to identify specific problems on an individual paddock for a specific cropping season. Other schemes such as the FAO land suitability scheme (FAO 1976) are designed to assess the suitability of a regional-scale soil unit for a specific land use or crop. The land capability assessment scheme for Victoria (Rowe et al. 1981) has specific criteria for individual land uses and so has similarities to the FAO system. This contrasts with the purpose of the LSC assessment scheme which evaluates land capability in relation to general lower intensity dry-land agriculture. The recommendation of van Gool et al. (2008) is that the term ‘suitability’ be applied to schemes wherever evaluations are made for specified land uses.

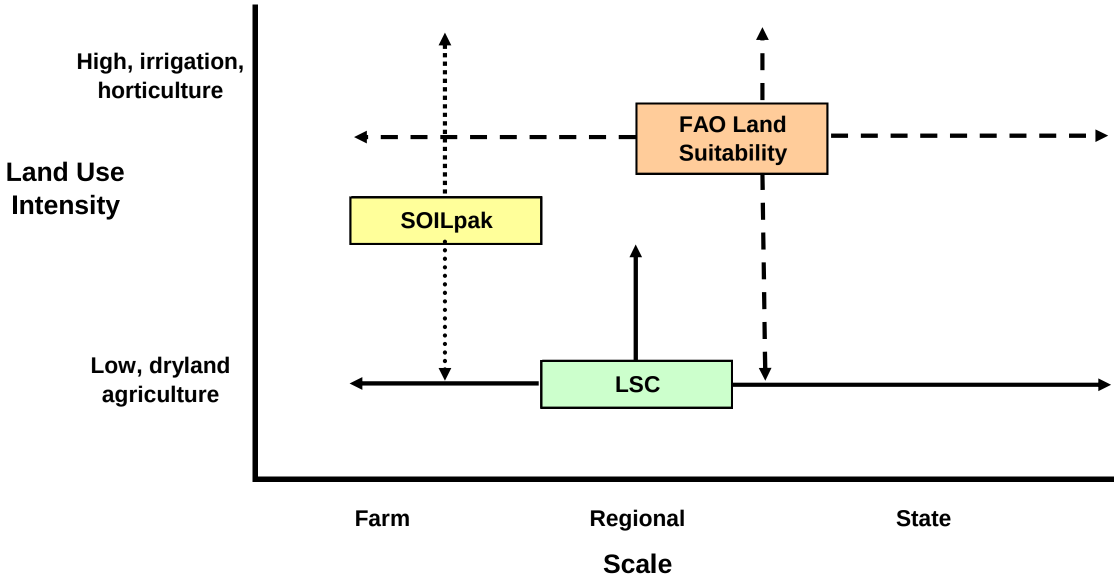


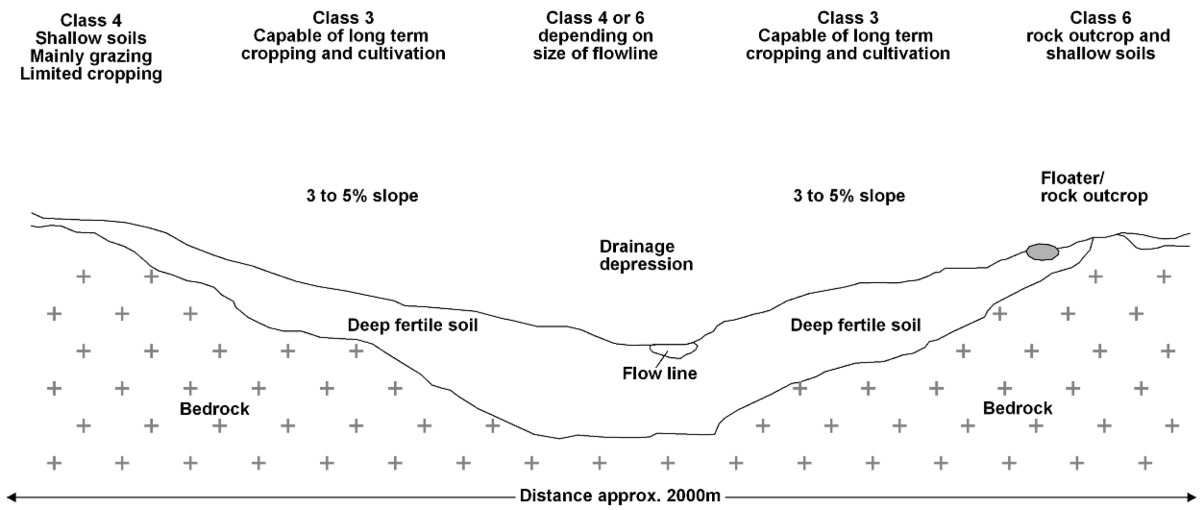
Figure 2. Comparison of LSC assessment scheme with other land assessment schemes

Table 1. A comparison of the LSC assessment scheme with other land assessment systems

Assessment system	Key features
LSC assessment scheme	Concentrates on the assessment of the likely land degradation hazards associated with implementing a broad agricultural land use on an area of land. Objective is to prevent on-site and off-site environmental degradation. Generally applies to low intensity, dry-land agriculture. However, it can identify some of the hazards that may influence more intense land uses. Has the capacity to be applied at the paddock, farm, regional and state scale. Relies on general land, climate and soil information.
SOILpak (McKenzie 1998, 2001)	Concentrates on soil limitations that will affect production. Objective is to obtain maximum short-term and long-term production. Is specifically designed to identify limitations that might affect production in high intensity land use such as horticulture and irrigation. Can be applied to less intensive land uses. Generally is most applicable at the paddock and farm scale. Generally relies on the collection of specific on-site data from soil pits and soil analysis.
FAO land suitability system (FAO 1976, 1983)	Concentrates on soil limitations that will affect production. A different set of criteria is developed for each specific land use and crop/pasture/horticultural type. Objective is to identify land that can be sustainably and productively used for a given purpose. Is specifically designed to identify limitations that might affect production in high intensity land use such as horticulture and irrigation. Can be applied to less intensive land uses. Has the capacity to be applied at the paddock, farm and regional scale. Relies on general land, climate and soil information. For some land uses and crops, specific detailed soil data is required.

While the LSC assessment scheme can be applied at the farm, regional and state scale, the products for each scale will vary in the information and resolution associated with them. At the state scale it is not possible to identify the landscape characteristics of every individual landform element and part of the landscape. It is therefore not appropriate to apply a state-scale LSC map to predict the LSC class of land at the farm scale. The logic is the same at different scales but the data or information that is used as inputs will vary with the scale.

Soil landscape map units that form the basis of mapping the LSC at the state scale are usually complex units with a range of soils on different landform elements, as shown in the topo-sequence diagram in Figure 3. This example shows that although the most common LSC class is Class 3 (midslopes) other LSC classes will occur on the crests and in the drainage depressions. Future NSW LSC mapping programs will consider methods to improve the presentation of the variability of LSC classes within mapping units, such as the method adopted in Northern Australia Land and Water Taskforce (2009).



1 Vertical axis is not to scale.

2 In this example the overall LSC class for the unit is Class 3 (the most common class on the midslopes). However, on the crests and in the drainage depressions LSC Classes 4 and 6 also occur.

Figure 3. Variation in LSC classes within a 1:250 000 scale mapping unit topo-sequence

3 Land and soil capability general assessment scheme

3.1 Overall process

The scheme defines LSC classes based on the biophysical features of the land. These biophysical features determine the on-site and off-site limitations and hazards of the land and include soil type, slope, landform position, acidity, salinity, drainage, rockiness and climate. The main hazards and limitations that are assessed include:

- water erosion, including sheet, rill and gully erosion
- wind erosion
- soil structure decline
- soil acidification
- salinity
- waterlogging
- shallow soils and rockiness
- mass movement.

Figure 4 shows how biophysical information is used to derive the LSC classes. The LSC class is determined for each hazard or limitation based on the logic tables in section 5. The final LSC class of the land is based on the most limiting hazard. The hazards are not applied in an additive way. For example, if most hazards at a site are rated as Class 3, but a single hazard is rated as Class 6, the overall rating of the site is Class 6.

The different nature of the various limitations means that care is required when comparing LSC ratings. For example, it can be difficult to directly compare an LSC rating of 3 for sheet erosion against a rating of 4 for structure decline. However, the scheme attempts to apply uniform weightings such that all limitations vary from extremely high to extremely low ability to withstand degradation.

3.2 Basic concepts

Both on-site and off-site impacts need to be considered in assessing LSC. The impact of not managing the limitation must also be considered. For example, in more marginal cropping land, if the water erosion limitation is not managed, significant water erosion will degrade the soil on-site, leading to sedimentation and turbidity off-site. However, on such land, the water erosion limitation can be controlled by readily available and widely accepted land management practices. The costs, technology and management practices to overcome the limitations also need to be considered. In theory, it is possible to overcome most limitations with sufficient investment and technology inputs, though this is often not a realistic option except for the most productive land uses.

In developing the definitions of the LSC classes it is necessary to consider two factors:

1. the biophysical features of the land to derive the LSC class associated with various hazards
2. the management of the hazards including the levels of inputs, expertise and investment required to manage the land sustainably.

