State of the catchments 2010

Land management within capability

Technical report series

Monitoring, evaluation and reporting program

Assessing land management within capability in NSW

Jonathan Gray
Greg Chapman
Brian Murphy

Office of Environment and Heritage

Monitoring, evaluation and reporting program
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Acronyms

ABS	Australian Bureau of Statistics
ALES	Automated Land Evaluation System
ASS	Acid sulfate soil
CAP	Catchment action plan
CMA	Catchment Management Authority
DECCW	Department of Environment, Climate Change and Water (DECC pre 1/7/09)
DPI	Department of Primary Industries
FAO	Food and Agriculture Organisation of the United Nations
FESLM	Framework for Evaluating Sustainable Land Management
GIS	Geographical information system
LMwC	Land management within capability
LSC	Land and Soil Capability
MER	Monitoring, evaluation and reporting
NRC	Natural Resources Commission
NRM	Natural resource management
OEH	Office of Environment and Heritage, Department of Premier and Cabinet
SALIS	Soil and Land Information System
SMU	Soil monitoring unit
SOC	State of the catchments
SOE	State of the Environment
USDA	United States Department of Agriculture

Glossary

Capability	The inherent physical capacity of the land and its soils to sustain a range of land-uses and management practices in the long term without degradation to soil, land, air and water resources (Dent & Young 1981).
Catchment management authority (CMA)	There are 13 CMAs in NSW.
Expert knowledge	Information on land management issues and trends gained from relevant experts with local knowledge from the CMAs and the former DECCW (now OEH) with the use of a series of standard question forms (see Appendix 1). This information supplemented the quantitative survey data.
Hazards	Processes that can lead to degradation of the land and soil environment, including sheet erosion, gully erosion, wind erosion, soil structure decline, organic carbon decline, soil salinity, soil acidification and acid sulfate soils.
Land management action	An individual operation or activity used to implement a land management practice, eg sowing with minimum disturbance, stubble burning, tillage with one-way disc plough, or addition of lime or fertiliser.
Land management practice	Used here to refer to the system or set of land management actions used to implement a land-use at site, eg direct drilling, no-till, time controlled grazing (Murphy et al. 2008).
LSC or LSC_{LAND}	The capability of the land according to the eight-class system of Murphy (2006, 2007), that provides individual rankings for a range of land and soil hazards. LSC_{LAND} refers to the actual LSC at a site.
LMwC	The concept of land at a site or region being managed sustainably, in accordance with the inherent physical capacity, so as to avoid degradation to soil and land resources.
LMwC Index	The five-class index indicating the degree to which land is being used within capability, that is, sustainably. Class 1 is the worst case with very high risk of land degradation, while Class 5 is the best case, with negligible risk of land degradation.
Land-use	The principle enterprise being undertaken on the land, eg cropping, grazing, horticulture, vegetables, forestry or conservation.
Monitoring site	The representative 25 m x 25 m block within a paddock, where sampling was undertaken. There are generally 10 sites per SMU.
Paired sites	Two generally adjoining sites with the same soil and land conditions but differing in their land-use or management. This concept allows for the impact of differences in land-use or management to be separated from other physical influences.
Pressure trend	Taken as the general regional trends in the adoption of sustainable land management, with declining trends in land management (that is, management becoming poorer) corresponding to increasing pressures. The term relates to the 'pressure-state-response' model.

SMU	A large tract of land with a relatively homogenous or repeating pattern of soils, parent material, geomorphology, and climate. Generally SMU boundaries coincide with soil landscape, soil mapping or land system mapping boundaries. They are generally regarded as priority areas within CMAs and were the focus of the monitoring program. There are generally 10 SMUs per CMA.
Soil condition	The ability of soil to deliver a range of essential ecosystem services, including habitat for soil biota, nutrient cycling, water retention and primary plant production. It is a measure of the health of the soil's ecosystems and agricultural productivity.
Upper sustainable LSC_{MGT}	The land and soil capability threshold where a land management action is still sustainable but beyond which it is no longer sustainable. An activity carried out on land that is not within its upper sustainable limit carries an unacceptable risk of land degradation.

Summary

Failure to manage land in accordance with its capability may result in a degradation of resources both on and off site, leading to a decline in natural ecosystem values, agricultural productivity and infrastructure function. This issue, as well as the key natural resource management (NRM) target and the closely associated soil condition theme target (Section E4, Targets 10 & 11), was identified in the NSW State Plan 2006 and is being addressed through the following land management within capability theme target:

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

The NSW monitoring, evaluation and reporting (MER) program described in this report was designed and implemented by the then NSW Department of Environment, Climate Change and Water (DECCW), now Office of Environment and Heritage (OEH), with contributions from catchment management authorities (CMAs) and the NSW Department of Primary Industries (DPI).

The program was designed to determine whether New South Wales lands are being managed on a sustainable basis, ie within their inherent capability. The aim was to provide a baseline for future comparison by establishing up to 100 monitoring sites within 10 priority soil monitoring units (SMUs) in each of the 12 larger CMA regions, with fewer sites established in the smaller Sydney Metropolitan CMA region. Soil data collection, along with laboratory analysis, was undertaken at each site to determine land and soil capability (LSC). Land management data were collected by surveying landholders and local experts.

By May 2009, 850 sites had been established and 497 landholder surveys returned. The land-uses examined included cropping, grazing, horticulture, forestry and nature conservation. Land degradation hazards identified included sheet erosion, gully erosion, wind erosion, soil structure decline, organic carbon decline, soil salinity, soil acidification and acid sulfate soils (ASS).

Methods

The process to determine the level of sustainable land management in NSW involves comparing the potential impact of land management actions at specific sites with the LSC of those sites; this is done in order to determine whether the land has the ability to withstand the potential adverse impacts. The LSC is a rule-set that provides a ranking of the inherent 'hazards' associated with common land management actions for a given set of soil and landscape properties. In this context, hazard refers to the potential for a problem to occur and not the problem itself. The system provides that particular land management operations, applicable to a land-use such as cereal cropping or grazing, are unlikely to cause degradation if matched correctly to the LSC of the land unit.

The potential adverse impact of the various land management actions on each of the land degradation hazards was rated using first principles, literature values and field observations and was ratified by soil scientists and extension officers. The adverse impact is correlated with an 'upper sustainable LSC' (the LSC above which the action is not sustainable) and then compared to the actual LSC of the site. Where the 'upper sustainable LSC' class is lower than the 'actual LSC' class of the site, then the site is being managed beyond its capability for that particular hazard. By way of example, if a particular land management action is suitable for LSC classes 1 to 3 (in an eight-class system) then the action is assigned an 'upper sustainable LSC' of 3 (ie requires good quality land). If the 'actual LSC' class at the site is 2 (ie, very good quality land) then the management action is

safely within capability by one unit. However, if the 'actual LSC' class at site is 5 (ie moderate to low quality land) then the action is beyond the sustainable capability by two units which represents a very high risk of land degradation.

Results were averaged over the different actions and converted into a land management within capability (LMwC) index for each hazard**.** The index indicates the degree to which land is being managed sustainably. The LMwC indices were progressively combined to give indices for each site, SMU, CMA regions and finally the whole state. Results were validated using expert knowledge from the former DECCW (now OEH) and CMA scientists.

Results

Results from the project were prepared for each of the 13 CMA regions in the NSW State of the catchments (SOC) 2010 reports. Due to confidentiality reasons, site and SMU results are not published directly within this report. Rather, an example of the information obtained for the NSW SOC land management within capability reports, including explanatory definitions of report criteria, is presented in Chapter 4. Results for a hypothetical region are presented on an (i) SMU basis and (ii) land degradation hazard basis. One hundred and twenty four SMUs were assessed across the state. The number of SMUs with a poor or very poor LMwC Index was summarised by region and hazard type with state-wide totals as follows:

- Organic carbon decline – 54
- Structure decline – 40
- Acidification – 32
- Wind erosion – 30
- Gully erosion – 24
- Salinity/waterlogging –24
- Sheet erosion – 21
- ASS – 5.

A state-wide summary was prepared for the NSW State of the Environment (SOE) Report (DECCW 2009a). This report showed that on average, land in NSW is being managed at a level just on par with its inherent physical capability. The overall LMwC Index across the state, derived from this LMwC component of the MER program, is 3 (in the 1–5 scheme); this indicates 'fair' land management relative to capability. However, 77 per cent of SMUs were found to be poorly managed in regards to at least one hazard. This means that these areas have a high risk of ongoing land degradation. On a state-wide basis, organic carbon decline and soil structure decline appear to be being managed the least sustainably.

There are no previous quantitative data available with which to compare the current results and establish firm trends. Qualitative data on trends were produced from the assessment of expert knowledge for each hazard within each SMU. Across the state, the trend in LMwC is steady but varies slightly across CMA regions and by hazard. There is consensus that management actions impacting on sheet erosion and salinity are improving with respect to capability; however, the management of organic carbon, soil structure and soil acidity appear to be becoming less sustainable. No assessment of the socio-economic and technological constraints driving the perceived trends was possible within the scope of the current program.

Discussion

There are a number of caveats on the reliability of these results that should be considered during interpretation. These include the incomplete dataset; the relatively small sample size for state coverage, uncertainty regarding representativeness of the sites and their land-uses, possible bias in the collaborating landholders towards those with more progressive and sustainable land management operations than typical landholders; the reliance on expert opinion rather than objective measurement for some elements of the program; and the use of averages which may mask problems with some land management issues.

This report recognises that the broad response strategies by government and other organisations at state and regional levels to help promote sustainable land management throughout NSW are comprehensive, and will help facilitate sustainable change towards meeting the 2015 LMwC target. However, the broad pressures currently driving both positive and negative changes to land capability within management are beyond the scope of this project to assess, as they are often complex and community and landscape-specific.

It is noted that issues such as the financial, technical and managerial capabilities of landholders; knowledge and perceptions of sustainable land management practices by landholders; market dynamics of products and production costs; tax and government financial and legislative settings to promote sustainable land management; and long-term climate variability and climate change, are at least in part dealt with in the community monitoring themes of the state monitoring program. It is recommended that coordination between these themes be enhanced to promote synergies in the facilitation of change.

It is recommended that activities be undertaken to complete the current baseline phase of the project, including:

- the continued establishment of monitoring sites to complete the aim of having 100 monitoring sites per CMA, and 40 monitoring sites in the Sydney Metropolitan CMA region
- dialogue with landholders to obtain outstanding land management survey results.

Recommendations for further possible work to improve the monitoring program include:

- acquiring and integrating Australian Bureau of Statistics (ABS) and NSW Primary Industries survey data ('Farm On' land management surveys)
- undertaking ongoing periodic monitoring on the basis of a five-year rolling review
- further analysis of the detail of land management activities from the landholder surveys to clarify the nature and extent of different practices, with an aim to identifying common constraints that hinder progress toward the target
- developing and proofing the concept of land-use versus land capability mapping, to extrapolate current concepts to an areal coverage consistent with the target
- developing a rapid field assessment procedure for LSC and LMwC, that will ultimately guide sustainable land management practices for landholders.

In conclusion, the MER program provides an effective feedback and control mechanism for the operation of the state's NRM system. Results presented for the LMwC theme indicate a need to improve progress towards the target. Identification of the socio-economic, cultural, government policy and long-term climatic factors affecting the management of land within capability can in part be addressed by reference to results from other themes. Identifying the constraints to progress toward the target is a precursor to modifying goals and objectives within the existing strategies to achieve the appropriate response to the MER program. Therefore it is recommended that synergies be assessed between current monitoring theme outcomes to better plan a coordinated response, and ultimately improve progress towards the target of increasing the area across NSW managed within capability.

1. Introduction

The management of land within its inherent physical capability is vital for the sustainable use of soil and land resources. Land capability is the inherent physical capacity of the land to sustain a range of long-term land-uses and management practices without degradation to soil, land, air and water resources (Dent & Young 1981; Emery 1986). It is a function of landscape features and processes including 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. Soil and land degradation is considered by Diamond (2005) to be the greatest ecological threat facing Australia, and is linked with the collapse of civilisations throughout history (Dale & Carter 1955).

The importance of this issue and the need for its monitoring has been recognised on a national level (McKenzie et al. 2002; Campbell 2008; Dixon et al. 2007) and at the state level by the NSW Natural Resources Commission (NRC) (NRC 2005). The LMwC target is one of 13 key NRM targets for NSW and is listed as:

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

The target was established as a theme of the MER program and is included in the NSW State Plan (Section E4, Target 11) (NSW Government 2006). The former DECCW (now OEH) was assigned responsibility for designing and implementing the monitoring program for eight of the 13 themes, including land management within capability together with the closely associated monitoring of soil condition theme (Natural Resources and Environment CEO Cluster Group 2006; Wilson et al. 2006).

Land management actions are activities undertaken in the course of rural land-uses such as cropping, grazing, horticulture, forestry and nature conservation. Management actions such as the intensity of tillage prior to sowing, length of bare fallow, maintenance of groundcover and the extent of fertiliser application can all adversely impact on the ability of land to provide ecosystem services.

Land degradation hazards associated with the target include sheet erosion, gully erosion, wind erosion, soil structure decline, organic carbon decline, soil salinity, soil acidification and ASS.

The MER program was primarily carried out by the former DECCW (now OEH) during 2008 and is briefly described in Gray et al. (2008).This report outlines the overall procedures and the primary results of the program. Detailed results are presented in the SOC reports (DECCW 2010), NSW SOE Report 2009 (DECCW 2009a) and in proposed publications.

1.1 Aims

The primary aims of the current program were to:

- design a monitoring procedure to allow assessment of progress towards meeting the state-wide LMwC target, ie assess whether there is an increase in the area of land managed within its capability by 2015
- develop a system to equate land management activities with the allocated LSC

- develop a baseline of permanent monitoring stations across NSW, distributed equally across representative SMUs for the 13 CMAs, with data on soil condition, LSC and land management practices
- provide results on the current degree of LMwC at each of the monitoring sites, their respective SMUs, CMAs and the entire state
- highlight particular land degradation hazards and geographic areas of concern for each CMA region and the state as a whole
- identify ongoing requirements for the MER program for this monitoring theme.

2. Background

2.1 Land evaluation schemes

The LMwC scheme outlined in this report represents a new land evaluation system. Such systems aim to effectively match land-use and land management practices with the inherent physical qualities and capacities of the land. They have been evolving since the 1950s and range from the essentially qualitative conventional approaches which are often empirically based (ie based on experience), to more quantitative process modelling approaches which generally contain explicit sets of rules (McKenzie et al. 2008; van Gool et al. 2008; Ringrose-Voase 2008).

One of the earliest formal land evaluation schemes was the United States Department of Agriculture (USDA) Land Capability Classification (Klingebiel & Montgomery 1961), which allocated land to one of eight classes depending on its limitations, with guidance on land-uses appropriate for each class. The following decade saw the Food and Agriculture Organisation of the United Nations (FAO) release the Framework for Land Evaluation (FAO 1976), a scheme that was widely used in many countries. This framework did not present precise methods but rather outlined principles, concepts and terminology that could form the basis of local, regional and national systems. More specific FAO guidelines relating to dryland agriculture (1983), irrigated agriculture (1985), extensive grazing (1991) and others followed. The Automated Land Evaluation System (ALES) (Rossiter 1990) provided a computer based adaption of the FAO framework, which gained wide international use.

Specific land management issues have been directly incorporated into another FAO land evaluation scheme, the Framework for Evaluating Sustainable Land Management (FESLM) (FAO 1993). The FESLM is designed as a pathway to guide analysis of land-use sustainability through a series of scientifically sound, logical steps. It seeks to connect all the interacting environmental, economic and social conditions to determine whether a form of land management is sustainable. It is designed for use over catchment size areas rather than small field size areas.

The USDA and FAO schemes led to the development of several land evaluations schemes in Australia, including those of Rowe et al. (1988) in Victoria, Wells & King (1989) and van Gool et al. (2005) in WA, and Emery (1985) and the more recent LSC system *of* Murphy et al. (2006 & 2007) (see Section 2.4) in NSW.

The impact of different land management strategies was specifically incorporated into land evaluation processes in Australia through the Threat Identification Model of Smith et al. (2000) which was subsequently further developed into the Land Use Impact Model (LUIM) of McNeill & MacEwan (2007). The LUIM is used to rate and map the risks to soil, land, water, and vegetation under different land-uses and management practices. It can evaluate current and possible future land management scenarios and considers a range of threatening land degradation processes such as soil structure decline, erosion, and vegetation loss.

The LUIM system applies the risk management framework of Standards Australia (2009), which is based on the concept that likelihood x consequence = risk. It incorporates knowledge of relationships between threatening processes, landscape characteristics and land management practices, which are formulated as specific rules and ratings. Geographical information systems (GISs) are used to apply these rules and ratings in the landscape and map their occurrence. The outputs of the LUIM are maps that rank the likelihood and level of risk associated with a particular threatening land degradation process. These can be used to guide investment to the areas of greatest risk.

The LMwC scheme presented here continues with the direct incorporation of land management strategies into a quantitative, explicit rule based land evaluation system. It attempts to quantify the potential impact of specific land management actions and compare this with the capability of the land in relation to a range of land degradation hazards, as outlined in Section 3.

2.2 Land management actions and potential impacts

A range of land management actions are carried out during the operation of different land-uses. Certain actions can have a large adverse impact on the soil and land, while others may have less impact. For example, an aggressive and frequent tillage regime will have a greater adverse impact on the soil than will a zero tillage regime. Those actions with a large adverse impact require land of higher capability in order to be sustainable. That is, they require high capability land. Conversely, land management actions with lesser adverse impact can be carried out on a wider range of land types, including land with lower capability.

To better understand the impact of land management on the soil, it is useful to distinguish between the terms land-use, land management practice and land management action. These terms have been defined below:

- Land-use: the principle enterprise being undertaken on the land, eg cropping, grazing, horticulture, vegetables, forestry or conservation.
- Land management practice: the system or set of land management actions used to implement a land-use at site, eg direct drilling, no-till, time controlled grazing.
- Land management action: an individual operation or action used to implement a land management practice, eg sowing with minimal disturbance, stubble burning, tillage with one-way disc plough, removal of stock from grazing, addition of lime or fertiliser.

Table 1 lists some land management actions typically associated with land-uses such as cropping, grazing, horticulture, forestry and nature conservation, together with an indication of their significance to different forms of land degradation.

Discussion and recommendations on the major land degradation hazards and sustainable land management are given in numerous publications including Charman & Murphy (2007), Lawrie et al. (2007), NSW Agriculture et al. (2004), Moore (1998), NSW Agriculture (1994), Squires & Tow (1991), Russell & Isbell 1988, Russell & Russell (1988) and Charman (1985).

Table 1: Dominant land management actions and their associated adverse impacts

Land management action	Relevant land-uses	Significance
Fertiliser use	All rural	Excessive use contributes to soil acidification. Insufficient use contributes to poor plant growth, low groundcover and low organic matter
Soil conditioner use	All rural	Insufficient use contributes to poor plant growth
Irrigation use	All rural	Excessive use contributes to acidification
Heavy vehicle movement, particularly in wet conditions	All rural	Excessive use leads to structure decline
Tillage frequency	Cropping	Excessive tillage leads to structure decline and erosion
Type of tillage equipment	Cropping	Aggressive tillage creates high levels of disturbance and leads to soil structure decline and erosion
Type of sowing equipment	Cropping	Excessive disturbance contributes to structure decline and erosion
Length of fallow	Cropping	Long fallow contributes to erosion, salinity and acidification
Type of stubble management	Cropping	Influences erosion, structure decline and acidification
Method of weed management	All rural	Influences potential structure decline and erosion
Extent of groundcover	All rural	Low cover leads to erosion, structure decline and acidification
Pasture height (condition)	Grazing	Low pasture height can lead to erosion, acidity and salinity
Stocking system	Grazing	Influences groundcover
Perennial v annual pastures	Grazing	Influences groundcover and root depth, groundwater recharge and leaching, salinity and acidification
Extent of erosion control measures	All rural	Influences the prevention of erosion
Timber harvesting methods	Forestry	Influences degree of ground disturbance
Exclusion of stock	Grazing, forestry	Influences groundcover

2.3 The hazards

The LMwC theme uses a number of hazards to assess capability. These hazards are the key land degradation hazards of sheet erosion, gully erosion, wind erosion, soil acidification, organic carbon decline, soil structure decline, ASS and soil salinity. The hazards also form the basis of the rule based LSC scheme of Murphy et al. (2006, see Section 2.4).

Traditionally, capability has been intended to assess the risk of land and soil degradation occurring. The assessment of land degradation risk requires an estimate of the potential consequences of land management actions on a hazard, and the likelihood that those consequences will be realised. The capability of the land provides the estimate of the degree of hazard at a site. The land management practice and its specific actions determine the likelihood of the consequences being realised (the risk). The use of hazards to assess capability is consistent with an established terminology and convention (Standards Australia 2009, DNR 2005; Murphy et al. 2007).

Each of the hazards is described in the following section including a brief definition, an explanation of the consequences of mobilising the hazard and the risk factor most likely to lead to degradation.

2.3.1 Soil erosion – sheet and rill

Definition

Sheet erosion is the removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff. Rill erosion involves the formation of numerous small channels on the surface, which can be destroyed by normal tillage (Rosewell et al. 2007).

Consequences

Continued long-term sheet and rill erosion can reduce soil quality and the capacity of soil to hold water and nutrients to grow plants. Severely sheet and rill eroded sites cease to provide virtually all ecosystem services and can contribute significantly to the deterioration of water quality in streams and water bodies. The sediment from sheet and rill erosion carries sand, silt and clay particles, as well as the nutrients and organic materials, resulting in significant siltation and eutrophication of streams, water courses and water storages. Nitrogen, phosphorus, organic materials and other nutrients associated with sediment can overwhelm aqueous ecosystems.

Risk factors

Sheet and rill erosion are generally a consequence of insufficient groundcover, resulting in unprotected soil, increased runoff and highly erosive rain splash and water flows, particularly on erodible soils. Specific land management actions contributing to the hazard include long periods of bare fallow, low retention of stubble, excessive tillage, use of high disturbance tillage equipment, low groundcover from high grazing pressures, low proportions of perennial plants and poor structural erosion controls (Miller 2008).

2.3.2 Soil erosion – gully

Definition

Gully erosion is the removal of top and subsoils by concentrated water flows, resulting in channels greater than 0.3m deep (Rosewell et al. 2007).

Consequences

Gullies cannot be filled or smoothed using normal tillage equipment, as the gullies are too deep for machinery to negotiate, and are often difficult to treat, control or eradicate. Topsoil and subsoil are removed and often delivered directly to water bodies with consequent sedimentation and eutrophication of aquatic ecosystems. Land is divided into small portions, constraining management options and reducing access. Like other erosion hazards, this hazard is expected to be sensitive to climate change, with associated increased storm intensity and possible decreased groundcover. Gullies are difficult to control and are caused by changes which increase soil detachment.

Risk factors

Gully erosion is a consequence of factors such as insufficient groundcover, increased runoff and highly erosive concentrated water flows, particularly on erodible soils. Specific land management actions of concern are very similar to those for sheet and rill erosion.

2.3.3 Soil erosion – wind

Definition

Soil erosion by wind occurs when the force of the wind is sufficient to detach and carry soil particles (Leys 2007).

Consequences

Wind erosion is sensitive to both climate and land management (Leys *et al.* 2008). It poses a threat to soil condition through the removal of soil, especially the clay and organic matter fractions leading to reduced soil quality, carbon sequestration capacity and food production.

Wind erosion has offsite impacts such as:

- reduced air and water quality
- increased health costs associated with air pollution
- atmospheric warming and cooling
- reduction in the biodiversity due to native vegetation burial and deposition of extra nutrients.

Risk factors

Wind erosion is generally a consequence of insufficient groundcover and lack of protection from highly erosive winds, particularly on dry, erodible, unprotected soils. Specific actions of concern are the same as for sheet and rill erosion, together with a lack of wind breaks.

2.3.4 Soil acidification

Definition

Acidification is the trend towards increasing acidity in the soil, ie decreasing pH (negative log of hydrogen ion concentration).

Consequences

Soil pH is the major soil chemical fertility attribute that affects many ecosystem services (Lockwood et al. 2003). It is arguably the main chemical indicator of soil health (Chapman et al. 2011) and affects nutrient supply, aluminium and manganese toxicity and soil fauna populations. Acidification is subject to irreversible decline if not managed. Summaries of causes, impacts and management can be found in Chapman et al. (2007), Fenton & Helyar (2007) and Lockwood et al. (2003).

Risk factors

Acidification is a consequence of inappropriate management practices such as:

- allowing over-production and significant removal of biomass (ie hay removal)
- providing conditions that allow leaching of nitrate past the root zone, such as long periods of bare fallow, excessive use of annual legumes, deep drainage from irrigation, poor pasture condition resulting from high grazing pressures and excessive use of nitrogen fertilisers
- insufficient use of ameliorants such as lime or dolomite.

2.3.5 Organic carbon decline

Definition

Organic carbon decline is a loss of carbon from the soil by processes that promote the formation and release of carbon dioxide into the atmosphere, or those that inhibit normal soil carbon production.

Consequences

The loss of soil organic matter results in a decline of physical and chemical properties. Soil organic carbon is an essential soil component and plays a critical role in a variety of soil processes and functions (Skjemstad et al. 2006; Charman & Roper 2007). Soil organic matter is a store of nutrients in the soil and is important for maintaining soil structure and stability as it binds soil particles into stable aggregates. It is a critical link in the nutrient cycling processes that operate in soils, and it also influences soil water-holding capacity. The abundance of organic matter provides an indirect measure of the extent of biological activity in the soil. Organic matter has a constant carbon composition of approximately 57 per cent (Hazelton & Murphy 2007).

Soil organic carbon is generally found in high concentrations in the uppermost layers of the soil, as this is where the bulk of organic input occurs. The total quantity of carbon in the soil is often considerably greater than that of the above-ground vegetation. The level of organic matter typically varies as a function of climate, drainage, land-use and land management. The overall quantities of soil organic carbon are generally higher where the climate is cooler and wetter.

Risk factors

Organic carbon decline is often greatest where there are high impact land management actions. It is generally a consequence of excessive extraction of organic materials where production exceeds replenishment. Specific management actions contributing to this hazard include high removal of biomass (eg frequent cropping or hay cutting), excessive disturbance such as by frequent tillage, stubble removal, insufficient fertilisers or conditioners, and poor pasture condition resulting from high grazing pressures (Charman & Roper 2007).

2.3.6 Soil structure decline

Definition

Soil structure is the physical arrangement of soil particles and the voids between them, and is a measure of the physical health of the soil. Structure decline is the degradation of the physical structure of the soil. Structural decline results from a disruption of the factors that provide stability to the soil structure and is often associated with organic carbon decline (see Section 2.3.5) and compaction (see below).

Consequences

A well structured soil can grow plants, absorb rainfall, provide an aerobic environment for biological activity, provide a good seedbed for crops and sown pastures and is well drained of water to maximise trafficability of machinery (Cass 1999; Geeves et al. 2007). A poorly structured soil fails in one and usually more of these functions. Structure decline is therefore the degradation of the physical structure of the soil, reducing the potential for water storage and movement, aeration and plant growth. The maintenance of good soil structure is vital for environmental and economic sustainability of agricultural land.

A decline in soil structure can have a marked adverse impact on agricultural production, animal health, production costs and greenhouse gas emissions. A decline in soil structure can take considerable time and money to correct (Shepherd 2007).

Risk factors

Soil structure decline is exacerbated by land management practices that cause disruption and compaction, especially when the soil is very wet, or dry and brittle. Such land management practices include movement of vehicles and stock, excessive tillage, use of high disturbance equipment, removal of stubble and poor pasture condition resulting from high grazing pressures.

2.3.7 ASS

Definition

ASS are naturally occurring sediments and soils containing iron sulfides (principally pyrite). ASS are found underlying many coastal floodplains, in coastal wetlands, and as bottom sediments in coastal rivers. They have also been recently found to be associated with some inland water bodies. Providing ASS are not disturbed nor drained, they are relatively harmless; however, where the sediments are exposed to air, the pyrite is oxidised and sulfuric acid is generated.

Consequences

The resulting acid discharges are known to kill fish and oysters, corrode engineering structures and severely reduce agricultural productivity. ASS also limit biodiversity by degrading valuable estuarine and wetland habitats and are reported to be a significant greenhouse gas emission source (Tulau 2008).

Risk factors

Specific management actions contributing to the disturbance and exposure of ASS include actions that disturb and expose potential acid sulfate material to the air, the construction of deep drains and a lack of suitable water level management (AASMAC 1998).

2.3.8 Salinity and waterlogging

Definition

Salinity and waterlogging hazards relate to the build-up of salt and/or saturated soils on, or near, the ground surface. Although both can occur naturally, they are frequently induced as a result of human activities which alter the balance of the water cycle in the landscape. Rising groundwater tables are often due to increased accession of water into groundwater systems, following a decline of deep rooted perennial plants (Charman & Wooldridge 2007).

Consequences

Salt has a highly adverse effect on plant growth, making it difficult for the plant to absorb water and having other toxic effects. Salinity and waterlogging can cause profound damage to terrestrial and aquatic ecosystem through adverse impacts on aeration and nutrient supply, as well as changes in water quality from increased salt and associated erosion.