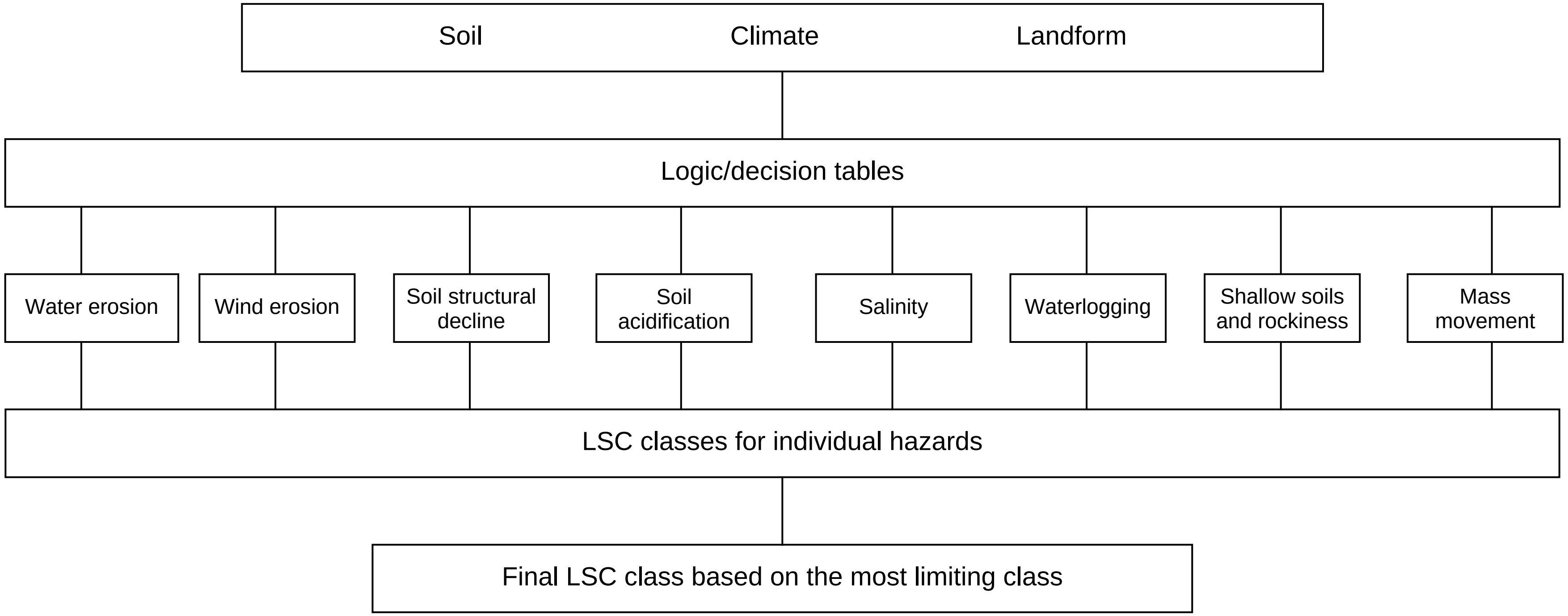


Figure 4. Biophysical information used to determine the LSC class

For higher LSC class numbers there are greater limitations to land use and a higher level of inputs, expertise and investment needed to manage the land sustainably. For the worst cases, the limitations may be so severe that they cannot be overcome with any level of input.

Since the publication of the original rural land capability classification (Emery 1986), there has been a revolution in the development of cropping and grazing practices (see Lawrie et al. 2007; Central West CMA 2008). Cropping has seen the development of practices such as direct drilling, new stubble management, no-tillage, controlled traffic, raised beds and pasture cropping. For grazing there have been developments such as tactical and strategic grazing, time-controlled grazing, cell-grazing and rotational grazing, as well as a shift to the wider use of perennial grasses. The options to manage the various land degradation hazards have expanded greatly with the adoption of these new practices. Where all these innovative practices fit into the new LSC assessment scheme is open to some debate and has not been fully quantified. Continued field experience will be required to settle some issues. The current assessments are guided by the effectiveness of the practices to manage or control the described hazards, and by the level of inputs, expertise and investment required to effectively implement the new practices.

Several other soil and landscape limitations apart from those currently addressed in the scheme are also potentially important in determining the agricultural potential of land and soil. These primarily influence agricultural productivity rather than susceptibility to degradation, and can also be a major determinant of ultimate land use:

- moisture stress limitations – a function of climate and soil water-holding capacity
- fertility – a function of nutrients content (major and trace element), cation exchange capacity, leaching potential, soil chemistry (including pH, phosphorus absorption capacity, presence of carbonates) (Sanchez et al. 2003)
- slope – in conjunction with water erosion, directly affects land capability through its effect on trafficability
- acid sulfate soil risk – these hazardous soils that generally occur in estuarine environments are a major constraint to land uses that involve excavation or disturbance of soils.

These and other limitations will be considered in future developments of the LSC assessment scheme.

3.3 Definitions of each class

The definitions and descriptions provide a guide to the type of land in each LSC class. Ultimately the LSC class is determined by the biophysical characteristics of the land using material provided in section 5. The LSC class will give an indication of the land management practices that can be applied to a parcel of land without causing degradation of the land and soil on-site, and to the environment, ecosystems and infrastructure off-site.

Soil types are generally referred to using the Australian soil classification system (Isbell 2002), followed by their Great Soil Group equivalent (Stace et al. 1968).

The definitions for each LSC class are in Table 2 and described below.

Table 2. Land and soil capability classes – general definitions

LSC class	General definition
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)	
1	**Extremely high capability land**: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.
2	**Very high capability land**: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	**High capability land**: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation)	
4	**Moderate capability land**: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology.
5	**Moderate–low capability land**: Land has high limitations for high-impact land uses. Will largely restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.
Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture)	
6	**Low capability land**: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation
Land generally incapable of agricultural land use (selective forestry and nature conservation)	
7	**Very low capability land**: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.
8	**Extremely low capability land**: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.

3.3.1 LSC Class 1

Description

LSC Class 1 is the best cropping country in NSW. It is most likely to occur in restricted areas on plains derived from basalt or basaltic alluvium. It is capable of most rural land uses and land management practices, and the few minor limitations can be very readily managed. It may be used for a wide variety of agricultural uses that involve regular cultivation, including vegetable and fruit production, grain and oilseed crops, and fodder and forage crops in specific areas. Occasional flooding may restrict its use for some specific rural land uses, such as some cropping and horticulture. Off-site impacts of land management are generally minor.

Class 1 land is usually uniform with deep, often productive soils. It has very gradual slopes (<1%) that are shorter than 500 m in length and no erosion problems. The soils have sufficient clay content to inhibit wind erosion and offer some resistance to soil structure decline even under regular tillage. However, under very intense use, some structure breakdown can occur and management of soil structure is required by reducing tillage and adding organic matter.

Land management considerations

No special land management practices to control water and wind erosion are required. Some land management practices that will preserve soil structure and chemical fertility are required. This land is free of rock outcrop and large stones that would restrict farm machinery operation. It has good drainage, with sufficient water holding capacity to supply growing crops and pastures. The soils generally have good buffering capacity against soil acidity and no specific management practices to control soil acidity are required.

Class 1 land

Photograph 1a. Typical Class 1 land comprising deep, unconstrained, well-structured self-mulching Black Vertosols (Black Earths) on level alluvial plains

F Townsend/OEH

Photograph 1b. Level alluvial plain with no significant limitations and deep, well-structured, basalt-derived cracking clay soils. These Black Vertosols (Black Earths) are resilient to high-impact land uses such as regular cultivation.

H Milford/OEH

3.3.2 LSC Class 2

Description

Land in this class is capable of a wide range of land uses and land management practices. Included in Class 2 is very good cropping land with often fertile soils and short, gradual slopes (1–3%, less than 500 m in length). This gently sloping land is capable of a wide variety of agricultural uses that involve cultivation. These uses include vegetable and horticultural production, and a range of crops including cereals, oilseeds and pulses. It has a high potential for agricultural production on fertile soils similar to Class 1, but has some restrictions on land use due to slight limitations.

Class 2 land is common on plains and on extensive footslopes where run-on from slopes above is not concentrated or can be controlled.

Off-site impacts of land management practices are slight and effects can be managed by readily available management practices.

Land management considerations

This land can be subject to sheet, rill and gully erosion as well as wind erosion and soil structure decline. However, these limitations can be controlled by land management practices that are readily available and easily implemented, such as conservation tillage and conservation farming practices. These practices include retaining stubble, reducing tillage, sowing with minimum disturbance and rotating pastures. Windbreaks and ground cover should be retained in areas prone to wind erosion. In more western areas, some timber should be retained in strips or clumps to reduce wind velocity. Salinity can be a slight hazard. Land managers need to be aware that deep drainage may cause salinity. Acidity can be a slight hazard. Land managers need to ensure their practices are not slowly acidifying the soils, and pH levels should be monitored regularly.