Risk factors

Land management actions that contribute to salinity and waterlogging are those that reduce transpiration or otherwise add excess water into the groundwater system, including:

- long fallows or periods with no plant growth
- low plant cover with cropping cycles
- maintenance of low tree and shrub cover over the whole property
- low proportions of perennial grasses
- poor pasture condition from grazing
- excessive deep drainage from irrigation.

2.4 Land and soil capability

Land capability refers to the inherent physical capacity of the land and its soils to sustain a range of land-uses and management practices in the long term without degradation to soil, land, air and water resources (Dent & Young 1981). For land to be used and managed sustainably it needs to be managed in accordance with its inherent capability. Failure to do so risks degradation of resources both on and off site, leading to a decline in natural ecosystem values, and reduced agricultural productivity and infrastructure damage. Land capability may be considered the 'ecological carrying capacity' of the land (Duggin 1992).

The LSC system is a comprehensive capability assessment scheme recently developed by the former DECCW (now OEH) (Murphy et al. 2006, 2007). It involves a series of rules to assign biophysical land characteristics to one of eight classes (see Table 1) for a range of land degradation hazards such as sheet erosion, acidification and structure decline. It builds on the NSW Rural Land Capability system (Emery 1986) but separately assesses each indicator. In the scheme, LSC Class 1 refers to land of highest capability, ie land least susceptible to degradation. At the other end of the scale, LSC Class 8 refers to land with the lowest capability, ie land with properties that are most susceptible to degradation.

The overall LSC rating for any site is taken as the worst capability rating of any of the component hazards. An overview of each LSC class is given in Table 2. The LSC considers only the inherent physical attributes of the site including soil, topographic and climatic factors. It does not consider issues associated with land suitability, such as socio-economic or land management factors.

It is important to note that the LSC land management monitoring rule-set follows the LSC rule-set prescribed for property vegetation planning (NSW Department of Natural Resources 2005) but is more comprehensive, as the range of issues is broader than those required for the assessment of native vegetation management.

Table 2: LSC classes for MER program

Class	Limitations and land management practices	Land-use, occurrence and implications
Land capable of regular cultivation		
1	Land has very slight to negligible limitations to land-use. No special land management practices required to overcome limitations except those aimed at maintaining or improving soil structure and soil nutrient levels and organic matter. Flooding is sometimes a problem on this land because it is often adjacent to major rivers and streams.	Land capable of a wide variety of agricultural uses that need regular cultivation. Generally found on level alluvial flats of major rivers with stable fertile soils that have a high potential for agriculture, or on plateau surfaces of high fertility basalt derived soils. It may be cultivated for vegetable and fruit production, grain crops, oil seed crops, fodder and forage crops and sugar cane in specific areas. Includes prime agricultural land.
2	Land has slight limitations to land-use. The practices to overcome limitations are minor and readily available. They include some conservation tillage practices, maintenance of groundcover to prevent water and wind erosion, adequate crop rotation and maintenance of levels of nutrients, organic matter and pH.	Usually gently sloping land capable of a wide variety of agricultural uses that need regular cultivation including vegetable and horticulture production, and a range of crops including cereals, oilseeds and pulse crops. It still has high potential for agricultural production on fertile soils similar to Class 1, but has some restrictions on land-use due to slight limitations. Includes some prime agricultural land.

Class	Limitations and land management practices	Land-use, occurrence and implications
3	Land has moderate limitations to land-use including moderate water and wind erosion hazard, and moderate soil acidification hazards. It can also have moderate limitations due to offsite effects such as rising groundwater and salinity. The practices to overcome limitations are substantial and readily available (eg conservation tillage, erosion control earthworks, well-planned rotations, liming, development of windbreaks, maintenance of groundcover, prevention of deep drainage). Land requires maintenance of levels of nutrients, organic matter, pH and water use.	Sloping land capable of some cultivation on a rotational basis. Can be readily used for a range of crops including cereals, oilseeds and pulse crops. Productivity will vary with soil fertility. There are increasing restrictions on land-use because of moderate limitations. Severe problems are caused if land management practices do not address the identified limitations, ie severe soil erosion is caused by regular cultivation without effective erosion control measures. Poor water quality can be caused by water erosion and dust storms by wind erosion. Pastures with low groundcover will cause water erosion. Some soils can become severely acidified without effective control measures.
Land not capable of regular cultivation – capable for grazing and cropping with limited cultivation		
4	Land has moderate to severe limitations to cropping and horticultural production and moderate limitation to grazing. Limitations are severe enough to restrict the use of cultivation for crops; however, crops can be grown using advanced conservation farming techniques including well-planned rotations, careful stubble management and specialised tillage methods. Other limitations will require practices such as liming, establishment of windbreaks and maintenance of sufficient groundcover to minimise soil movement and erosion. Practices to overcome the limitations for grazing include pasture improvement (ie sowing perennial grasses), application of fertiliser and lime, re-establishment of permanent pasture, perennial and native groundcover.	Land capable of low intensity, intermittent, low disturbance cropping due to limitations such as erosion hazard, weak structure, salinity, acidification, shallowness of soils, climate, wetness, stoniness or a combination of these. Can be cultivated to a limited extent for sowing of pastures and preparation of a seedbed. Required erosion control measures include advanced conservation tillage, well-planned rotations and maintenance of groundcover. This land still has high potential to be grazing land. Soil acidification hazard is sufficient to require specialised management practices to prevent soils becoming strongly acidified. Soil structure decline, rockiness and soil depth can be moderate to severe. Practices to control these include well-planned rotations, additions of lime, maintenance of groundcover using perennials and natives.

Class	Limitations and land management practices	Land-use, occurrence and implications
Class	**Limitations and land management practices**	**Land-use, occurrence and implications**
Land suitable primarily for grazing – not capable for regular cultivation		
5	Land has severe limitations to cropping and moderate to severe limitations to grazing. Includes land that has been eroded. Limitations are so severe that the land is used primarily for grazing. Practices to overcome limitations include maintenance of groundcover, pasture improvement with suitable species, especially perennials and natives, applications of lime and fertiliser, development of windbreaks maintenance of groundcover, erosion control earthworks and diversion banks.	Land is not capable of supporting regular cultivation owing to a range of limitations including slope, terrain, soil erosion, shallow/ rocky soils, climate or other limitations. Soil erosion can be severe without adequate erosion control measures. Fertility is generally lower than lands in Class 4 and land has a lesser capacity to regenerate groundcover. Can be cultivated occasionally for fodder crop or pasture renewal or establishment. Includes land that has been damaged or degraded by earlier erosion.
6	Land is not capable of cropping and has very severe limitations to grazing and other land-uses. Limitations are such that the land-use is restricted to low intensity grazing. Practices to overcome limitations include management of groundcover, pasture improvement using the broadcasting of seed and fertiliser, development of windbreaks, control of feral animals and strategic erosion control earthworks (eg in-flow lines).	Land is not capable of any cultivation or cropping. It has severe to very severe site limitations for grazing and other land-uses. Limitations include slope, terrain location, soil erosion, shallowness and rockiness, light soil texture, poor drainage, flooding, wind erosive power, and climatic limitations to plant growth. It may have very severe limitations due to offsite 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 soil depth and type. Comprises less productive grazing land. Limitations prevent a wide range of land-uses.
Land capable only for non-agricultural land-use		
7	Land has very severe to extremely severe limitations to land-use. Limitations are so severe that the land-use is best suited to non-agricultural land uses including green timber, nature reserve and honey or tree seed production.	This land includes steep slopes, shallow soils with extensive rock outcrop, sand dunes, riparian zones adjacent to streams, or areas of salt outbreak and very severe gully erosion. It is important to maintain groundcover by limiting grazing and minimising fire damage. Destruction of trees is not recommended. Generally land is unusable for agriculture.

Class	Limitations and land management practices	Land-use, occurrence and implications
	Land has extremely severe limitations to land-use and is unusable for agricultural land-uses.	Land is unusable for any agricultural purposes. Includes areas where agricultural activity is totally impractical, eg land with precipitous slopes (> 50 per cent area), cliffs, rock fields and swamps, lagoons, wetlands, lakes, tidal flats and estuaries, for dunes to a beach, and sand dunes and beaches which are bare or prone to extreme wind erosion. Includes the beds and stream banks of streams of fifth order or greater. Recommended uses are those that are compatible with the preservation of natural vegetation including water supply catchments, wildlife refuges, national and state parks and scenic areas.

Source: Murphy et al. 2006

3. Methods

The process of monitoring the LMwC theme (NRC Target 11) was carried out in conjunction with the monitoring of soil condition (Target 10). The two themes are closely related and shared the same monitoring sites. The LMwC theme was dependent on data collected for the soil condition theme. LMwC is interpreted as the pressure component for soil condition within the pressure-state-response paradigm. An LMwC Index is calculated for each site.

A comprehensive description of the process for the monitoring of soil condition, including the selection of sites, collection of samples with field data, laboratory analysis of samples and evaluation of data is given in DECCW (2009b) and Chapman et al. (2011). Readers are referred to those documents for full details of the elements of the process that were common to both themes.

An eight-step method is used to calculate the LMwC indices as shown in Figure 1. A worked example is provided in Section 3.4.

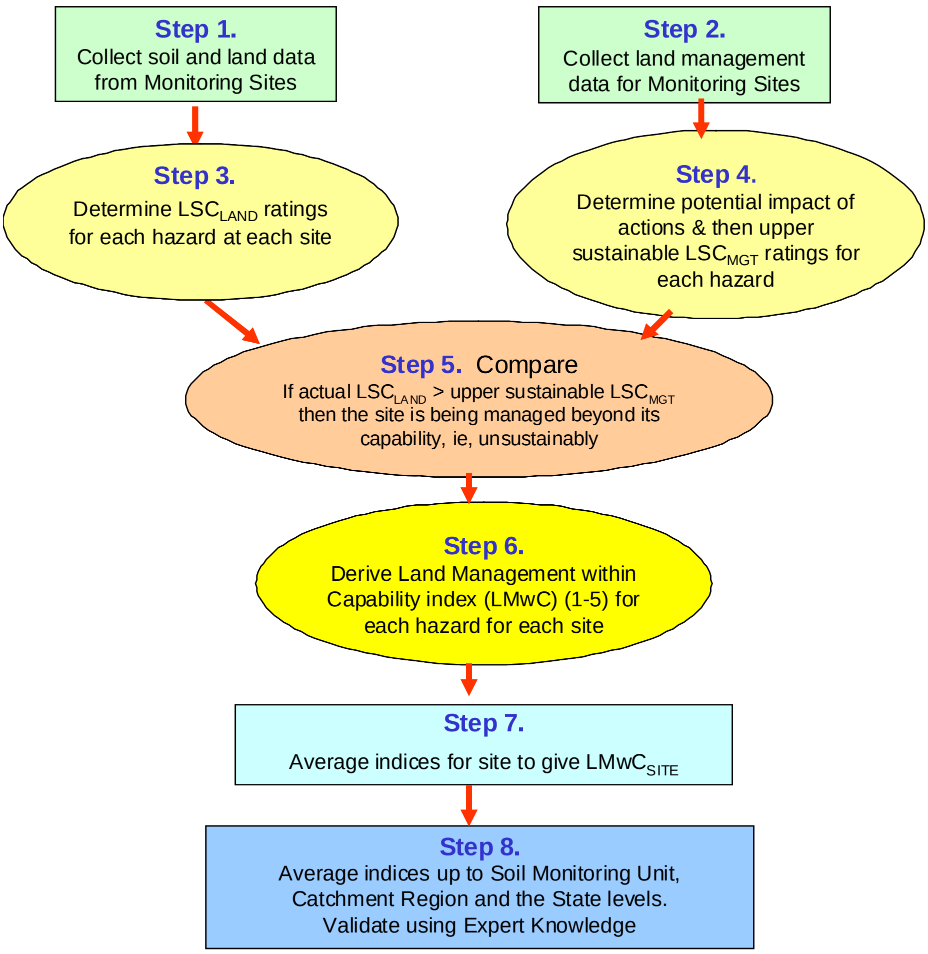


Figure 1: Overview of the assessment process

3.1 Data collection

In addition to the soil and land data collected from the monitoring sites, extensive land management data were also collected from the landholders. This information was supplemented by field observations by local extension officers and soil scientists.

3.1.1 Site selection

The assessment involved the establishment of up to 10 priority SMUs within each of NSW's 13 CMA regions, leading to a total of 124 SMUs across the state. An SMU is a large tract of land with a relatively homogeneous or repeating pattern of soils (and parent material, geomorphology, and climate). It is suitable for the periodic observation of changes in soil condition and land management. The identification of the priority SMUs involved a detailed stratification process in collaboration with CMA staff (Chapman et al. 2011).

Within each SMU, up to 10 representative sites were set up as monitoring sites (as shown in the stylised Figure 2). Usually five typical paddocks were selected for the most extensive land-use. Where possible, neighbouring typical paddocks were selected for the second most extensive land-use, resulting in paired sites involving the two land-uses.

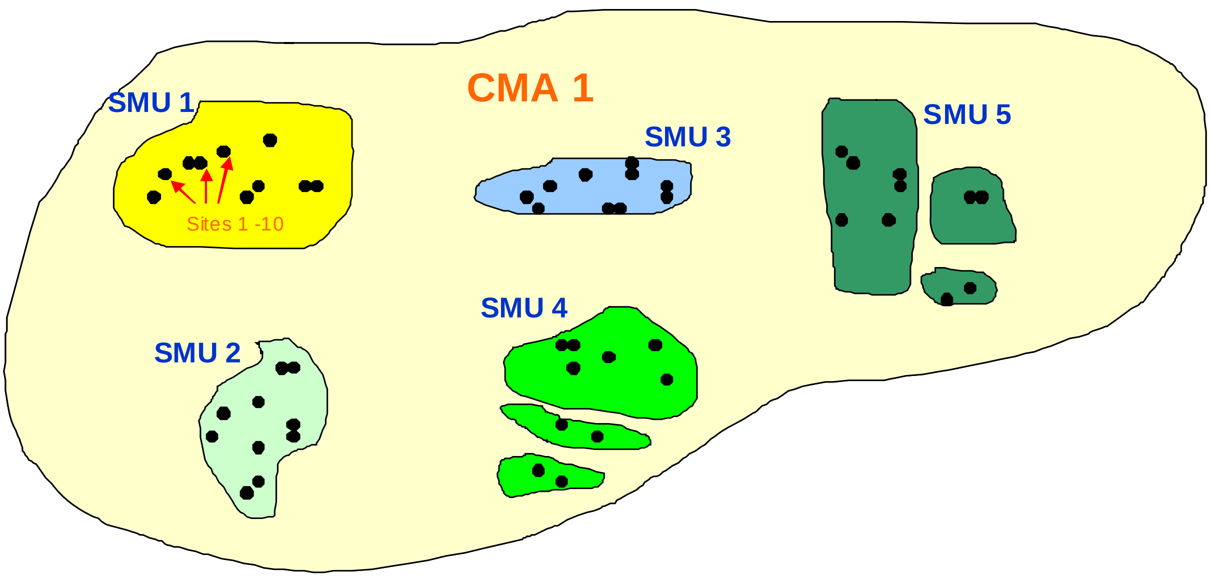


Figure 2: Stylised representation of CMA–SMU–monitoring site hierarchy

3.1.2 Step 1: soil and land data collection

At each monitoring site, extensive soil data were collected. This involved collection of 10 random sub-samples over a 25 m x 25 m grid, as described for the soil condition theme (Chapman et al. 2011) and in the associated protocol document (DECCW 2009b).

3.1.3 Step 2: land management data collection

Land management data were collected using the following approaches:

Landholder surveys

The primary source of land management data was derived from landholder surveys using a standard questionnaire (presented in Appendix 4). The survey sought information from the landholder on:

- overview of land management history and future plans (Section A)
- broad land management actions, eg, fertiliser use, vehicle use and erosion control (Section B)
- land management actions in relation to specific land-uses – cropping (Section C), grazing (Section D), horticulture and viticulture (Section E), commercial forestry (Section F), wooded/other vegetated areas (Section G)
- other general comments regarding land management issues or the MER program.

Expert knowledge forms

A formal process of collecting 'expert knowledge' information on land management issues and trends for each SMU was implemented. Relevant experts with local knowledge from the CMAs and the former DECCW (now OEH) responded to a series of standard questions (see Appendix 1). This information supplemented the quantitative survey data and was particularly used to assess trends in land management. It was also used in cases where no quantitative data were available. Although there is low confidence in this more qualitative data source, use of expert knowledge provided the opportunity to assess LMwC for the emerging issue of inland ASS.

3.2 Analysis of land management actions

3.2.1 Step 3: determine the actual LSC_{LAND} of sites for each hazard

The actual LSC of the site (designated LSC_{LAND}), ie its physical potential, was determined for each of the hazards using the acquired field and laboratory data (Step 1). For each site, each hazard was rated between 1 (most stable and resilient) and 8 (least stable or resilient).

The rating process involves a documented set of rules for each hazard (Murphy et al. 2006; Murphy et al. 2007). These rules are explicit and unambiguous, generally with quantitative boundaries. The process was carried out with the assistance of a semi-automated system in an OEH MS Access database called ABDUL (Site).

3.2.2 Step 4: determine the upper sustainable LSC_{MGT} for each of the hazards

Land management actions associated with highly adverse impacts require high capability land, otherwise they are not sustainable.

The land management actions applicable to the various hazards at each site were determined using data obtained in the landholder survey data. Individual land management actions were given an impact rating that varied from extremely low adverse to extremely high adverse impact. The action was allocated a corresponding upper sustainable LSC_{MGT} class using the scheme set out in Table 3.

The upper sustainable LSC_{MGT} class is the land capability threshold where a land management action is still sustainable but beyond which it is no longer sustainable. An activity carried out on land that is not within its upper sustainable limit carries an unacceptable risk of land degradation. For example, a high impact action such as multiple tillage operations may be sustainable on Class 1 land, but is not sustainable on any other land class, that is Class 2 to Class 8. The upper sustainable LSC_{MGT} is 1. On the other hand, a relatively low impact action such as zero tillage may be sustainable on Class 1 to 4 land. In this case the upper sustainable LSC_{MGT} is 4.

The assessments of upper sustainable LSC_{MGT} limits were based on first principles, field observations by experts and literature review, including Charman & Murphy (2007), NSW Agriculture et al. (2004), Moore (1998) and others given in section 2.2. The ratings were reviewed and ratified by numerous NRM scientists from DECCW (now OEH), DPI and each of the CMAs. The upper sustainable LSC class ratings of all land management actions which impact on land degradation are listed in Appendix 2, an extract of which is shown in Table 4.

In some cases, the interaction between different management actions and hazards is complex, with certain actions having a positive influence on some hazards but a negative influence on other hazards. For example, the application of nitrogen fertilisers may generally be beneficial to fertility and plant growth, thus reducing erosion hazards particularly in the short term, but ultimately it may lead to acidification that is detrimental to plant growth, thus exacerbating erosion hazards. Such interactions were always considered in deriving the final upper sustainable LSC_{MGT} limits.

For most land-uses there will be several land management actions undertaken during the year. They are collectively considered a land management practice. To assess the land management practice with respect to individual hazards at any site, the combined upper sustainable LSC capability rating of every land management action was assessed and then averaged to give the overall upper sustainable LSC_{MGT} class. Strictly speaking, there is a risk of land degradation if any land management action is not within capability. This would suggest that minimum values rather than average values should be used to assess sustainability. It was, however, considered more meaningful to use average values as if minimum value were used, a single unsustainable land management action amongst many sustainable actions would imply a completely inappropriate land management regime, giving an unduly negative assessment.

Table 3: Impact of land management actions and LSC_{MGT} ratings

Adverse impact of land management on soil	Upper sustainable LSC_{MGT}	
Extremely high	1	
Very high	2	
High	3	Best
Moderate	4	↓
Moderate to low	5	↓
Low	6	Worst
Very low	7	
Extremely low	8	

Table 4: Upper sustainable LSC_{MGT} ratings for selected land management actions*

Land management actions	Option	Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity & waterlogging	Organic carbon decline
		Upper sustainable LSC_{MGT} class						
Tillages prior to sowing	0	4	4	4	4	-	-	4
	1	3	3	3	2	-	-	3
	2	2	2	2	2	-	-	2
	3	2	2	2	1	-	-	2
	4	1	1	1	1	-	-	2
	>4	1	1	1	1	-	-	2
Cultivation equipment	Do not cultivate	4	4	4	5	-	-	4
	Rotary hoe	2	1	1	1	-	-	2
	One way disc	2	2	2	1	-	-	2
	Two way disc	3	3	3	2	-	-	2
	Tined implement (narrow spacing < 20cm)	3	3	3	2	-	-	3
	Tined implement (wide spacing ≥ 20cm)	3	3	3	3	-	-	-
Length of bare fallow (stubble and plant free) (in days)	0	4	4	4	5	5	6	5
	1-7	3	3	3	4	5	5	5
	8-28	3	3	3	3	4	5	4
	29-90	2	2	2	2	3	4	3
	91-180	1	1	1	1	2	3	2
	>180	1	1	1	1	2	2	2
Stubble management	Left intact	3	3	3	4	4	4	4
	Left intact with chemical treatment of weeds	3	3	3	4	4	3	3
	Slashed/mulched	4	4	4	5	4	4	4
	Removed by baling	2	2	2	3	2	3	2
	Lightly grazed	2	2	2	4	3	4	3
	Heavily grazed	1	1	1	2	2	2	2
	Ploughed in	1	1	1	2	4	3	3

Land management actions	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity & waterlogging	Organic carbon decline
	Cold burn	2	2	2	3	3	4	3
	Hot burn	1	1	1	2	2	2	2

Extract from Appendix 2

* The relationship between upper sustainable LSC and adverse impact of action is shown in Table 3.

3.2.3 Step 5: compare upper sustainable LSC_{MGT} with site LSC_{LAND} for each hazard

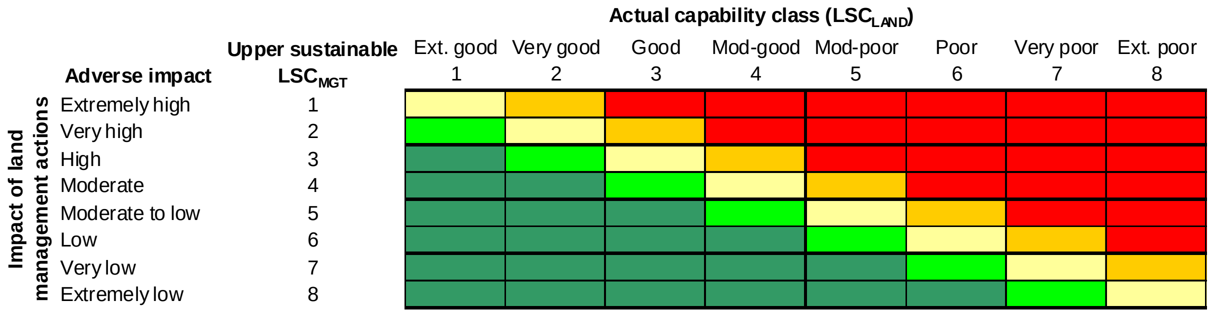
The derived upper sustainable LSC_{MGT} class for each hazard was compared against the actual LSC_{LAND} values of the hazard as determined from the field data.

The calculated unit difference between the two values identifies the extent to which the land is being used within capability. Where the upper sustainable LSC_{MGT} class is lower than the LSC_{LAND} class of the site, the site is being managed beyond its capability for that particular hazard. For example, if the prevailing management actions results in an upper sustainable LSC_{MGT} class for sheet erosion of 2 (requiring high capability land) but the actual surveyed LSC_{LAND} class of the land for sheet erosion is 4 (land with moderate capability), then that land is being managed two classes beyond its capability and there is a high risk of land degradation. This concept is illustrated in Figure 1 and in Table 5.

Photograph 1: Example of land being managed beyond its capability – down slope cultivation only sustainable on Class 1 land is being applied on Class 4 land

Source: GA Chapman/OEH

Table 5: Comparison of upper sustainable LSC_{MGT} with actual LSC_{LAND}



Key	Risk of land degradation	Sustainability	Upper sustainable $LSC_{MGT} - LSC_{LAND}$	Land management at site compared to land capability
	Very low	Very high	>2	Very conservative
	Low	High	1-2	Conservative
	Low–moderate	Fair	0-1	Acceptable
	High	Low	-1-0	Unacceptable
	Very high	Very low	<-1	Highly unacceptable

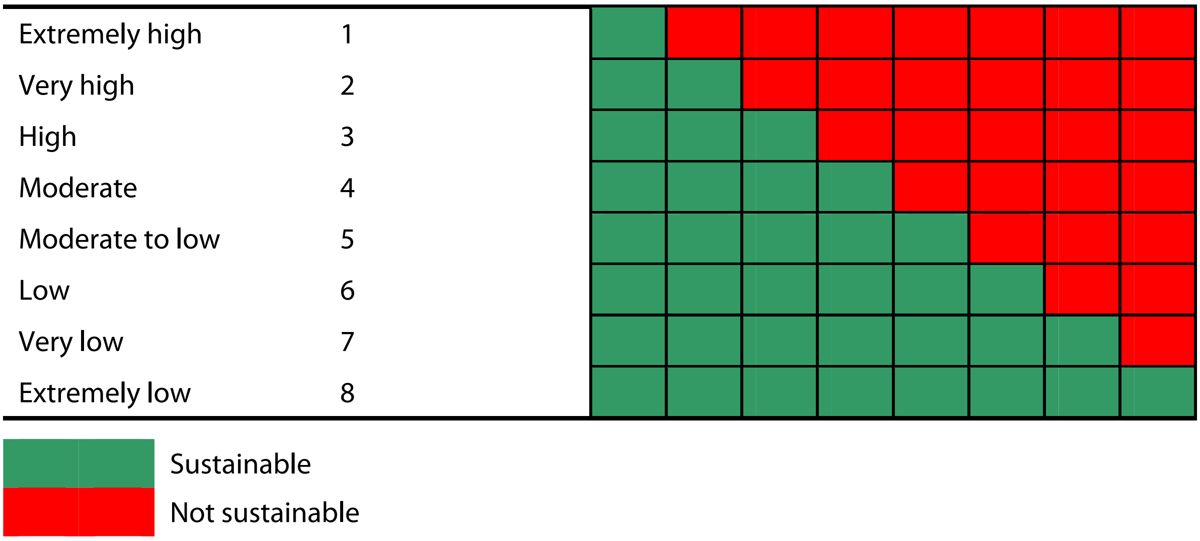
Best → Worst

The upper sustainable capability class is plotted against the actual capability class for each hazard to give the risk of degradation.

A summary of the sustainability of different actions with increasing adverse impact (and upper sustainable LSC_{MGT}) with different capability class land is shown in Table 6.

Table 6: Sustainable LSC classes

Adverse impact of land management on soil	Upper sustainable LSC_{MGT}	LSC_{LAND} class of site: 1	2	3	4	5	6	7	8
Extremely high	1								
Very high	2								
High	3								
Moderate	4								
Moderate to low	5								
Low	6								
Very low	7								
Extremely low	8								



Sustainable
Not sustainable

3.3 *LMwC indices*

LMwC indices were derived for individual sites, SMUs, CMA regions and the state as a whole.

3.3.1 Step 6: calculate LMwC indices for each hazard

The LMwC index for each hazard is calculated by considering the average unit difference between the upper sustainable capability and the actual capability, that is: LSC_{MGT} minus LSC_{LAND}. The unit difference may fall in a range of negative to positive values. Positive values indicate that the combined management actions are within the capability of the land, a zero value indicates that management actions are at capability, and negative values indicate management actions are beyond capability. Values are assigned a corresponding LMwC score as shown in Table 7.

Table 7: Relationship between the LMwC Index, LSC_{LAND} and LSC_{MGT}

LMwC Index	Average unit difference between LSC_{MGT} and LSC_{LAND}	Risk of land degradation	
5	≥ 2 units within capability	Negligible	Best
4	1-2 units within capability	Very low	↓
3	≤ 1 unit within capability	Low-moderate	↓
2	≤ 1 unit beyond capability	High	↓
1	≥ 1 units beyond capability	Very high	Worst

The $LMwC_{HAZ}$ index ranges from 1 (worst) to 5 (best). The $LMwC_{HAZ}$ indicates the degree to which land is being managed within capability for a particular hazard. An index of 5 indicates very highly sustainable land management in which the risk of land degradation is negligible. Alternatively, an index of 1 indicates very unsustainable land management, with a very high risk of land degradation by that hazard.

3.3.2 Step 7: calculate the LMwC for the site

The overall LMwC Index for the site ($LMwC_{SITE}$) is obtained by averaging the indices for each hazard ($LMwC_{HAZ}$).

3.3.3 Step 8: calculate LMwC indices for SMUs, regions and the state

Indices for each hazard at each site were combined using an averaging process to give an LMwC Index for the SMU, which were then averaged to give an LMwC Index for the entire CMA region and subsequently for the state. The averaged indices are allocated to five categories according to the scheme shown in Table 8.