Class 2 land

Photograph 2a. Deep structured Brown Vertosols (Brown Clays) on level alluvial plains with a minor risk of soil structural decline under cultivation

F Townsend/OEH

Photograph 2b. Very gently undulating rises with deep, well-structured, resilient soils that are capable of many agricultural enterprises such as broad-acre wheat production

J Fitzgerald/OEH

3.3.3 LSC Class 3

Description

Class 3 land has limitations that must be managed to prevent soil and land degradation. However, the limitations can be overcome by a range of widely available and readily implemented land management practices. Included are sloping lands (3–10%) with slopes longer than 500 m that will require earthworks to control runoff and erosion if used for regular cultivation. Also included are lands that can be subject to wind erosion when cultivated and left bare. It is important to minimise soil disturbance, maintain stubble cover and maintain good organic matter levels. This class includes other soils with acidification and soil structure limitations that are sufficient to require the application of specific management practices.

Class 3 land includes sloping land that is capable of sustaining cultivation on a rotational basis. This land can be readily used for a range of crops including cereals, oilseeds and pulses. Productivity will vary with soil fertility. There are greater restrictions on land use than for Classes 1 and 2 due to increased limitations. Severe problems may arise if land management practices do not address the limitations of Class 3 land. For example, severe soil erosion can be caused by regular cultivation without effective erosion control measures, poor water quality can be caused by water erosion and dust storms may result from wind erosion.

Off-site impacts of land management can be significant if limitations are not managed adequately (for example, water erosion, water quality and sedimentation, wind erosion and air quality, or salinity).

Class 3 land is especially widespread on the NSW slopes and in the coastal areas. It includes a large proportion of the major agricultural producing areas of the State.

Land management considerations

This land can be subject to sheet, rill and gully erosion as well as wind erosion and soil structure decline. However, these limitations can be controlled by land management practices that are readily available and easily implemented.

Included are conservation tillage and farming practices such as retaining stubble, reducing tillage, sowing with minimum ground disturbance and the use of pasture rotations in the cropping system. Windbreaks and ground cover should be retained in areas prone to wind erosion. In western areas some timber should be retained in strips or clumps to reduce wind velocity. Salinity can be a moderate hazard. Land managers need to ensure that management practices do not cause deep drainage and movement of salt stores in the soil. Practices to manage salinity are ensuring that plant growth is adequate to maintain evapotranspiration rates, and minimising the length of fallows in cropping cycles. Acidity can be a moderate hazard and needs to be managed or the soils will suffer long-term degradation, particularly if acidity extends deep into the soil. Under long-term acidifying land uses, soil acidity levels should be monitored and lime added, or acid-tolerant perennials used where required. The management of soil structure in weakly sodic surface soils may require the use of soil ameliorants such as gypsum, attention to soil conditions before tillage and stock management to prevent surface soil compaction.

Class 3 land

Photograph 3a. Recently sown gently sloping crop land on red Chromosols (Non-calcic Brown soils)

B Murphy/OEH

Photograph 3b. Gently undulating rises to low hills with long slopes (>500 m) which require basic earthworks, such as the graded banks seen here, to control runoff and erosion

C Murphy/OEH

3.3.4 LSC Class 4

Description

Class 4 land has moderate to severe limitations for some land uses that need to be consciously managed to prevent soil and land degradation. The limitations can be overcome by specialised management practices with high levels of knowledge, expertise, inputs, investment and technology. This class includes sloping lands (10–20% slope).

Land management considerations

This land is generally used for grazing, and is suitable for pasture improvement. Acidification can be a problem under introduced annual legume pastures.

Class 4 land can be cultivated occasionally for sowing of pastures and crops. However, it has cropping limitations because of erosion hazard, weak structure, salinity, acidification, shallowness of soils, climate, wetness, stoniness or a combination of these factors. It is only suitable for intermittent cultivation with specialised practices. Required erosion control practices include advanced conservation tillage, pasture cropping, well-planned rotations and maintenance of ground cover.

Class 4 land has a high potential as grazing land. Soil structure decline, stoniness and soil depth can be moderate to severely limiting. Practices to manage these include well-planned rotations, additions of lime and maintenance of ground cover using perennials and natives. Erosion problems encountered in these lands include sheet, rill and gully erosion as well as wind erosion and soil structure decline under cropping. Land with weakly sodic surface soils is included in this classification. These limitations can be managed by well planned and carefully implemented conservation farming practices. Essential cropping practices include retaining stubble, reducing tillage and sowing with minimum disturbance. Minor drainage depressions with low flows are included in this class. Windbreaks and ground cover should be retained in areas prone to wind erosion. In western areas, some timber should be retained in strips or clumps to reduce wind velocity.

Salinity can be a moderate to severe hazard. Land management practices need to prevent deep drainage that causes salinity. Practices to manage salinity include ensuring plant growth is adequate to maintain evapotranspiration rates and maintaining the perenniality of pastures. Acidification can be a moderate to severe hazard and needs to be managed so soils do not suffer long-term degradation. It is particularly a problem if deeper parts of the soil profile become acidified. Land management practices need to prevent possible soil acidification and pH should be monitored regularly. Lime should be added or acid-tolerant perennials should be grown when required.

Class 4 land

Photograph 4a. Moderately sloping land capable of occasional cultivation showing evidence of stubble burning

J Young/OEH

Photograph 4b. Undulating to rolling low hills which have increased risk of soil erosion and are unsuitable for regular cultivation

A Murrell/OEH

3.3.5 LSC Class 5

Description

Class 5 land has severe limitations for high impact land management uses such as cropping. There are few management practices generally available to overcome these limitations. However, highly specialised land management practices can overcome some limitations for high value crops or products. This land is generally more suitable for grazing with some limitations or very occasional cultivation for pasture establishment.

Class 5 land includes sloping lands (10–20% slope) with highly erodible soils and/or significant existing soil erosion, or land that will be subject to wind erosion when cultivated and left bare. Other limitations include shallow soils, stoniness, climatic limitations, acidification, potential for structure decline and salinity hazards.

Land management considerations

This land is not capable of supporting regular cultivation due to the various limitations. Soil erosion can be severe without adequate erosion control measures. Fertility is generally lower than land in Class 4 and there is a lower capacity to regenerate ground cover. Class 5 land can be cultivated occasionally for fodder crops and pasture renewal or establishment. It is important to minimise soil disturbance, maintain cover and maintain good organic matter levels.

Eroded lands that require earthworks for rehabilitation are included in this class. This land is usually best suited for grazing, especially with pasture improvement and fertiliser application. Windbreaks and ground cover should be retained in areas prone to wind erosion. In western areas, some timber should be retained in strips or clumps to reduce wind velocity.

Salinity can be a severe hazard. Land managers need to ensure their practices don’t cause deep drainage and movement of the salt stores in the soil. Practices to manage salinity include minimising deep drainage with plant growth to increase evapotranspiration rates and increase perenniality of pastures. Acidification can be a severe hazard, particularly under introduced annual legume pastures, and soils can be naturally acidic near the surface and at depth. Where natural acidity is a problem, practices that are needed include growing acid-tolerant species and adding lime.

Class 5 land

Photograph 5a. Drainage plain with highly concentrated run-on, sodic subsoils and gully erosion

F Townsend/OEH

Photograph 5b. Land formed on acid volcanic parent materials with naturally acidic surface soils and sodic subsoils in lower parts of the landscape

B Murphy/OEH

3.3.6 LSC Class 6

Description

Class 6 land has very severe limitations for a wide range of land uses and few management practices are available to overcome these limitations. Land generally is suitable only for grazing with limitations and is not suitable for cultivation.

Class 6 land includes steeply sloping lands (20–33% slope) that can erode severely even without cultivation, or land that will be subject to severe wind erosion when cultivated and left exposed. Other limitations can include shallow soils (less than 50 cm deep), stoniness, rock outcrop (50–70% coverage), salt outbreaks, naturally acid soils of low fertility, major flow lines with high flows and flooding, areas that are poorly drained and wet for long periods, areas that are severely eroded, including scalds, and strong climatic limitations.

Land management considerations

Class 6 land has severe to very severe site limitations for grazing and other land uses. It may have very severe limitations due to off-site effects such as salinity and the impact of soil erosion on water and air quality. Soil erosion can be very severe without adequate erosion control measures. Fertility varies with geology, soil depth and type. This land is suited for less productive grazing. Limitations prevent most other land uses.

This land requires careful management to maintain good ground cover (maintaining grass or cover taller than 8 cm is a guide). Grazing pressures need to be lower than those used on Class 4 and 5 land. Rotational grazing systems with adequate recovery time for plant regrowth are essential. It is important to minimise soil disturbance, retain perennial ground cover and maintain high organic matter levels.

Salinity can be a very severe hazard. Land management practices need be changed in badly affected saline catchments. Practices to prevent salinity include minimising deep drainage, treatment of discharge areas and ensuring suitable perennial plants are retained in recharge areas to maintain evapotranspiration rates.

Acidification can be a very severe hazard. Soils can be naturally acidic both at the surface and at depth. This is particularly a problem when associated with low fertility. The land management options are very limited for these soils.