Table 8: Aggregate LMwC Index definitions

Index range	Category	Definition
4.6–5.0	Very good	Managed well within capability, very low risk of degradation and probable improvement of soil and land resources
3.6–4.5	Good	Managed within capability, low risk of degradation to soil and land resources
2.6–3.5	Fair	Managed at capability, low–moderate risk of degradation to soil and land resources
1.6–2.5	Poor	Managed slightly beyond capability, high risk of degradation to soil and land resources
<1.5	Very poor	Managed well beyond capability, very high risk of degradation to soil and land resources
	No data	Not included for change monitoring. Information may be available in support documents

3.4 Example derivation of LMwC indices

The following example illustrates the derivation of the LMwC indices for a hypothetical cropping site. It initially focuses on the hazard of sheet erosion (steps 3–6), before considering all hazards for the site and higher level assessments (steps 7–8):

- Step 1: collect soil and land data – the site is moderately gently sloping (eight per cent) with sandy loam soil and moderate fertility.
- Step 2: collect land management data and determine relevant land management actions – the site is used for wheat cropping. Key actions include an average of one tillage prior to sowing using a one-way disc plough, cold burning stubble, and leaving the ground bare for 90 days during fallow. Other actions are also relevant but are not included in this example.
- Step 3: the LSC_{LAND} for the site is determined from the site data (Step 1) – the slope, soil and other site characteristics contribute to a rating of 3 for sheet erosion (see description in Table 2)
- Step 4: determine potential adverse impact of each land management action and corresponding upper sustainable LSC_{MGT} – from Table 4 and Appendix 2, it can be seen that the various individual land management actions have the following impacts in relation to sheet erosion:

Table 9: Examples of land management actions and their impacts

1 tillage prior to sowing	adverse impact = high	upper sustainable LSC_{MGT} = 3
one-way disc plough	adverse impact = very high	upper sustainable LSC_{MGT} = 2
bare ground for 90 days	adverse impact = ext. high	upper sustainable LSC_{MGT} = 1
stubble cold burn	adverse impact = very high	upper sustainable LSC_{MGT} = 2
other actions	adverse impact = very high	upper sustainable LSC_{MGT} = 2

Considering all actions associated with the cropping enterprise, the average combined adverse impact on sheet erosion is very high, which has an associated combined upper sustainable LSC_{MGT} rating of 2 (very good land required).

- Step 5: compare the actual LSC_{LAND} rating at the site (Step 3) with the average upper sustainable LSC_{MGT} rating for sheet erosion (Step 4):

  upper sustainable LSC_{MGT} = 2 (very good land required): actual LSC_{LAND} = 3 (good)

  The unit difference is -1. Although the land has good agricultural potential, the current land management actions require very good condition. The land is being managed beyond capability by one unit.

- Step 6: derive ($LMwC_{HAZ}$) index for sheet erosion at the site – from Table 7, land being managed at one unit beyond capability has a LMwC Index of 2, ie there is a high risk of degradation.
- Step 7: amalgamate indices up to the site level – a similar process to that outlined above is carried out for the other hazards and then averaged to give the LMwC Index for the site, with results as follows:

Table 10: Example of average LMwC Indexes for sites

Hazard	LMwC Index
sheet erosion	2
gully erosion	2
wind erosion	3
structure decline	1
acidification	2
organic carbon decline	2
salinity	3
acid sulfate soils	not relevant
Total site	2.1

The site has a combined $LMwC_{SITE}$ Index of 2.1, which falls in the 'poor' category as shown in Table 8.

- Step 8: results from other monitoring sites in the SMU are averaged to give a combined LMwC for the SMU – further averaging amalgamates site LMwC indices up to the CMA and ultimately the state level.

3.5 Assessment of the current pressure trend

There are no previous quantitative data available with which to compare the current results and establish firm trends in LMwC, ie to determine whether land management is generally improving, remaining steady or declining. Data on trends were therefore assessed from the formal 'Expert Knowledge' results gained from the former DECCW (now OEH) and CMA staff familiar with local land management conditions (see Appendix 1). Trends were established for each hazard indicator within each SMU. They were initially derived using a five-category system and then converted to the standard MER program's three-category system by amalgamating the two increasing categories and also the two decreasing categories, as presented in Section 4.1.2.

For the purposes of the MER program and the 'pressure-state-response' model, these trends are considered here to be the 'pressures' acting on sustainable land management, with declining trends in land management corresponding to increasing pressures.

4. Results

Results from the project were prepared for each of the 13 CMA regions in the NSW SOC reports (DECCW 2010). A state-wide summary has been prepared for the NSW SOE Report 2009 (DECCW 2009a).

4.1 Results for CMA regions

An SOC report has been produced for each region. The reports include:

- results on the nature and extent of LMwC for each SMU
- indices for the region for each of the eight capability hazards
- maps showing the location of each SMU.

4.1.1 Results by SMU

An example of the summary result page from a SOC report is given in Figure 3 for a hypothetical region. An explanation of the data columns is given below:

- SMU name and details – includes the major soil types present and the land-uses that were monitored. This normally corresponds to the dominant land-uses.
- LMwC Index – the overall index averaged from all land degradation hazards for all sites within the SMU. Definitions are as provided in Table 8 and at the base of the summary page. The colour of each index box represents the LMwC Index category, in addition to the precise value.
- Range of indices – the variability of LMwC indices between different sites and hazards within each SMU is displayed by a small pie chart. For example, for SMU 3 (Stace Plateau) in Figure 1, the overall average index is 3.1 (fair), but the pie chart shows there is a range of values from the different hazards with 20 per cent having a poor rating and 20 per cent having a good rating.
- Worst indicators and index – the hazard with the lowest (worst) LMwC Index for the SMU is displayed. This is the hazard that is being managed least sustainably and of potential greatest concern for the land. The associated LMwC Index is also given.
- Data source – identifies the primary sources of data used in the derivation of the results. Codes are used as follows:
    - B **B**aseline data for soil condition – from field and laboratory measurements
    - L **L**andholder survey on land management
    - K Expert **K**nowledge – from the former DECCW (now OEH) and CMA staff
- Data confidence – three levels of confidence in the data are identified:
    - High – derived from numerous landholder surveys and field data from representative sites in the baseline study, and validated using expert knowledge.
    - Medium – derived from limited landholder surveys and field data from sites in the baseline study or roadside surveys, in conjunction with expert knowledge.
    - Low – derived only from modelling or expert knowledge.

Factors considered when assigning data confidence categories included compliance with NSW Soil Condition Monitoring Protocols (DECCW 2009b); this was necessary to assess the veracity of LSC assessment methods, site selection and analysis. Other considerations included data age (during baseline establishment or earlier) and the degree of data replication (number of sites per SMU/land-use combination).

High data confidence is not necessarily the highest level of data confidence that is possible. Data confidence is a relative ranking and is dependent on the context of use. There is expected to be high data confidence in comparing the landholder data from the same sites with future surveys. Confidence should be lower when the findings are extrapolated spatially, such as across an entire SMU or CMA region.

4.1.2 Results by hazard

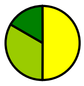
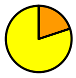
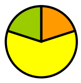
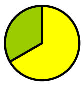
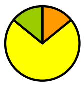
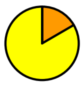
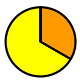
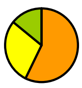
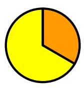
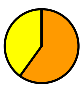
A summary result page for capability hazard types for a hypothetical CMA region is given in Figure 4. The information contained in each column presents the key aspects of the results for each of the eight hazards, and is described below.

- Capability hazard – lists the eight hazards and a brief description.
- LMwC Index – the overall index for the indicator averaged from all SMUs for the CMA region. Definitions of each category are provided at the base of the summary page. The colour of each index box represents the LMwC Index category.
- Range of indices – the variability of LMwC Index categories for each indicator throughout the CMA region is displayed by a small pie chart.
- Apparent trend – as discussed in Section 3.5, there are no previous quantitative data available with which to compare the current results and establish firm trends, meaning data on trends had to be gained from the formal 'Expert Knowledge' results (see Appendix 1). Trends were established for each hazard within each SMU, using the three categories presented below:

↑ Improving: there appears to be a steady adoption by landholders of more sustainable land management practices, leading to an improvement in soil and land condition.

↔ Steady, no change: there is no apparent move towards or away from more sustainable practices.

↓ Declining: there appears to be a general move away from sustainable practices, leading to a decline in soil and land condition.

Soil monitoring unit	**Soil monitoring unit name.** Soil types and monitored land use	Land management within capability index[a]	Range of indices	Worst indicators & index		Data source & confidence
1	**Munsell Floodplains** Brown Dermosols. Improved pastures & cropping	3.7		Acidification, OrgC decline, Structure decline	3.0	B & K, Medium
2	**Northcote Plateau** Red Ferrosols. Improved pasture & cropping	3.3		Structure decline	2.5	B & K, Medium
3	**Stace Plateau** Red Ferrosols. Improved pasture, cropping & horticulture	3.1		Structure decline	2.3	B & K, Medium
4	**Isbell Alluvials** Black Vertosols. Pasture & cropping	3.3		Acidification, Structure decline	2.7	B & K, Medium
5	**Marshall Metasediments** Yellow Kurosols. Improved & unimproved pasture	2.9		Gully erosion	2.0	B & K, Medium
6	**Holmes Basin** Natric Grey and Brown Kurosols. Forestry & pasture	2.8		Gully erosion	2.0	B & K, Medium
7	**Patton Low Hills** Rudosols and Red Chromosols. Forestry, national park & pasture	2.9		Structure decline	2.3	B & K, Medium
8	**Hubble Hills** Brown Kurosols and Brown Kandosols. Pasture	2.9		Gully erosion	2.0	B & K, Medium
9	**McKenzie Ranges** Red and Yellow Chromosols. Improved & unimproved pasture & forestry	2.8		Salinity/waterlog	2.0	B & K, Medium
10	**Butler Estuary** Brown and Grey Hydrosols. Grazing, forestry & sugar cane	2.4		OrgC decline, Structure decline, Salinity/waterlog	2.0	B & K, Medium

a: Land Management within Capability (LMwC) Index

4.6 – 5.0	Very good	Managed well within capability, very low risk of degradation and probable improvement of soil and land resources
3.6 – 4.5	Good	Managed within capability, low risk of degradation to soil and land resources
2.6 – 3.5	Fair	Managed at capability, low–moderate risk of degradation to soil and land resources
1.6 – 2.5	Poor	Managed slightly beyond capability, high risk of degradation to soil and land resources
<1.5	Very poor	Managed well beyond capability, very high risk of degradation to soil and land resources
	No data	Not included for change monitoring. Information may be available in support documents

Figure 3: LMwC in a hypothetical region – results by SMU

Capability hazard	Land management within capability index[a]	Range of indices	Apparent trend	SMUs of concern (<=2.5)	Data source & confidence
Erosion - sheet Erosion of topsoil by overland flows. Generally a consequence of insufficient ground cover.	3.2		↔	8	B & K High
Erosion - gully Erosion of topsoil and subsoils by concentrated overland flows Generally a consequence of insufficient ground cover and changes to runoff and infiltration patterns.	2.9		↓	5, 6, 8	B & K Low
Erosion - wind Erosion of soils by the action of wind. Generally a consequence of insufficient ground cover and inappropriate tillage practices.	4.0		↑	-	B & K Low
Acidification Trend towards increasingly acid soils, leading to reduced chemical health. A consequence of inappropriate management such as over intense use, allowing excessive leaching, over use of nitrogen fertilisers and insufficient use of lime.	2.9		↓	8, 9	B & K Medium
Organic carbon decline The loss of soil organic matter with resulting decline of physical and chemical condition. A consequence of over intense use with insufficient return of biomass to the soil.	2.9		↔	8, 10	B & K Low
Structure decline Degradation of the physical structure of the soil, reducing the potential for water movement and plant growth. A consequence of practices such as over-cultivation, compaction by heavy vehicles and stock, and insufficient plant root growth.	2.7		↔	2, 3, 7, 10	B & K Low
Acid sulfate soils Mismanagement can lead to release of highly acid waters into the ecosystem. This can arise from the exposure of buried potential ASS layers to oxygen such as from lowering of watertable by drainage.	3.0		↔	-	B & K Medium
Salinity/water logging Build up of salt or saturated soils on ground surface. A consequence of rising groundwater tables following a reduction of deep rooted perennial plants.	3.2		↓	7, 9, 10	B & K High
Overall index : Catchment	3.1				
State	3.0				

a: see legend for Figure 3

Figure 4: LMwC in a hypothetical region – results by indicator

- SMUs of concern – lists the SMUs for each hazard that have poor or very poor results (LMwC ≤2.5), signifying potentially unsustainable land management. For example, in the hypothetical region presented in Figure 4, there is high gully erosion pressure for SMUs 5 (Marshall Metasediments), 6 (Holmes Basin) and 8 (Hubble Hills).
- Data source and confidence – see Section 4.1.1.

4.1.3 Summary of SMUs with poor or very poor LMwC indices

The number of SMUs with poor or very poor LMwC indices (LMwC ≤2.5) for each hazard was determined for each CMA region. Results shown to this point have been for a hypothetical set of SMUs; however, the results presented in Table 9 are actual summary results for the regions. They give an indication of the main hazards of concern in each CMA region, where land is not being managed sustainably. The results are also discussed in the following section.

Table 11: Number of SMUs by region with poor LMwC*

CMA region	Sheet erosion	Gully erosion	Wind erosion	Acidification	Organic carbon decline	Structure decline	ASS	Salinity/ waterlogging
Border Rivers–Gwydir	3	2	2	0	5	7	0	4
Central West	0	0	0	8	1	1	0	1
Hunter–Central Rivers	3	2	0	2	2	3	0	4
Hawkesbury–Nepean	1	2	0	5	5	0	0	1
Lachlan	4	1	6	0	9	6	0	1
Lower Murray Darling	0	1	2	0	3	0	1	0
Murrumbidgee	3	2	6	4	4	3	2	2
Murray	0	1	5	5	4	3	1	2
Namoi	1	1	2	0	8	7	0	2
Northern Rivers	1	3	0	2	2	4	1	3
Sydney Metropolitan	1	0	0	3	2	2	0	2
Southern Rivers	4	7	4	3	7	4	0	2
Western	0	2	3	0	1	0	0	0
NSW total	**21**	**24**	**30**	**32**	**54**	**40**	**5**	**24**

* Poor LMwC for each indicator is defined by LMwC Index <=2.5

4.2 State-wide results

The results from individual SMUs and CMA regions were consolidated to provide a whole-of-state view. Table 9 shows the extent of poor and very poor land management scores for each hazard across NSW. State-wide LMwC indices for each of the eight land degradation hazards and the state index are given in Table 10. Table 11 shows the ranges of index values for each hazard.

Table 12: Average LMwC indices for NSW

Sheet erosion	Gully erosion	Wind erosion	Acidification	Organic carbon decline	Structure decline	ASS	Salinity/waterlogging	Overall State index
3.1	3.2	3.2	3.0	2.8	2.9	2.7	3.1	3.0

Table 13: Percentage of SMUs falling in each LMwC Index category across NSW

Condition index category		Sheet erosion	Gully erosion	Wind erosion	Acidification	Organic carbon decline	Structure decline	ASS	Salinity/ waterlogging	Overall SMU index	Worst indicator in SMU
4.6–5.0	Very good	3	6	3	8	0	1	0	2	0	0
3.6–4.5	Good	14	22	27	6	10	11	25	16	12	3
2.6–3.5	Fair	66	52	43	55	46	54	38	60	73	20
1.6–2.5	Poor	18	19	27	30	43	33	25	21	15	72
<1.5	Very poor	0	1	1	1	1	1	13	1	0	5

From the results presented in Tables 11, 12 and 13, it is evident that on average on a state-wide basis, land in NSW appears to be managed at a level just in accordance with its inherent physical capability. The overall index for LMwC across the state, derived from the MER program, is 3.0 (in the 1–5 scheme) indicating 'fair' land management relative to capability. Further analysis of the data shows that there are considerable variation in results and therefore causes for concern. Table 13 reveals that 77 per cent of SMUs have at least one indicator with a 'poor' or 'very poor' LMwC rating. These areas are at risk of land degradation.

Some parts of the state and some land degradation hazards are poorly managed in terms of land capability. For example, on a state-wide basis, organic carbon decline and soil structure decline are the hazards being managed the least sustainably.

A brief summary of the adequacy of management of each of the monitored land degradation hazards is given below. It is important to bear in mind that the results are based on averages of LMwC for SMUs and are, in turn, based on average scores from land management actions practiced at individual sites:

- ***Organic carbon decline*** – management is poor relative to the capability of the land over extensive areas of the state, and is of widespread concern over the majority of regions as well as being a concern in at least part of all regions. The state-wide average LMwC Index is 2.8, with the range in indices for individual SMUs generally varying between 2.0 (poor) and 3.0 (fair). The index is poor in 54 (44 per cent) of the 124 SMUs. Organic carbon decline is a significant issue of concern (that is, has a poor index in three or more SMUs in eight of the 13 CMA regions.

- ***Soil structure decline*** – management is poor for extensive parts of the state. The state-wide LMwC Index is 2.9, with the range for individual SMUs generally between 2.0 (poor) and 3.5 (fair). Indices were poor (<2.5) for 40 (34 per cent) of the 117 assessed SMUs. Soil structure decline is an issue of concern in eight CMA regions and it appears to be critical in many areas, ie where surface soils are sodic.
- ***Acidification*** – poor management of acidification is common in most CMA regions throughout the eastern and central parts of NSW, and an issue of concern in seven regions. The state-wide LMwC Index of 3.0 is composed of values that range generally between 2.0 (poor) and 3.5 (fair). Poor average scores (<2.5) occur in 32 (31 per cent) of the 103 assessed SMUs.
- ***Wind erosion*** – poor management of this hazard relative to capability is common in the western and south-western parts of the state. The state-wide LMwC Index of 3.2 is mostly composed of scores ranging from 2.0 (poor) to 4.0 (good). Indices fell in the poor range (<2.5) for 30 (28 per cent) of the 108 assessed SMUs. Management of wind erosion hazard is a significant issue in the five western most CMA regions.
- ***Sheet and gully erosion*** – management relative to capability is typically fair across the state; however, it is poor in some areas, particularly where there are moderate slopes. The state-wide LMwC indices for sheet erosion and gully erosion are 3.1 and 3.2 respectively with average SMU values ranging generally between 2.0 (poor) and 4.0 (good). Sheet erosion has poor (<2.5) ratings for 21 (18 per cent) of the 120 assessed SMUs and gully erosion has poor ratings for 24 (20 per cent) of the 119 assessed SMUs.
- ***Salinity and waterlogging*** – management of this hazard relative to capability is mostly fair across the state; however, it is a concern in some areas. The state-wide LMwC Index is 3.1 with average SMU values ranging generally between 2.0 (poor) and 4.0 (good). Indices are poor (<2.5) for 24 (22 per cent) of the 107 assessed SMUs. Salinity and waterlogging are significant issues of concern in two CMA regions, although areas of concern exist in almost all CMA regions.
- ***ASS*** – most of the coastline is managed within capability, but areas of concern remain. Poor management of these soils is recognised as an emerging problem in some billabongs and weirs along the Murray Darling. ASS have a state-wide average LMwC Index of 2.8 (covering the eight assessed SMUs), with average values for individual SMUs varying between 1.0 (very poor) to 4.0 (good).

Across the state, the trend in LMwC is broadly steady. However, the situation varies across CMA regions and between different land degradation hazards. In some CMA regions there appears to be an overall slight move towards more sustainable land management actions (ie working within capability), while in others there appears to be a slight move away from sustainable actions (ie, not working within capability). The management of sheet erosion and salinity appears to be trending towards being more sustainable; however, the management of organic carbon decline, acidification and structure decline appears to be trending towards being less sustainable.

5. Discussion

5.1 Reliability of the results

Interesting and important results have been derived from this LMwC monitoring project. The results highlight particular hazards and geographic areas of concern, where greater attention needs to be given to encouraging sustainable land management practices.

This is the first time that such a land management monitoring project has been attempted and elements of the process may still need some refining. There are several issues that should be considered when drawing conclusions from the results:

- Results presented in this report are based on the incomplete data available as at May 2009. At that time 850 monitoring sites had been sampled, of which 353 land management surveys have not yet been completed. Furthermore, additional monitoring sites need to be established in most CMA regions, particularly the Lower Murray Darling and Western catchment regions.
- The proposed baseline with up to 1240 monitoring sites will only represent a small dataset for the entire state. This makes it difficult to make comprehensive conclusions about land management across the state. The relatively small dataset means there are insufficient data to allow meaningful statistical analysis of results at the individual CMA level, but nevertheless the results should still be useful for regional NRM decision-making. A greater level of statistical analysis and assessment of change should be possible following the proposed revisiting of monitoring sites.
- Despite great care being taken to carefully select sites, the representativeness of all the sites cannot be assured. The sites were collected for priority areas of each catchment where monitoring is most required, yet do not cover all types of land or all land-uses in the catchment. They did not target all areas most at risk. There may be numerous locations throughout each catchment region where land management is unsustainable, which are not being monitored.
- The landholders who agreed to participate in the monitoring project may be more progressive in the adoption of sustainable land management practices than typical landholders across their regions. They have generally had previous collaboration with their local CMAs, suggesting that they are at least partially committed to improving some aspects of NRM. Therefore, there is concern that there may be biasing of results towards better land management. This concern is reinforced by the broad tendency for local experts to report poorer land management practices across an area than that revealed by the landholder surveys. An alternative approach would be to select landholders and sites at random, but problems in gaining access in the time available effectively prevented the use of this approach. An experiment involving random sites may be established to assess the degree of bias.
- The reliance on expert knowledge where inadequate quantitative data were available reduces the reliability of some results. Although the information was acquired through a formal, systematic process (see Appendix 1), it is considered low confidence data. Such data is more subjective and less repeatable than quantitative data collected over specific sites. As further quantitative data is acquired, the reliance on expert knowledge will be reduced. Results from expert knowledge analyses generally reveal poorer land management across SMUs and CMA regions than revealed by the quantitative data derived from individual monitoring sites.

- Several elements of the assessment process may need further refining, including the choice of effective and measurable key land management actions, the evaluation of upper sustainable limits for emerging land management practices, and the assessment of LSC_{LAND} for the individual sites (which involved some simplifications).
- Results are presented as averages for SMUs, which may effectively mask some serious problems. Analysis of individual scores across the state has not been completed.
- The broad pressures that control the extent of LMwC within any given region are complex and beyond the scope of this project to assess and monitor. They are at least partly dealt with in the community monitoring themes of the state monitoring program and include issues such as:
    - financial, technical and managerial capacities of landholders
    - knowledge and perceptions of sustainable land management practices by landholders
    - market dynamics of agricultural products and production costs (eg cost of fuel, fertiliser, labour
    - tax and government financial and legislative settings to promote sustainable land management
    - long-term climatic changes, such as increasing severity of droughts.

  Due to this complexity, this project deals only with direct pressures influencing sustainable land management, these being specific hazard and land-use combinations, eg sheet erosion with cropping or acidification with grazing. These combinations may be considered as the immediate pressures on sustainable land management in the region, highlighting hazards that require attention.

5.2 Management response strategies

The MER program is an effective feedback and control mechanism for the operation of the state's NRM system. The system is composed of themes which are independent and synergistic. The LMwC theme provides a score card which has indicated less than desirable progress towards the target but does not identify why. Identification of the socio-economic, cultural, evolutionary and episodic factors affecting the management of land within its capability can be addressed in part by reference to results from other themes. Identifying the constraints to the progress toward the target is a precursor to modifying goals and objectives within the existing strategies, providing an appropriate response to the MER program. It is recommended that synergies be assessed between current theme outcomes; this will ensure a coordinated response to the apparent minor progress towards the target of increasing the area across NSW managed within capability.

Addressing the target of increasing the area of land being managed sustainably across NSW involves initiatives and programs at the state and regional levels. Such initiatives and programs aim to ultimately bring about the adoption of best land management practices by landholders. These are briefly outlined in this section, with further detail provided in each of the 13 NSW SOC reports (DECCW 2010) and the NSW SOE Report 2009 (DECCW 2009a).

5.2.1 State level activities

The NSW Government guides NRM throughout the state through various legislation, policies, strategies and programs.

i Legislation

The *Catchment Management Authorities Act 2003* established the 13 CMAs and outlined their broad responsibility for NRM in their regions. The *Soil Conservation Act 1938* provides for the conservation of soil resources; however, its role in effective soil management has diminished over time. Various other Acts provide direct and indirect mechanisms for soil protection and management, including *Protection of the Environment Operations Act 1997, Environmental Planning & Assessment Act 1978* (EP&A Act), *Native Vegetation Conservation Act 1997,* and the *Crown Lands Act 1989*.

ii Policies and strategies

The State Soils Policy (1987) sets out important principles for the protection and management of NSW soils. It is has recently been reviewed and is undergoing a public consultation phase. Other significant instruments that promote sustainable land management include the Total Catchment Management Policy (1987), Sustainable Agriculture Policy (1998), and the NSW State Salinity Strategy (2000).

iii Programs

A number of relevant programs operate at the state level:

- *MER program* – as outlined in this report, OEH is responsible for continuing its MER program and completing a baseline across all CMAs relating to soil condition and land management (State Plan E4.10 & 11). The Australian Department of Agriculture, Fisheries & Forestry (DAFF) is funding a pilot program for national monitoring of water erosion, wind erosion, soil acidification and soil carbon.
- *Soil and land-use mapping* – much of eastern and central NSW is now covered by Soil Landscape mapping at 1:100 000 or 1:250 000. This is primarily undertaken by OEH and earlier natural resource agencies. A program of detailed land-use mapping across the state is nearing completion.
- *Assessment systems* – examples from OEH include (i) an LSC assessment system, with draft mapping completed across NSW (ii) Soil and landscape constraint assessment system and (iii) the Tools2 (SLICK) modelling system which allows for assessment of the impact on soils from different management options.
- *Information exchange and advice* – provision of soil and landscape information and land management advice is provided through various publications, maps and databases (see www.environment.nsw.gov.au/soils/index.htm). Examples include the NSW Soil and Land Information System (SALIS), the Natural Resource Atlas (www.nratlas.nsw.gov.au/) and the NSW Land Management Database (LMD). Extension services that encourage sustainable land management practices are undertaken widely by DPI staff.

- *Research* – research programs aimed at improving soil condition, productivity and sustainable land management practices are carried by various national and state institutions, including the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities, OEH, DPI and rural industry bodies (eg, Grains Research Development Corporation).

5.2.2 Regional level activities

The CMA catchment action plans (CAPs) are the key documents that coordinate and drive the effort to improve natural resources across the regions. The CAPs describe the whole-of-government approach to soil condition and sustainable land management targets at the regional scale and specify regional targets and activities to contribute to achievement of the state-wide targets. They set the direction for investment in NRM over the next decade. An example of a CAP can be found at www.brg.cma.nsw.gov.au/index.php?page=catchment-action-plan.

The CAPs include specific targets, with specific areas (hectares), which aim to address the broader state target. Programs and strategies that are being adopted to help achieve the targets generally fall in the following categories:

- *Data collection* – this involves processes such as developing baselines of soil information and developing registers of beneficial land management practices.
- *Planning* – involves identifying priority issues and locations for improved land management and associated investment and LSC mapping across the regions.
- *Collaboration* – partnerships are formed with farming organisations, industry groups, relevant government agencies (particularly OEH, DPI and Land and Property Information), tertiary institutions, Landcare and similar community groups and individuals.
- *Awareness and skills-raising* – training days and workshops are held and guidelines and information sheets are produced.
- *Contracts and programs with landholders* – contracts are developed with landholders to modify and improve land management practices and incentive programs aimed at improving land management practices are implemented.
- *Monitoring and evaluation* – monitoring will continue, to assess progress towards the improved soil condition and sustainable land management targets under CMA and OEH programs.
- *Other programs* – these include drought recovery programs, conservation farming programs, fencing programs.

Further details and examples of many of these activities are reported in the CMA's recent annual reports.

Other regional or local based bodies and programs that aid in improved land management include:

- local councils through their implementation of the *Local Government Act 1993* and local or regional planning instruments such as local environmental plans (LEPs) and regional environmental plans (REPs)
- Landcare groups that facilitate improved landholder knowledge and on-ground works
- universities that undertake research programs in the region

- rural development and research corporations such as the Meat and Livestock Australia, the Grains Research Development Corporation and Cotton Australia.

5.3 Proposed future MER activities

The following activities are proposed and recommended to complete the current baseline phase of the LMwC monitoring program, and ensure its progress.