Class 6 land

Photograph 6a. Extensive plains with high wind erosion hazard

H Milford/OEH

Photograph 6b. Moderately steep slopes and moderately shallow, sometimes rocky soils, generally suitable only for low-impact grazing

H Milford/OEH

3.3.7 LSC Class 7

Description

This land has extremely severe limitations for most land uses. It is unsuitable for any type of cropping or grazing because of its limitations. Use of this land for these purposes will result in severe erosion and degradation. It may be too steep, rocky, swampy or fragile for grazing. The land may be suitable for commercial timber plantations or for native timber on undeveloped land. These areas can be high recharge areas and cause salinity problems off-site if cleared. Class 7 land includes slopes of 33–50% (except on basalt soils which could still be Class 6). It also includes areas with extreme soil erodibility (often sodic soils, or prior stream sand dunes), catchments where salinity and recharge are a serious problem, severely scalded areas and where rock outcrop, stoniness and shallow soils are a severe problem. Other limitations include flooding, wind erosion hazard and severe climatic limitations.

Land management considerations

Class 7 land is not capable of any cultivation or grazing by stock. It also has severe to very severe site limitations for other land uses, but may be suitable for wood production, passive tourism or honey production. Soil erosion control is difficult because of site limitations. Fertility varies with geology, soil depth and type. These limitations prevent most land uses.

Class 7 land

Photograph 7a. Steep hills with shallow, rocky soils which are generally unsuitable for agricultural use

H Milford/OEH

Photograph 7b. Steep slopes, discontinuous rocky soils and other hazards including seasonal waterlogging

C Murphy/OEH

3.3.8 LSC Class 8

Description

Class 8 land is not suitable for any agricultural production due to its extremely severe limitations. Class 8 land includes precipitous slopes (>50% slope) and cliffs, areas with a large proportion of rock outcrop (>70% area), or areas subject to regular inundation and waterlogging (swamps, lakes, lagoons, stream beds and banks).

Land management considerations

This land is unusable for any agricultural purposes. Recommended uses are restricted to those compatible with the preservation of natural vegetation including water supply catchments, wildlife refuges, national and State parks, and scenic areas.

Class 8 land

Photograph 8a. Precipitous hills with little or no soil, abundant cliffs and boulders and severe mass movement (rock fall) hazard

H Milford/OEH

Photograph 8b. Inland swamp subject to permanent inundation

J Fitzgerald/OEH

4 Land and soil capability mapping

4.1 Application and development

To produce maps showing the spatial coverage of LSC classes, soil and landscape attributes that describe the biophysical features of the land are first collated in a database referred to as ABDUL (Access Based Data Utility for LSC). A series of logic or decision tables (section 5) are then applied to determine the most limiting factor for each spatial area (landscape).

The LSC assessment scheme was first applied at a broad scale in 2008 to support implementation of the MER Strategy. An interim land and soil capability map for NSW that provided an initial broad-scale assessment of the capability of the land was developed.

The broad-scale MER LSC dataset is currently being used by the NSW Department of Primary Industry to assist in the determination of Biophysical Strategic Agricultural Land as a component of the NSW Government's Strategic Regional Land Use Plans (SRLUP). To assist in this process, OEH is undertaking a desktop revision of the initial MER LSC data for each of the SRLUP priority areas. This review is examining the 2008 MER LSC data together with soil survey reports, remote sensing data (SPOT5, radiometrics), digital elevation models and soil profile data from the NSW Soil and Land Information System. During this process a number of corrections to the original data underpinning the 2008 LSC assessments have been made and deficiencies in the original logic or decision tables have been identified for improvement in the future as the LSC assessment scheme is progressively enhanced.

4.2 Intended usage

The 2008 MER program LSC map and regional LSC maps for strategic regional land-use plans provide a guide to the capability of the land and the broad identification of soil management problems. The mapping is broad-scale and should only be used at the scale of the soil map datasets that underpin the maps. These maps are not suitable for site assessment at the property scale.

This mapping is based on the best soil maps (soil landscapes, reconnaissance soils mapping, land systems) available at the time of production, plus expert local knowledge where available. No new mapping was undertaken in the production of this dataset.

Each map unit is likely to contain a range of capability classes. The LSC class adopted for each unit is the dominant class within the unit.

4.3 Expert modifications to land and soil capability assessments

When an initial LSC determination does not match known or indicative conditions of the landscape or soils, expert knowledge is used to record a modified LSC class that overrides the original assessment. The original value and reasons for the change are documented. This provides a mechanism to refine the logic/decision tables based on applied usage and feedback in a process of continual improvement.

Areas already identified for improvement through the SRLUP desktop revision include:

- water erosion hazard: the logic/decision tables may need to be enhanced with a further breakdown of the Eastern and Central divisions according to regions, based on their varying rainfall erosivity.
- wind erosion hazard: the wind power map used is very broad and often did not correlate with actual wind erosion hazard. Future versions of the LSC assessment scheme should include a better assessment of wind erosive power. Soil landscape information provided the basis of the wind erosion hazard assessment.
- soil structure decline hazard: in particular the ‘very high levels of silt and fine sand’ modifier tends to affect the final rating too severely, with many continuously cropped areas being ranked outside cropping-capable lands. In the Central West SRLUP priority area, where this problem was most apparent, this modifier has been adjusted from Class 4 to Class 3. The surface condition modifiers for clayey topsoils also require some refinement, in particular to better delineate more productive self-mulching Grey, Brown and Red Clays from those which are crusting and/or hardsetting and thus have lower productivity.
- soil acidity hazard: the logic/decision tables tend to rank soil acidity too severely, requiring manual override so that soil acidity did not unrealistically affect the final LSC class and thereby lands suitable for cultivation were not ruled out.
- soil salinity hazard: due to locally significant variables, the LSC classes for salinity hazard had to be manually adjusted based on expert advice. Some transcription errors were evident in the original LSC for the salinity hazard logic table, and these have been manually adjusted where necessary. The salt stores map was rarely used because of its broad scale and lack of relevance at a local landscape level. Soil landscape information was used in preference to provide the basis for salt store assessment. Additional salt store information was derived from geological maps. In general, the salinity logic/decision tables require refinement to better reflect actual conditions and processes.
- mass movement hazard: the logic/decision tables tend to overestimate the effect of mass movement hazard in areas where it is highly localised. In these cases a manual override was applied to modify the LSC assessment to Class 6.

5 Decision tables for individual hazards

5.1 Introduction

The decision tables in the LSC assessment scheme are an essential part of the scheme and are partly based on those in the *Native Vegetation Regulation 2005 environmental outcomes assessment methodology* (DECCW 2011). They use landscape, soils and climate data on the various hazards or limitations to allocate a tract of land to an LSC class for each hazard or limitation. The logic tables for each hazard or limitation are outlined below. The operation of the logic tables requires several sources of data and these are outlined below.

Each hazard is assigned one of eight LSC classes where Class 1 represents the least hazard and Class 8 represents the greatest hazard. Each hazard is assessed individually and in this way a profile of hazards is developed for the parcel of land being assessed. The final hazard assessment for a parcel of land is based on the highest hazard in that parcel of land (see Figure 4). For example, a parcel of land may be assessed to have no significant hazard for several limitations but a Class 8 hazard for mass movement hazard; this land will be Class 8 land.

5.2 Base information

Various base information is required to commence assessment of LSC. Some of the base information, such as climate and slope, feeds into other hazard assessments, while other base information, such as that on landform features and existing erosion, is sufficient to identify the capability immediately. The data required to determine the LSC class of a parcel of land is summarised in Table 3.

5.3 Water erosion hazard

Water erosion hazard refers to the likelihood of soil detachment and movement under the effects of raindrop impact, initiation of runoff, and flowing water (Geeves et al. 2007).

The amount of water erosion is controlled by:

- the slope gradient and slope length, which control the erosive power of water flowing down the slope
- the erodibility of the soil, which can be assessed on the detachability and transportability of the soil
- the amount of vegetation cover on the landscape, as this can intercept raindrop impact and attenuate the effects of rainfall erosivity
- the condition of the soil, whether in a loose, tilled or settled coherent condition: soils in a loose, tilled condition are more easily detached and transported.

While the coast has the most intense rainfall, usually it is the cropping areas in the north-west of the State (Namoi and Border rivers) that have the highest water erosion hazard. These lands have the combination of relatively intense rainfall, highly erodible soil (easily detached and transported) and the common occurrence of cropping, meaning that there is the potential for the soil to have a low surface cover for significant periods of the year. Soils in a loose, tilled condition are highly susceptible to water erosion.

5.3.1 Effects of water erosion

The major effects of water erosion are:

- loss of the soil from the landscape and a subsequent deterioration in the productive capacity of the landscape and its capacity to deliver ecosystem functions
- movement of soil materials and associated nutrients and chemicals into waterways and storages, with consequent reductions in water quality and the storage capacity of reservoirs
- damage to infrastructure caused by both erosion and deposition of soil materials.

Table 3. Data requirements for determining LSC classes

	Water erosion	Wind erosion	Soil structure decline	Soil acidification	Salinity	Water-logging	Shallow soils and rock	Mass movement
NSW Division	✓							
Sand dune or mobile sand body	✓							
Slope %	✓							✓
Scree or talus slope								✓
Footslope or drainage plain receiving high run-on	✓							
Gully erosion or sodic dispersible subsoils	✓							
Annual rainfall		✓		✓				✓
Wind erosive power		✓						
Exposure to wind		✓						
Surface soil texture		✓	✓	✓				
Surface soil texture modifier			✓					
Great Soil Group				✓				
pH of surface soil				✓				
Surface soil modifier				✓				
Parent material				✓				
Recharge potential of landscape					✓			
Discharge potential of landscape					✓			
Salt store of landscape					✓			
Waterlogging duration						✓		
Return period of waterlogging						✓		
Rocky outcrop							✓	
Soil depth							✓	
Presence of existing mass movement								✓

5.3.2 Assessment of water erosion hazard

The rule set for water erosion hazard is in Table 4. These rules are based on slope classes in the original rural land capability scheme (Emery 1986) and these were based on more than 20 years' field experience of the SCS throughout NSW.

The Western Division is distinguished from the Eastern and Central divisions because of its drier climate, resulting in less protective groundcover.

The data required to complete this assessment may be derived from topographic maps, digital elevation models, direct field measurement with a clinometer or from existing soil-landscape maps.

The influence of specific localised issues such as highly erodible soils, potential for crusting or hardsetting topsoils, shallow texture contrast soils and long slope length have not been directly addressed in this version of the scheme.

5.3.3 Effects of water erosion

The major effects of water erosion are:

- loss of the soil from the landscape and a subsequent deterioration in the productive capacity of the landscape and its capacity to deliver ecosystem functions
- movement of soil materials and associated nutrients and chemicals into waterways and storages, with consequent reductions in water quality and the storage capacity of reservoirs
- damage to infrastructure caused by both erosion and deposition of soil materials.

Table 4. Slope class for each LSC class used to determine water erosion hazard

NSW division	Slope class (%) for each LSC class							
	Class 1	Class 2	Class 3	Class 4 [1]	Class 5 [2]	Class 6	Class 7	Class 8
Eastern and Central divisions	<1	1 to <3	3 to <10 or 1 to <3 with slopes >500 m length	10 to <20	10 to <20	20 to <33	33 – <50	>50
Western Division [3]	<1	1 to <3 or <1 for hardsetting red soils	1–3	3–5	3–5	5–33	33–50	>50

Sand bodies are classified as Class 1 for water erosion hazard.

[1] No gully erosion or sodic/dispersible soils are present.

[2] Gully erosion and/or sodic/dispersible subsoils are present.

[3] Western CMA provided advice on the slope classes.

5.4 Wind erosion hazard

Wind erosion hazard refers to the likelihood for soil detachment and movement under the effects of wind blowing across the soil surface (Leys 2007; Leys and McTainsh 2007). Wind erosion hazard tends to be the highest in coastal areas and on the inland plains.

Wind can detach and transport soil particles over a range of distances. Three major transport processes occur in wind erosion:

- creep, as the soil particles (>0.5 mm) roll and bump along the unstable surface as result of the impact of other fast moving particles
- saltation, where particles are transported short distances in a series of bounces – particles in the size range 0.1–0.5 mm are detached and transported this way; this is the material that often builds up along fences and other barriers with active wind erosion
- suspension, whereby soil particles are suspended in the air and transported large distances (hundreds or thousands of kilometres); this is the material seen in dust storms and particles in the size range <0.1 mm are transported this way.

The wind erosion hazard is dependent on the:

- wind erosive power or wind erosivity, which is influenced by overall wind patterns but also by the potential for local modifications by landform, trees and buildings
- exposure of the land to wind, taking into account local variation in wind power. Areas exposed to long wind fetches tend to be subjected to higher wind erosive power. In some landforms the wind flow is channelled and accelerated, increasing the wind erosive power, such as between hills or across saddles. Elevated areas of the landscape will likely have higher exposure than valley floors, while some landforms have naturally high exposure, for example beach fronts, sand dunes on plains, and the crests of ridgelines.
- detachability and transportability of the soil particles to wind. Generally, sandy soils are more erodible than clayey soils. While sand particles are more readily detached by wind they tend to travel only short distances under the process of saltation. It is the clay and silt particles in the sandy soils or aggregated clays that travel long distances and create the familiar dust storm clouds associated with severe wind erosion.

5.4.1 Effects of wind erosion

The major effects of wind erosion are:

- loss of the soil from the landscape and a subsequent deterioration in the productive capacity of the land and in the capacity of the land to perform ecosystem functions. There is a disproportionate loss of nutrients and organic carbon from soils affected by wind erosion as the finer and more nutrient-rich fractions are winnowed out by wind erosion.
- movement of soil materials at close range (saltation) onto fences, roads and buildings that can result in infrastructure damage, or at least the need to remove the deposited soil material at considerable cost.
- movement of suspended soil materials at some distance from the original site. This material is moved as dust clouds that can adversely affect visibility, deposit dust and lead to air quality and infrastructure problems.

5.4.2 Assessment of wind erosion hazard

The LSC assessment scheme uses the following factors:

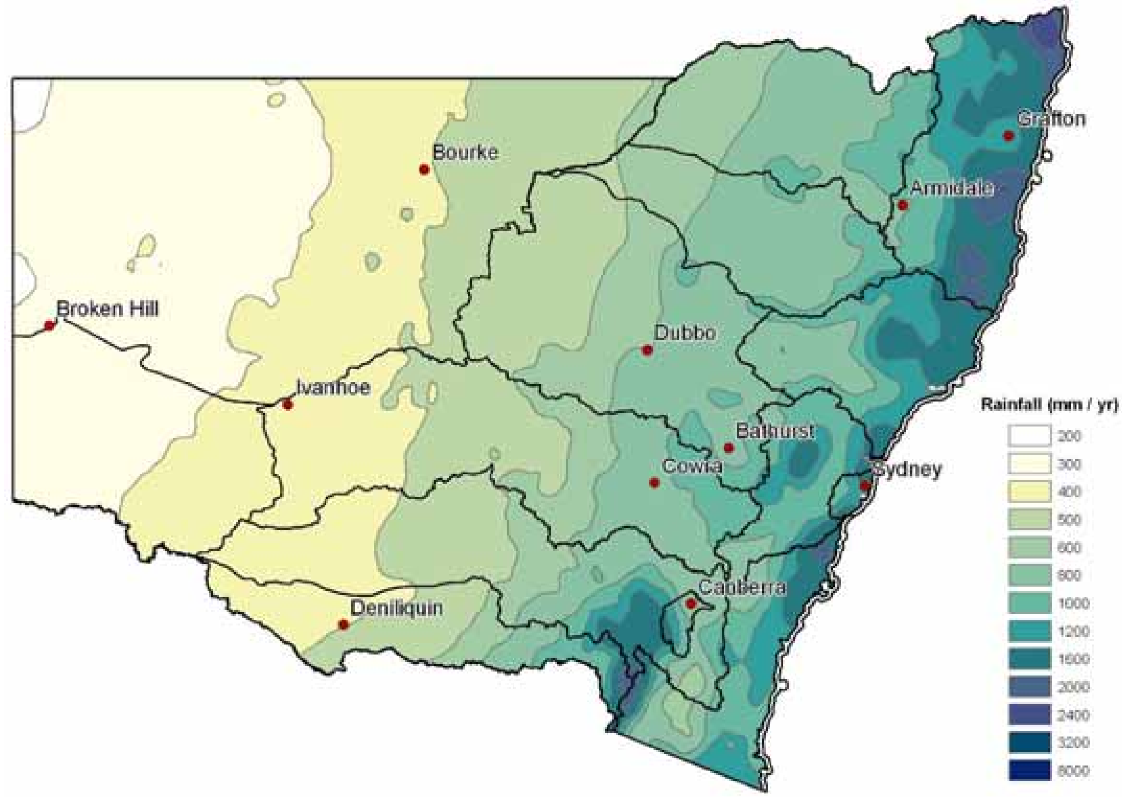
- the average rainfall which determines the capacity of the land to maintain surface cover and keep the soil wet. The wind erosion hazard increases as the average annual rainfall declines (Figure 5).
- the wind erosive power or wind erosivity based on overall wind patterns. Figure 6 is a map of the wind erosive power for NSW.
- the exposure of the tract of land to wind, taking into account local variations in wind power. For example, at the local scale, the landform might channel the prevailing wind into some areas (Table 5).
- the soil erodibility to wind. This is largely determined by the texture of the soil as this determines the detachability and transportability of the soil particles (Table 5).

In assessing the wind erosion hazard, the assumption is made of land management associated with low surface cover. This is consistent with the objective of identifying the land management practices that can be imposed on the landscape without causing long-term degradation. The LSC class for different annual rainfall regimes is shown in Table 6.