5.3.1 Continued data collection

Proposed activities include the following:

- Continued establishment of monitoring sites, aiming for the original target of up to 1240 sites across the state (up to 100 sites per CMA depending on the number of land-uses within SMUs, with 40 sites in the Sydney Metropolitan CMA region). There will be increased focus on regions that are currently under-represented, for example the Lower Murray Darling, Lachlan and Western regions.
- Follow up with landholders for outstanding land management survey results. In May 2009 only 58 per cent of 850 monitoring sites established have had surveys returned.
- Prepare land-use versus land capability maps for the entire state. These maps will use land-use as a surrogate for land management to prepare maps with continuous polygonal coverage of complete CMA regions, ie not just point data. Each land-use is associated with upper sustainable LSC classes for each land degradation indicator, assuming best- and worst-case management scenarios. OEH land-use mapping and LSC mapping will be used. The maps will identify land that is:
    - always managed within capability
    - sometimes managed within capability
    - never managed within capability.
- A pilot program to trial this procedure is currently underway for the Hunter–Central Rivers CMA region (see Appendix 3). If successful, an areal estimate of LMwC may be possible. This process will be dependent on the current and future quality of state LSC and state land-use mapping.
- Undertake roadside surveys of key soil condition and land management observations using the LandMAPT software (Murphy & Murphy 2007) during autumn seasons.
- Develop a rapid field assessment system for CMA and other professional officers to determine LSC and LMwC and ultimately guide sustainable land management actions by landholders.
- Acquire and integrate other land management data as it becomes available from:
    - the ABS – five-yearly landholder land management surveys (expected to be available in 2009)
    - NSW Department of Primary Industries – ‘Farm-On’ land management surveys
    - other sources , such as other OEH projects, CMAs and industry bodies such as Grains Research Development Corporation (GRDC).

- Ongoing periodic monitoring – this involves returning to established sites at regular intervals (on average, every five years). Only a subset of sites may be selected for revisits. A program to cover the state on a five-yearly basis, with up to 20 per cent of NSW being updated each year, is a possible way forward.
- Future land management surveys may incorporate questions that ask landholders ***why*** particular activities are undertaken. This information will contribute to a better understanding of landholder attitudes and philosophies and thereby assist in NRM education and program design. The results may also contribute to MER themes 12 (economic sustainability and social well-being) and 13 (capacity to manage natural resources).
- Further possible work required for both the soil condition and LMwC MER themes is provided in Chapman et al. (2011).

5.3.2 Analysis of land management practices

Much useful information will be gained from a detailed analysis of land management practices as revealed by the land management surveys. The analysis will examine the nature and extent of different actions such as:

- groundcover – for example, the most common minimum percentage groundcover in grazing operations
- tillage practices – for example, the most common number of tillages prior to sowing, and the most common equipment used
- stubble management – for example, the most common treatment of stubble
- use of fertilisers – for example, the most common levels of application
- controlled traffic – for example, the extent of vehicle use in wet conditions.

These analyses will enhance our understanding of the extent of sustainable land management practices and associated landholder behaviours across each CMA region and the state. They will help pinpoint the precise reasons as to why land may be being used beyond its capability. For example, in a particular SMU we may have identified a low LMwC Index (poor management) in relation to acidification, but at this stage we have not yet determined which actions are giving rise to that low index. Data analysis may reveal overuse of nitrogen fertilisers as a primary cause of the problem. Results could be compared with the results at CMA level from the ABS Agricultural Resource Management Survey (2007–08) when available.

The results will provide further useful baseline data to compare with future studies.

5.3.3 Data storage and management

The land management data is currently stored in the Land Management Survey Database, an MS Access database created specifically for this MER program. This data will be also transferred and stored in the OEH Land Management Database (Bickmore et al. 2007).

Further details relating to the storage and management of MER program's soil and land management data are given in Chapman et al. (2011).

6. References

AASMAC 1998, *NSW Acid Sulfate Soil Manual*, Acid Sulfate Soil Management Advisory Committee, NSW Government, Sydney.

Bickmore J, Henry N, Waski R & Turner B 2007, *Using the Land Management Database (version 1.6) and standard template to record CMA incentive projects, output map products and enable reporting*, Department of Environment and Climate Change NSW, Hawkesbury Nepean CMA and Southern Rivers CMA, Sydney.

Campbell A 2008, *Managing Australia's Soils: A policy discussion paper*, prepared for the National Committee on Soil and Terrain (NCST) through the Natural Resource Management Ministerial Council (NRMMC).

Cass A 1999, 'Interpretation of some soil physical indicators for assessing soil physical fertility' in Peverill KI, Sparrow LA & Reuter DJ (eds.), *Soil Analysis: an interpretation manual*, CSIRO Publishing, Melbourne.

Chapman GA, Gray JM, Murphy BW, Atkinson G., Leys JF, Muller R, Peasely B, Wilson BR, Bowman G, McInnes-Clarke SK, Tulau MJ, Morand DT & Yang X 2011, *Assessing the condition of soils in NSW*, Monitoring, evaluation and reporting program, Technical report series, Office of Environment and Heritage, Sydney.

Charman PEV (ed.) 1985, *Conservation Farming,* NSW Soil Conservation Service, Sydney.

Charman PEV & Murphy BW (eds.) 2007, *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources.

Charman PEV & Roper MM 2007, 'Soil Organic matter' in Charman PEV & Murphy BW (eds.), *Soils - Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 277–286.

Charman PEV & Wooldridge AC 2007, 'Soil Salinisation' in Charman PEV & Murphy BW (eds.), *Soils – Their Properties and Management*, 3rd edn), Oxford University Press in association with Department of Natural Resources, pp. 238–257.

Dale T & Carter VG 1955, *Topsoil and Civilisation,* University of Oklahoma Press.

DECCW 2009a, *NSW State of the Environment Report 2009*, DECCW, Sydney.

DECCW 2009b, *Protocols for Soil Condition and Land Capability Monitoring,* prepared by Bowman G, Chapman G, Murphy B, Wilson B, Jenkins B, Koen T, Gray J, Morand D, Atkinson G, Murphy C, Murrell A & Milford H, DECCW, Sydney.

DECCW 2010, *State of Catchment Report for the Hunter–Central Rivers Catchment,* DECCW, Sydney.

Department of Natural Resources NSW 2005, Soil Assessment in *Native Vegetation Regulation 2005, Environmental Outcomes Assessment Methodology,* NSW Department of Natural Resources, Sydney.

Dent D & Young A 1981, *Soil Survey and Land Evaluation,* George Allen and Unwin, London.

Diamond J 2005, *Collapse: How societies choose to fail or succeed*, Penguin, New York.

DixonJ, McKenzie NJ, Crawford D, Gazey C, Grose C, Hughes B, Merry R, Moody P & Wilson B 2007, Soil Acidification in *Monitoring Soil Condition Across Australia—Recommendations from the Expert Panels to the National Committee on Soil and Terrain Information and the National Land and Water Resources Audit Advisory Council*, Canberra, ACT.

Duggin JA 1992, Land Evaluation lecture notes*,* University of New England, Department of Ecosystem Management, Armidale, NSW, unpublished.

Emery KA 1986, *Rural Land Capability Mapping*, pamphlet, NSW Department of Land and Water Conservation, Sydney.

FAO 1976, *A Framework for Land Evaluation*, Soils Bulletin 32, Food and Agricultural Organisation of the United Nations, Rome.

FAO 1993, *FELSM: An international framework for evaluating sustainable land management,* World Soil Resources Report 73, Food and Agricultural Organisation of the United Nations, Rome.

Fenton G & Helyar KR 2007, 'Soil Acidification' in Charman PEV & Murphy BW (eds.), *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 224–238.

Geeves, Craze & Hamilton 2007, 'Soil Physical Properties' in Charman PEV & Murphy BW (eds), *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 168–189.

Gray J, Chapman G & Murphy B 2008, Land Management within Capability: a NSW Monitoring, Evaluation and Reporting Project in *Proceedings of Australian and New Zealand Soil Conference 2008*, Palmerston North, New Zealand, 1–5 December 2008.

Hazleton PA & Murphy BW 2007, *Interpreting Soil Test Results, What Do All The Numbers Mean?*, CSIRO Publishing, Melbourne.

Klingebiel AA & Montgomery PH 1961, *Land Capability Classification*, Agriculture Handbook No.210, Soil Conservation Service, US Dept of Agriculture, Washington, DC.

Lawrie JW, Murphy BW, Packer IJ & Harte AJ 2007, Soils and sustainable Farming Systems in Charman PEV & Murphy BW (eds.), *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 297-329.

Leys JF 2007, 'Wind Erosion' in Charman PEV & Murphy BW (eds.) *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 26–31 (see also pp 213–222).

Leys JF, McTainsh GH, Strong CL, Heidenreich S, Biesaga K 2008, 'DustWatch: using community networks to improve wind erosion monitoring in Australia', *Earth Surface Process and Landforms,* 33, pp. 1912–26.

Lockwood PV, Wilson BR, Daniel H & Jones MJ 2003, *Soil acidification and natural resource management directions for the future* NSW Agriculture, Armidale, NSW [www.une.edu.au/agronomy/acidification.htm].

McKenzie NJ, Henderson B & McDonald WS 2002, *Monitoring soil change: Principles and practices for Australian conditions*, Land and Water Technical Report, 18/02, CSIRO, Canberra, ACT.

McKenzie NJ, Ringrose-Voase AJ & Grundy MJ 2008, Rationale in McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ (eds.), *Guidelines for Surveying Soil and Land Resources*, 2nd edn, Australian Soil and Land Survey Handbook Series, CSIRO Publishing.

McNeill JM & MacEwan RJ 2007, *The Land-Use Impact Model (LUIM)*, Department of Primary Industries, Victoria.

Miller W 2008, *Practical Guide to Soil Erosion: A guide to preventing, assessing and treating soil erosion on your farm,* Border Rivers–Gwydir CMA, Inverell.

Moore G 1998*, Soil guide – a handbook for understanding and managing agricultural soils,* Agriculture Western Australia, Bulletin No. 4343.

Murphy S & Murphy BW 2007, *Land Management Actions for Priority Targets (LandMAPT) Database, Proof of Concept, Cowra Roadside Survey July 2007*, NSW Department of Primary Industries.

Murphy B, Cauchi J, Lawrie J, Taylor S & Welch A 2008, *Land and Soil Capability – How we safely manage our soil, Land classifications of the Central West – 2008,* Central West CMA, Wellington, NSW.

Murphy B, Murphy C, Bowman G, Wilson B, Emery E, Atkinson G, Welsh A, Leys J, Chapman G, Lawrie J, Geeves G, Taylor S, Lucas S & Thomas D 2006, *A Rural Land and Soil Capability Scheme to Support Monitoring and Evaluation in NSW*: *Rule Set to Determine LSC Classes,* DECCW NSW, Version 4.2, September 2006.

Murphy C, Murphy B, Thomas D, Atkinson G, Emery E, Bowman G, Lucas S, Taylor S & Murrell A 2007, MER Interim Land and Soil Capability (LSC) Mapping Project: Mapping Method and Rule Sets, based on Version 4.2 of Murphy et al. 2006, *A Rural Land and Soil Capability Scheme to Support Monitoring and Evaluation in NSW*, DECCW NSW, Version 2, December 2007.

Natural Resources Commission 2005, *Recommendations: State-wide standards and targets*, Natural Resources Commission, Sydney.

Natural Resources and Environment Chief Executive Officers Cluster Group 2006, *NSW Natural Resources Monitoring, Evaluation and Reporting Strategy*, NSW Government, unpublished.

NSW Agriculture 1994, *Soils and their management*, Books 1–4, Home Study Program, Land Management Series, NSW Agriculture, Tocal.

NSW Agriculture, Department of Infrastructure, Planning and Natural Resources (DIPNR) & Hawkesbury Nepean CMA 2004, *Best Management Practices for Graziers in the tablelands of NSW*, NSW Agriculture, DIPNR, and Hawkesbury Nepean CMA.

NSW Government 2008, *NSW State Plan – a new direction for NSW*, Sydney.

Ringrose-Voase AJ 2008, 'Quantitative land evaluation' in McKenzie NJ, Grundy MJ, Webster R & Ringrose-Voase AJ (eds), *Guidelines for Surveying Soil and Land Resources*, 2nd edn,, Australian Soil and Land Survey Handbook Series, CSIRO Publishing.

Rosewell CJ, Crouch RJ & Morse RJ 2007, 'Water Erosion' in Charman PEV & Murphy BW (eds.), *Soils – Their Properties and Management*, 3rd edn, Oxford University Press in association with Department of Natural Resources, pp. 16–26.

Rossiter DG 1990, 'ALES: A framework for land evaluation using a microcomputer', *Soil use and Management,* vol. 6, pp. 7–20, see also [www.css.cornell.edu/landeval/ales/ales.htm].

Rowe RK, Howe DF & Alley NF 1988, *Manual of Guidelines for Land Capability Assessment in Victoria*, Victorian Department of Conservation, Forests and Lands.

Russell EW & Russell EJ 1988, *Russell's soil conditions and plant growth*, Longman Scientific & Technical, Essex, UK.

Russell JS & Isbell RF (eds.) 1996, *Australian Soils: The Human Impact,* University of Queensland Press, St Lucia.

Shepherd GT 2007, *Visual Soil Assessment (Volume 1), Field guide for pastoral grazing and cropping on flat to rolling country*, 2nd edn, Horizons Regional Council, Palmerston North.

Skjemstad JO, Dalal RC, Slattery WJ, Wilson BR, Mele PM, Murphy DV, Dixon J & McKenzie NJ 2006, 'Soil Organic Carbon 'in McKenzie NJ & Dixon J (eds.), *Monitoring soil condition across Australia: recommendations from the expert panels*, prepared on behalf of the National Coordinating Committee on Soil and Terrain, National Land and Water Resources Audit, Canberra [www.nlwra.gov.au].

Smith CS, McDonald GT & Thwaites RN 2000, 'Assessing the sustainability of agricultural land management', *Journal of Environmental Management,* vol. 60, pp. 267–288.

Squires V & Tow P 1991, *Dryland Farming, a Systems Approach, an Analysis of Dryland Agriculture in Australia,* Oxford University Press, Melbourne.

Standards Australia 2009, *AS/NZS ISO 31000:2009, Risk management – Principles and guidelines*.

Tulau MJ 2008, *Acid Sulfate Soil Remediation Guidelines for Coastal Floodplains in NSW,* DECCW NSW, Sydney.

van Gool D, Tille P & Moore G 2005, *Land Evaluation Standards for Land Resource Mapping*, 3rd edn, WA Department of Agriculture, Perth.

van Gool D 2008, 'Conventional land evaluation', in Grundy MJ, McKenzie NJ, Ringrose-Voase AJ & Webster R (eds), *Guidelines for Surveying Soil and Land Resources*, 2nd edn, Australian Soil and Land Survey Handbook Series, CSIRO Publishing.

Wells MR & King PD 1989, *Land Capability Assessment Methodology – for rural residential development and associated agricultural land uses*, Western Australian Department of Agriculture, Land Resource Series No. 1, WADA, Perth.