Table 5. Factors in assessing wind erosion hazard

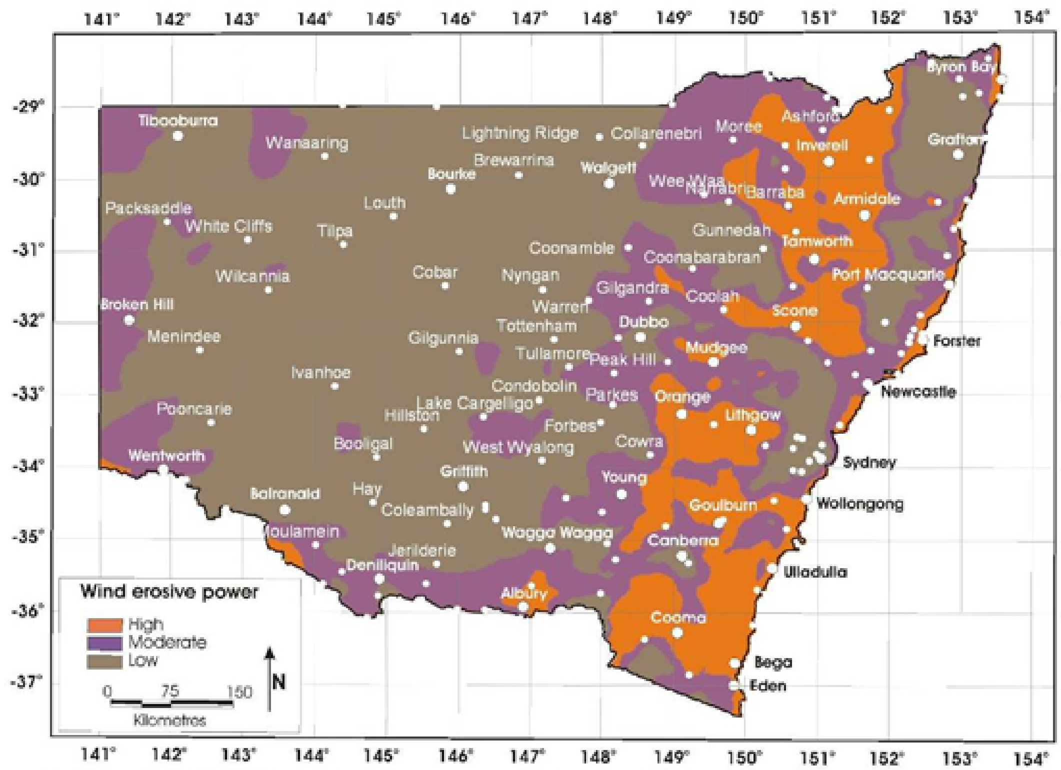
Class	Factor		
	Surface soil texture	**Site exposure to prevailing winds**	**Wind erosive power***
Low	Loams, clay loams or clays (all with >13% clay)	Sheltered locations in valleys or in the lee of hills	Low
Moderate	Fine sandy loams or sandy loams (all with 6–13% clay); also includes organic peats	Intermediate situations – not low or high exposure locations	Moderate
High	Loamy sands or loose sands (all with <6% clay).	Hilltops, cols or saddles, open plains or exposed coastal locations	High

* See Figure 6.



Based on data provided by Australian Bureau of Meteorology.

Figure 5. Average annual rainfall in NSW



Source: NSW Department of Trade and Investment (undated).

Figure 6. Wind erosive power in NSW

Table 6. LSC class for wind erosion hazard

Wind erodibility class of surface soil	Wind erosive power	Exposure to wind	Average annual rainfall (mm)			
			>500	300–500	200 to <300	<200
Low	Low	Low	1	2	3	6
		Moderate	1	2	3	6
		High	2	3	4	7
	Moderate	Low	1	2	3	6
		Moderate	2	3	4	6
		High	3	4	5	7
	High	Low	2	3	4	6
		Moderate	3	4	5	7
		High	4	5	6	7
Moderate	Low	Low	2	3	4	7
		Moderate	3	4	5	7
		High	4	5	6	8
	Moderate	Low	2	3	4	6
		Moderate	3	4	5	7
		High	4	5	6	8
	High	Low	3	4	5	7
		Moderate	4	5	6	8
		High	5	6	7	8
High	Low	Low	3	4	5	7
		Moderate	4	5	6	8
		High	5	6	7	8
	Moderate	Low	4	5	6	8
		Moderate	5	6	7	8
		High	6	7	8	8
	High	Low	5	6	7	8
		Moderate	6	7	8	8
		High	7 (8*)	8	8	8

* Mobile sand bodies such as coastal beaches, foredunes and blowouts are Class 8.

5.5 Soil structure decline hazard

Soil structure decline refers to the breakdown of the physical arrangement of soil particles and pore spaces in the soil, typically as a result of compaction and tillage. It results in the loss of pore space, fissures and tunnels that allow movement and exchange of air, water, nutrients and penetration of plant roots. It is a hazard for all agricultural systems. Organic matter decline is also often associated with soil structure decline. The approach taken here is that soil structure decline is a sufficiently severe soil degradation problem that it should be assessed as an identifiable hazard, especially in the case of sodic surface soils and some other very hardsetting surface soils high in silt and fine sand.

This assessment concentrates on the surface characteristics as described in Lawrie et al. (2002, 2007) who identified that good soil structure is dependent on soil organic matter in the soils with less clay (sandy loams to loams), whereas the level of sodium becomes more important in soils with more clay (clay loams, light clays and heavy clays) where it leads to clay dispersion. Kay (1990) identified that soil structure is dynamic, and that an assessment of soil structural decline hazard requires an estimation of the current soil structural condition, a prediction of the stability of the structural condition and the capacity of the soil to redevelop soil structure should it become degraded (its resilience). This assessment takes some account of the dynamic nature of soil structure.

The stability of soil structure is very dependent on organic matter in soils with less clay and is more affected by sodium as the amount of sodium increases. The resilience of the soil structure is dependent on the capacity of the soil to shrink and swell, and the capacity of the soil to support plant growth.

5.5.1 Effects of soil structure decline

The major effects of poor soil structure are:

- low infiltration and runoff resulting in water erosion and less than optimum use of rainfall for plant growth
- overall poor plant growth
- poor germination and emergence of crops
- poor friability of soils making them difficult and costly to till and to sow.

5.5.2 Assessment of soil structure decline hazard

The LSC classification assesses the soil structure decline hazard using the nature of the surface soils. The nature of the surface soils is assessed using the following criteria:

- surface soil texture
- degree of sodicity
- degree of self-mulching.

These criteria enable an estimate of the likely structural condition, stability and resilience to be made. The features are estimated by observation in the field using standard procedures as defined in Lawrie et al. (2007) and Murphy et al. (2012). Subsoil character may be incorporated into the assessment in future versions of the scheme.

The soil structure decline hazard is assessed using a combination of Tables 7 and 8. The main assessment is provided in Table 7 and uses the texture, sodicity, degree of self-mulching, amount of organic matter and the presence of iron stabilised peds from basalt-type parent materials. Table 8 provides some guidelines on evaluating the degree of self-mulching and sodicity of clay surface soils.

Soil structure decline in many instances can be more easily overcome by a range of management practices than some of the other hazards; therefore, its effect on the LSC class is generally less than hazards such as water and wind erosion.

Table 7. LSC class for soil structural decline hazard

Field texture (surface soils)	Modifier	Outcome – surface soil type	LSC class
Loose sand	Nil	Loose sand	1
Sandy loam	Nil	Fragile light textured surface soil	3
Fine sandy loam	Normal	Fragile light textured soil	3
	High levels of silt and very fine sand (>60%)	Fragile light textured soil – very hardsetting	4
Loam	Normal	Fragile medium textured soil	3
	Friable/ferric[1]	Friable medium textured soils – includes dark, friable loam soils	1
	High levels of silt and very fine sand	Fragile medium textured soil – very hardsetting	4
	Mildly sodic	Mildly sodic loam surface soil	4
	Moderately sodic	Moderately sodic loam surface soil	6
Clay loam	Normal	Fragile medium textured soil	3
	Friable/ferric[1]	Friable clay loam surface soil – includes dark, friable clay loam soils	1
	High levels of silt and very fine sand (>60%)	Fragile medium textured soil – very hardsetting	4
	Mildly sodic	Mildly sodic clay loam surface soil	4
	Moderately sodic	Moderately sodic clay loam surface soil	6
Clay	Friable/ferric[1]	Friable clay surface soil	2
	Strongly self-mulching	Strongly self-mulching surface soil	1
	Weakly self-mulching	Weakly self-mulching surface soil	3
	Mildly sodic	Mildly sodic/coarsely structured clay surface soil	4
	Moderately sodic	Moderately sodic/coarsely structured clay surface soil	6
	Strongly sodic	Strongly sodic surface soil	7
Highly organic soils	Mineral soils with high organic matter[2]	Mineral soils with high organic matter	-[2]
	Organosol/peat soils[3]	Organic/peat soils	7

[1] The occurrence of friable or ferric surface soils is associated with (a) basaltic or basic parent materials and soils of the Ferrosols groups in the Australian Soil Classification or the Krasnozems and Euchrozem Great Soil Groups, and (b) the dark loam surface soils of the Chernozems and Prairie Soils on alluvial flats.

[2] Loosely defined here as soils with over 8% organic carbon. These soils revert to the LSC class determined by the mineral component of the soils.

[3] Organosols have organic material layers over 0.4 m thick with minimum organic carbon of 12% if sands or 18% if clays (Isbell 2002).

Table 8. Guidelines for evaluating some surface soil properties of clays

Sodicity/size of soil structural units	Character of surface soil
Very low exchangeable sodium (<3%), high exchangeable calcium, strongly swelling clays (smectitic) as in Vertosols (GSG Black Earths) Peds/aggregates 2–5 mm in an air dry condition	Strongly self-mulching surface soil
Low exchangeable sodium (3–5%), moderate exchangeable calcium, moderately swelling clays (illitic, interstratified, kaolinitic) as in many Dermosols and fertile Chromosols (GSG, Krasnozems, Euchrozems and others) Peds/aggregates 5–10 mm in an air dry condition	Weakly self-mulching surface soil
Moderate levels of exchangeable sodium (5–8%), often moderately low exchangeable calcium relative to exchangeable magnesium (ratio <2:1) Peds/aggregates 10–20 mm in an air dry condition	Mildly sodic surface soils
High levels of exchangeable sodium (8–15%), often low exchangeable calcium relative to exchangeable magnesium (ratio <1:1) Peds/aggregates 20–50 mm in an air dry condition	Moderately sodic surface soils
Very high levels of exchangeable sodium (>15%), often very low exchangeable calcium relative to exchangeable magnesium (ratio <0.5:1) Peds/aggregates >50 mm in an air dry condition	Strongly sodic surface soils

5.6 Soil acidification hazard

Soil acidification hazard is a major limitation in many important areas of agricultural production in NSW. Soils vary considerably in their natural acidity status and in their buffering capacity to resist changes in pH. The climate imposes an acidification potential on the soil by providing a leaching regime than can drive acidifying processes, especially nitrate leaching, but also by increasing plant growth and the plant-related acidifying processes such as nitrogen fixation. Land management practices also vary considerably in their acidification potential. The removal of agricultural produce as grain, vegetable mass or meat adds to the acidification pressure on the soil (Fenton and Helyar 2007; Fenton et al. 1996).

5.6.1 Effects of soil acidification

Soil acidification impacts on plant growth by:

- direct impact on biological and plant growth systems
- increased presence of some toxic elements, including aluminium at pH_{CaCl} levels below 4
- reduction in availability of some plant nutrients.

The resulting poor plant growth means:

- less farm productivity
- increased potential for soil erosion
- increased recharge into groundwater systems leading to increased salinity hazard
- reduced biodiversity.

5.6.2 Assessment of acidification hazard

Buffering capacity is estimated using Table 9, but Tables 10 and 11 may be used if a Great Soil Group classification is not available. The LSC class for soil acidification hazard is estimated using Table 12.

Table 9. Estimating buffering capacity based on Great Soil Group

Great Soil Group	Buffering capacity of surface soil	Great Soil Group	Buffering capacity of surface soil
Acid Peats	VL	Non-calcic Brown soils	M
Alluvial Soils – Light sandy textured (Sands to Sandy Loams)	L	Peaty Podzols	L
Alluvial Soils – Medium textured (Loams clay loams)	M	Podzols	VL
Alpine Humus soils	M	Prairie Soils	H
Black Earths	VH	Red and Brown Hardpan Soils	H
Brown Earths	M	Red-brown Earths	M
Brown Podzolic Soils	M	Red Earths – less fertile (granites and metasediments)	L
Calcareous Red Earths	H	Red Earths – more fertile (volcanics, granodiorites) or highly structured	M
Calcareous Sands	M	Red Podzolic Soils – less fertile (granites and metasediments)	L
Chernozems	H	Red Podzolic Soils – more fertile (volcanics, granodiorites) or highly structured	M
Chocolate soils	M	Rendzinas	H
Desert Loams	M	Siliceous Sands	VL
Earthy Sands	VL	Solodic soils	L
Euchrozems	H	Solonchaks	H
Gleyed Podzolic Soils	L	Solonetz	M
Grey-brown and Red Calcareous Soils	H	Solonized Brown Soils	M
Grey-brown Podzolic soils	L	Solonized Solonetz	L
Grey, Brown and Red Clays	VH	Soloths	L
Humic Gleys	L	Terra Rossa Soils	M
Humus Podzols	L	Wiesenboden	H
Krasnozems	M	Xanthozems	M
Lateritic Podzolic Soils	L	Yellow Earths	L
Lithosols	VL	Yellow Podzolic Soils – less fertile (granites and metasediments)	L
Neutral to Alkaline Peats	M	Yellow Podzolic Soils – more fertile (volcanics, granodiorites) or highly structured	M

Table 10. Estimating buffering capacity based on surface soil texture

Surface soil texture	Buffering capacity of surface soil
Sands and sandy loams – no calcium carbonate	VL
Sands and sandy loams – with calcium carbonate	M
Fine sandy loams – no calcium carbonate	L
Fine sandy loams – with calcium carbonate	M
Loams and clay loams – no calcium carbonate	M
Loams and clay loams – with calcium carbonate	H
Dark loams and clay loams (e.g. topsoils in Chernozems and Prairie Soils)	H
Clays – no calcium carbonate	H
Clays – with calcium carbonate	VH
Clays – with high shrink–swell	VH

Table 11. Estimating buffering capacity based on geology

Nature of parent material	Buffering capacity of surface soil
Highly weathered shales and metamorphic rocks, quartzose sandstones – highly siliceous	VL
Siliceous granites, sandstones	VL to L
Intermediate parent materials – granodiorites, less weathered shales and metamorphic rocks, andesites	M
Intermediate to basic rocks and parent materials – basalts, some andesites, gabbros, dolerites	H
Basic to ultrabasic rocks and parent materials – highly mafic or carbonates present, e.g. limestones	VH
Alluvium with high levels of carbonates and clays	H
Alluvium – sandy light textured	L
Alluvium – medium textured	M

Table 12. LSC class for soil acidification hazard

Texture/ buffering capacity	pH of the natural surface soil				
	<4.0 ($CaCl_2$) <4.7 (water)	4.0–4.7 ($CaCl_2$) 4.7–5.5 (water)	4.7–6.0 ($CaCl_2$) 5.5–6.7 (water)	6.0–7.5 ($CaCl_2$) 6.7–8.0 (water)	>7.5 ($CaCl_2$) >8.0 (water)
Mean annual rainfall <550 mm					
Very low	6*	5	4	3	n/a
Low	5	5	3	3	n/a
Moderate	5	4	3	2	1
High	4	3	2	1	1
Very high	n/a	n/a	1	1	1
Mean annual rainfall 550–700 mm					
Very low	6*	5	5	4	n/a
Low	5	5	4	3	n/a
Moderate	5	4	3	3	1
High	n/a	n/a	2	2	1
Very high	n/a	n/a	1	1	1
Mean annual rainfall 700–900 mm					
Very low	6*	5	5	4	n/a
Low	6*	5	4	4	n/a
Moderate	5	4	3	3	2
High	n/a	n/a	2	2	1
Very high	n/a	n/a	2	1	1
Mean annual rainfall >900 mm or irrigation					
Very low	6*	5	5*	4	n/a
Low	6*	4	4	3*	n/a
Moderate	5	4	3	3	2
High	5	3	2	2	1
Very high	5	3	2	1	1

Based on natural pH status, buffering capacity and climate
* These lands usually have very low fertility.

5.7 Salinity hazard

Salinity hazard is the potential for salts to be mobilised in a catchment and brought to the ground surface and waterways by changes in land use and land management. Widespread vegetation clearing, excessive irrigation inputs and other land management practices that increase recharge to groundwater are major drivers for this hazard.

5.7.1 Effects of salinity

Salinity is a major land degradation problem in NSW. Mobilisation of salts can have the effect of:

- saline outbreaks and scalding on the ground surface
- increased salinity concentration in streams
- increased salt loads leaving the catchment and being transported downstream.

Salt has a highly adverse effect on plant growth by:

- making it difficult for plants to extract water
- increasing the level of toxic elements to plants
- increasing sodicity levels in soils with resulting soil structure decline, crusting and other problems.

Reduced plant growth is associated with reduced crop and pasture productivity, and increased soil erosion.

5.7.2 Assessment of salinity hazard

The LSC classes for salinity hazard provide a simple initial evaluation of salinity hazard. A more detailed assessment of the salinity hazard can be achieved using the Hydrogeological Landscapes framework (Jenkins et al. 2010; Wilford et al. 2010). That system has been developed by OEH and the NSW Department of Primary Industries and is being progressively applied at a range of scales across NSW.

The LSC assessment for salinity hazard is based on the methodology in the environmental outcomes assessment methodology for the Native Vegetation Regulation (DNR 2005; DECCW 2011) and requires the following three inputs.

Recharge potential is the potential for water from rainfall, irrigation or streams to infiltrate past the plant root zone into the underlying groundwater system. This can occur over a whole landscape, or a component of the landscape, where water readily infiltrates soil, sediment or rock. Typically recharge areas have permeable, shallow and/or stony soils and fractured and/or weathered rock.

Recharge potential is highest where there is high rainfall relative to evaporation, low leaf area and plant water use, low water-holding capacity, and high permeability of the soils, regolith and rocks. Under natural conditions it relates to the climate, land use and hydrological characteristics of the catchment. It is exacerbated by land-use practices that disturb the vegetation cover or soil surface.

The value assigned for recharge potential is a qualitative assessment based on aerial photography, field observation and/or available literature, in particular soil landscape maps and reports.

Discharge potential is the potential for groundwater to flow from the saturated zone to the land surface. It is a function of position in the landscape, depth to water table, groundwater pressure, soil type, substrate permeability and evapotranspiration. Discharge may occur as leakage to streams, evaporation from shallow water tables, or as springs and wet areas where water tables intersect the land surface or where narrow breaks occur in low permeability layers above confined aquifers. Typical discharge areas are low in the landscape and have high water tables, or higher in the landscape if sub-surface barriers impede groundwater flow.

Discharge potential is highest when recharge rates are greater than the amount of water that leaves the groundwater system through base flow and evapotranspiration.

The value assigned for discharge potential is a qualitative assessment based on aerial photography, field observation and/or available literature, in particular soil landscape maps and reports.

Salt stores are high for many soils, regolith materials and rock types. This will depend on weathering characteristics, geological structures, rock and soil type, depth of the various materials and salt flux. It is possible to have areas of low salt store and still have a salinity hazard due to evaporative concentration of salts at the soil surface.

Conversely, areas of high salt store can have a lower hazard due to low rainfall. For example, in areas of low rainfall and low slope, salinity hazard can be low. Figure 7 provides a broad indication of salt stores throughout NSW. This map is generalised and local information should be used where available.

These three inputs are combined to provide a simple assessment of salinity hazard as described in Table 13. For localised assessments, it is important to calibrate the LSC estimates to local conditions and to validate against known areas of salinity, as reported in soil-landscape and hydrogeological landscape reports and other available sources. Consideration should be given to factors not used in the simplified LSC ranking, including salt mobility, local climate, soil buffering capacity and position in the landscape.

Table 13. LSC class for salinity hazard

Recharge potential	Discharge potential	Salt store	LSC class
Low	Low	Low	1
		Moderate	3
		High	4
	Moderate	Low	1
		Moderate	4
		High	4
	High	Low	1
		Moderate	4
		High	5
Moderate	Low	Low	1
		Moderate	3
		High	4
	Moderate	Low	2
		Moderate	5
		High	6
	High	Low	1 (3) *
		Moderate	6
		High	6
High	Low	Low	1
		Moderate	4
		High	5
	Moderate	Low	3 (2) *
		Moderate	4
		High	7
	High	Low	2 (3) *
		Moderate	6
		High	7

* The values in brackets are more accurate and should be used in preference to the original rating.

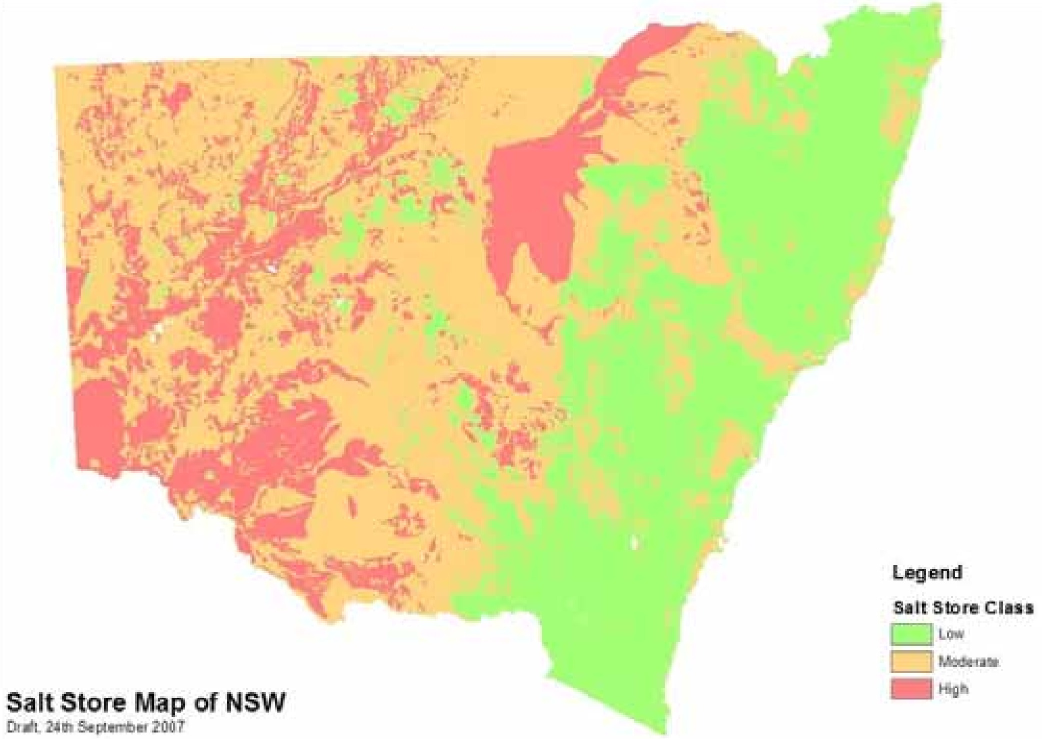


Figure 7. Salt store map

5.8 Waterlogging hazard

Waterlogging of soils is a major limitation in some generally low-lying areas of the landscape. Soils vary considerably in their natural drainage depending on the climate, their position in the landscape and their textural characteristics. Soils may be wet or waterlogged, for short periods, for long periods of several months, particularly in the wetter winter season, or even most of the year.

5.8.1 Effects of waterlogging

Waterlogging can severely affect agricultural production and land use. It restricts or prevents the supply of oxygen to plant roots, thus it can severely impact on plant health and survival. Plants and crops have differing abilities to tolerate waterlogged conditions. For example, rice and cotton require these conditions; however, most agricultural crop and pasture plants will suffer. Waterlogging also inhibits vehicular access, tillage and sowing operations and stock management.

5.8.2 Assessment of waterlogging hazard

Waterlogging hazard assessment is largely based on the drainage classes in NCST (2009). Table 14 is used to assess waterlogging hazard. It relies on information contained in soil landscape reports and other natural resource products or knowledge from local soil and land practitioners to determine the waterlogging duration and return period.

Table 14. LSC class for waterlogging hazard

Typical waterlogging duration (months)	Return period	Typical soil drainage*	LSC class**
0	every year	rapidly drained and well drained	1
0–0.25	every year	moderately well drained	2
0.25–2	every year	imperfectly drained	3
2–3	every 2 to 3 years	imperfectly drained	4
2–3	every year	imperfectly drained	5
>3	every year	poorly drained	6
Almost permanently	every year	very poorly drained	8

* NCST (2009, p.202–4)
** Based on slope position, climate and length of time soils are wet.

5.9 Shallow soils and rockiness hazard

5.9.1 Effects of shallow soils and rockiness

Shallow soils and rockiness reduce the land-use capability of soils and land. The more rock outcrop and the shallower the soils, the less volume of soil available for storing nutrients and water. Rock outcrop impedes access by vehicles and farm machinery and restricts potential for tillage and sowing of crops.

5.9.2 Assessment of shallow soils and rockiness hazard

The criteria used by the LSC classification to assess shallow soils and rockiness hazard are:

- estimated percentage exposure of rocky outcrops
- average soil depth.

The relationship between the criteria in determining the LSC class is shown in Table 15.

5.10 Mass movement hazard

Mass movement relates to the large scale movement of earth under the force of gravity. It is a function of the gravitational stress acting on the land surface and the resistance of the surface soil, sand or rock materials to dislodgement (Hicks 2007). In general the hazard for mass movement increases with an increase in slope and an increase in rainfall when more water is available to saturate and reduce the strength of the soil. Certain combinations of slope, soils, landform, climate and geology are more susceptible to mass movement. Disturbance of soils in some land management actions (for example cutting of batters into slopes) can also increase the likelihood of mass movement.

5.10.1 Effects of mass movement

Mass movement is a serious threat to many land uses. The most serious consequences are damage to or destruction of buildings and other infrastructure, and injury or loss of life of people or livestock.

5.10.2 Assessment of mass movement hazard

The criteria used in the LSC classification to assess mass movement hazard are:

- existing evidence of mass movement
- slope class
- average annual rainfall.

The relationship between the criteria in determining the LSC class is shown in Table 16.

In some circumstances land that has been classified as Class 7 or 8 because of mass movement hazard may be used for limited agricultural land uses.

Table 15. LSC class for shallow soils and rockiness hazard

Rocky outcrop (% coverage)*	Soil depth (cm)	LSC class**
Nil	>100	1
<30 (localised*)	>100	2
	75– <100	3
	50– <75	4
	25– <50	6
	0– <25	7
30–50 (widespread*)	>100	4
	75–100	5
	25–75	6
	<25	7
50–70 (widespread*)	>100	6
	50–100	6
	25– <50	7
	<25	7
>70	n/a	8

* Rock outcrop limitation from soil landscape report.
** Based on rocky outcrop and soil depth

Table 16. LSC class for mass movement hazard

Mean annual rainfall (mm)	Mass movement present	Slope class (%)	LSC class
<500	No	n/a	1
	Yes	n/a	8
>500	No	n/a	1
	Yes	<20	6
		>20–50	7
		>50 or any scree or talus slope	8

Note that scree or talus slopes go automatically into Class 8.

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