Wilson BR, Chapman GA, Murphy BW, Atkinson G, Emery K, Bowman G, Wright P, McGowen I, Lawrie R & Howling G 2006, 'A Program to Monitor and Evaluate Soil and Land Resource Condition in NSW', Draft Implementation Plan (unpublished), Department of Natural Resources, Sydney, NSW.

Appendix 1: Expert knowledge form example

Management of Land and Soil Hazards

CMA: Border Rivers–Gwydir SMU: Gwydir floodplains

Completed by:…………………… Organisation: …………………… Date:……………..

Land degradation process	Management of land degradation process (relative to the land capability)		Trend of management		Dominant land management actions contributing to degradation	
Sheet erosion	Very good	☐	Greatly improving	☐	Long period of bare fallow	☐
	Good	☐	Slightly improving	☐	Low retention of stubble on surface	☐
	Fair	☐	Steady	☐	Excessive tillage	☐
	Poor	☐	Slightly declining	☐	High disturbance equipment	☐
	Very poor	☐	Strongly declining	☐	Low groundcover from grazing	☐
					Low proportion of perennial plants	☐
					Minimal structural erosion controls	☐
					Other	
Gully erosion	Very good	☐	Greatly improving	☐	Long period of bare fallow	☐
	Good	☐	Slightly improving	☐	Low retention of stubble on surface	☐
	Fair	☐	Steady	☐	Excessive tillage	☐
	Poor	☐	Slightly declining	☐	High disturbance equipment	☐
	Very poor	☐	Strongly declining	☐	Low groundcover from grazing	☐
					Low proportion of perennial plants	☐
					Minimal structural erosion controls	☐
					Other	
Wind erosion	Not an issue	☐	Greatly improving	☐	Long period of bare fallow	☐
	Very good	☐	Slightly improving	☐	Low retention of stubble on surface	☐
	Good	☐	Steady	☐	Excessive tillage	☐
	Fair	☐	Slightly declining	☐	High disturbance equipment	☐
	Poor	☐	Strongly declining	☐	Low groundcover from grazing	☐
	Very poor	☐			Low proportion of perennial plants	☐

Land degradation process	Management of land degradation process (relative to the land capability)	Trend of management	Dominant land management actions contributing to degradation
			Minimal structural erosion controls ☐
			Other
Structure decline	Very good ☐	Greatly improving ☐	High frequency of cropping (with tillage) ☐
	Good ☐	Slightly improving ☐	Removal of stubble ☐
	Fair ☐	Steady ☐	Excessive tillage ☐
	Poor ☐	Slightly declining ☐	High disturbance equipment ☐
	Very poor ☐	Strongly declining ☐	Frequent traffic in wet conditions ☐
			Stock trampling in wet conditions ☐
			Poor pasture condition from grazing ☐
			Other
Acidification	Very good ☐	Greatly improving ☐	High removal of biomass ☐
	Good ☐	Slightly improving ☐	Frequent growth of annual legumes ☐
	Fair ☐	Steady ☐	Excessive use of N fertiliser ☐
	Poor ☐	Slightly declining ☐	Insufficient use of lime ☐
	Very poor ☐	Strongly declining ☐	Long period of bare fallow ☐
			Deep drainage from irrigation ☐
			Poor pasture condition from grazing ☐
			Low proportion of perennial grasses ☐
			Other
Salinity/water logging	Not an issue ☐	Greatly improving ☐	Long period with no plant growth ☐
	Very good ☐	Slightly improving ☐	Low plant cover with cropping ☐
	Good ☐	Steady ☐	Low tree and shrub cover over property ☐
	Fair ☐	Slightly declining ☐	Low proportion of perennial plants ☐
	Poor ☐	Strongly declining ☐	Poor pasture condition from grazing ☐
	Very poor ☐		Deep drainage from irrigation ☐

Land degradation process	Management of land degradation process (relative to the land capability)		Trend of management		Dominant land management actions contributing to degradation	
					Other	
Organic carbon decline	Very good	☐	Greatly improving	☐	High removal of biomass	☐
	Good	☐	Slightly improving	☐	Excessive frequency of cropping	☐
	Fair	☐	Steady	☐	Stubble removal	☐
	Poor	☐	Slightly declining	☐	Insufficient fertilisers or conditioners	☐
	Very poor	☐	Strongly declining	☐	Poor pasture condition from grazing	☐
					Excessive use of herbicides	☐
					Excessive tillage	☐
					Other	
Acid sulfate soils	Not an issue	☐	Greatly improving	☐	Deep depth of drains	☐
	Very good	☐	Slightly improving	☐	High density of drains	☐
	Good	☐	Steady	☐	Lack of suitable controlling structures	☐
	Fair	☐	Slightly declining	☐	Other	
	Poor	☐	Strongly declining	☐		
	Very poor	☐				

Appendix 2: Upper sustainable LSC_{MGT} for land management actions

The relationship between the potential adverse impact of land management actions and upper sustainable LSC_{MGT} is shown the table below.

Potential adverse impact of land management actions on soil condition	Upper sustainable LSC_{MGT} rating
Extremely high	1
Very high	2
High	3
Moderate	4
Moderate to low	5
Low	6
Very low	7
Extremely low	8

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
General								
Frequency of traffic control in cropping (% of time)	Rarely (< 10%)	-	-	-	2	-	-	-
	Sometimes (10–50%)	-	-	-	3	-	-	-
	Frequently (51–90%)	-	-	-	4	-	-	-
	Always (>90%)	-	-	-	4	-	-	-
Frequency traffic avoided in wet (% of time)	Rarely (< 10%)	-	-	-	2	-	-	-
	Sometimes (10–50%)	-	-	-	3	-	-	-
	Frequently (51–90%)	-	-	-	4	-	-	-
	Always (>90%)	-	-	-	4	-	-	-
N Fertiliser application rates crop and horticulture (kg N/ha/yr)	Low (<20)	2	2	2	3	5	3	3
	Moderate (20–80)	3	3	3	4	4	4	4
	High (>80)	4	4	4	5	3	5	5

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
N Fertiliser application rates grazing (kg N/ha/yr)	Low (<20)	4	4	4	3	5	4	4
	Moderate (20–80)	5	5	5	4	4	5	5
	High (>80)	6	6	6	5	3	6	6
N Fertiliser application rates plantation establishment (kg N/ha/yr)	Low (<20)	5	5	5	4	6	5	5
	Moderate (20–80)	6	6	6	5	5	6	6
	High (>80)	7	7	7	6	4	7	7
Fertiliser rate determination method	Landholder assessment	-	-	-	-	3	-	-
	Manufacturer recommendation	-	-	-	-	3	-	-
	Consultant recommendation	-	-	-	-	4	-	-
	Government agronomist recommendation	-	-	-	-	5	-	-
	Set rates	-	-	-	-	3	-	-
	Soil tests	-	-	-	-	5	-	-
Lime application rates (tonne/ha/year)	>1	6	6	6	6	5	6	5
	0.5–1.0	5	5	5	5	4	5	4
	0.1–0.5	4	4	4	4	3	4	3
	<0.1	3	3	3	3	2	3	2
Gypsum application rates (tonne/ha/year)	>1	6	4	6	6	6	6	6
	0.5–1.0	5	-	5	5	5	5	5
	0.1–0.5	4	-	4	4	4	4	4
	<0.1	3	3	3	2	3	3	3
Method of irrigation	Pivot		-	-	3	3	3	-
	Travel		-	-	3	3	3	-
	Hand shift piping		-	-	3	3	3	-
	Mechanical shift piping		-	-	3	3	3	-
	Furrow		-	-	3	2	2	-
	Flood		-	-	3	2	2	-
	Micro sprinklers (including drip)		-	-	5	4	4	-

Land management action	**Option**	**Upper sustainable LSC_{MGT} class**						
		Sheet erosion	**Gully erosion**	**Wind erosion**	**Structure decline**	**Acidification**	**Salinity and waterlogging**	**Organic carbon decline**
Irrigation rate determination method	Landholder assessment	-	-	-	-	3	3	-
	Professional recommendation	-	-	-	-	4	4	-
	Set rates	-	-	-	-	3	3	-
	Soil tests/monitoring	-	-	-	-	4	4	-
	Water balance calculations	-	-	-	-	4	4	-
Salinity mitigation measures	Salinity mitigation plan	-	-	-	-	-	5	-
	Stock exclusion	-	-	-	-	-	5	-
	Revegetation on saline sites	-	-	-	-	-	4	-
	Revegetation in potential recharge areas	-	-	-	-	-	5	-
	Engineering solutions	-	-	-	-	-	4	-
	Deep rooted perennials	-	-	-	-	-	5	-
Percentage of whole property with trees & shrubs	>25	-	-	-	-	-	6	-
	15–25	-	-	-	-	-	5	-
	5–15	-	-	-	-	-	4	-
	1–5	-	-	-	-	-	3	-
	<1				-		2	
Cropping specific								
Average frequency of cropping (including lucerne) by conventional tillage	>1 per year	2	2	2	1	2	2	2
	1 per year	3	3	3	2	2	3	3
	1 per 1–2 years	4	4	4	3	3	4	4
	1 per 2–3 years	4	4	4	4	4	5	4
	< 1 per 3 years	4	4	4	4	5	5	5
Average number of hay cuts/year	< 1 cut per year	-	-	-	-	5	-	5
	1 cut per year	-	-	-	-	4	-	4
	2–4 cuts per year	-	-	-	-	3	-	3
	> 4 cuts per year	-	-	-	-	2	-	2

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
Proportion of time with annual legumes growing	none	-	-	-	-	5	-	?
	<10%	-	-	-	-	5	-	-
	10–25%	-	-	-	-	4	-	-
	25–50%	-	-	-	-	3	-	-
	>50	-	-	-	-	2	-	-
Tillages prior to sowing	0	4	4	4	4	-	-	4
	1	3	3	3	2	-	-	3
	2	2	2	2	1	-	-	2
	3	2	2	2	1	-	-	2
	4	1	1	1	2	-	-	2
	>4	1	1	1	1	-	-	2
Cultivation equipment	Do not cultivate	4	4	4	5	-	-	4
	Rotary hoe	2	1	1	1	-	-	2
	One-way disc	2	2	2	1	-	-	2
	Two-way disc	3	3	3	2	-	-	2
	Tined Implement (narrow spacing < 20cm)	3	3	3	2	-	-	3
	Tined implement (wide spacing ≥ 20cm)	3	3	3	3	-	-	-
Length of bare fallow (stubble & plant free) (in days)	0	4	4	4	5	5	6	5
	1–7	3	3	3	4	5	5	5
	8–28	3	3	3	3	4	5	4
	29–90	2	2	2	2	3	4	3
	90–180	1	1	1	1	2	3	2
	>180	1	1	1	1	2	2	2
Sowing equipment	Disc seeder	4	4	4	5	-	-	-
	Tine (narrow point)	3	3	3	4	-	-	-

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
	Tine (broad point)	2	2	2	4	-	-	-
Percentage disturbance in sowing phase	<5%	4	4	4	5	-		5
	5–20%	3	3	3	4	-		4
	20–50%	2	2	2	3	-		3
	50–100%	1	1	1	2	-		2
Stubble management	Left intact	3	3	3	4	4	4	4
	Left intact with chemical treatment of weeds	3	3	3	4	4	3	3
	Slashed/mulched	4	4	4	5	4	4	4
	Removed by baling	2	2	2	3	2	3	2
	Lightly grazed	3	3	3	4	3	4	3
	Heavily grazed	1	1	1	2	2	2	2
	Ploughed in	1	1	1	2	4	3	3
	Cold burn	2	2	2	3	3	4	3
	Hot burn	1	1	1	2	2	2	2
Minimum groundcover maintained (90% of time)	71–100%	4	4	5	4	5	5	5
	51–70%	3	3	4	4	4	4	4
	26–50	2	2	3	3	3	3	3
	11–25	2	2	2	2	2	2	2
	<10	1	1	1	2	2	2	1
Average groundcover in normal years during grazing rotations (%)	>70	4	4	4	5	5	5	5
	60–70	3	3	3	4	4	4	4
	50–60	3	3	3	3	3	3	3
	30–50	2	2	2	2	2	2	2
	<30	1	1	1	1	1	1	1
Average pasture height in normal during grazing rotations (cm)	>30	-	-	-	5	5	5	5
	15–30	-	-	-	4	4	4	4
	7–15	-	-	-	3	3	3	3

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
	2–7	-	-	-	2	2	2	2
	<2	-	-	-	1	1	1	1
Effective erosion control measures	Cultivation along the contour	3	3	-				
	Pasture cropping	4	4	5				
	Erosion control banks	3	3	-				
	Sediment traps and dams	-	3	-				
	Gully reshaping							
	Windbreaks			3				
	None	2	2	2				
Grazing specific								
Average groundcover % in normal years	>70	6	6	6	6	5	5	5
	60–70	5	5	5	5	4	4	4
	50–60	4	4	4	4	3	3	3
	30–50	3	3	3	3	2	2	2
	<30	2	2	2	2	2	2	2
Average pasture height in normal years (cm)	>30	-	-	-	6	6	6	6
	15–30	-	-	-	5	5	5	5
	5–15	-	-	-	4	4	4	4
	2–5	-	-	-	3	3	3	3
	<2	-	-	-	2	2	2	2
Stocking rates determined by groundcover and height	Rarely (< 10%)	2	2	2	2	2	2	2
	Sometimes (10–50%)	4	4	4	4	3	3	3
	Frequently (51–90%)	5	5	5	5	4	5	5
	Always (>90%)	6	6	6	6	5	6	6
Minimum groundcover for destocking (%)	>70	6	6	6	6	5	6	6
	51–70	5	5	5	5	4	5	5
	25–50	4	4	4	4	3	4	4
	<25	2	2	2	2	2	2	2

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
Frequency paddock destocked in extended wet periods	Rarely (< 10%)	-	-	-	2	-	-	-
	Sometimes (10–50%)	-	-	-	2	-	-	-
	Frequently (51–90%)	-	-	-	4	-	-	-
	Always (>90%)	-	-	-	5	-	-	-
	Does not get wet	-	-	-	6	-	-	-
Areal coverage of perennial species during grazing phases (%)	>80	6	6	6	6	5	6	6
	50–80	5	5	5	5	4	4	4
	20–50	4	4	4	5	3	5	5
	5–20	3	3	3	3	2	3	3
	<5	2	2	2	2	2	2	2
Method of renovation	Broadcast seeding	6	6	6	6	6	6	6
	Sowing with direct drill	5	5	5	5	5	5	5
	No renovation (but required)	4	4	4	3	3	3	3
	Sowing with multiple cultivation	3	3	3	3	4	4	4
	Natural regeneration/renovation not required	5	5	5	6	5	5	5
Effective erosion control measures	Erosion control banks	5	5	-				
	Sediment traps and dams		6					
	Gully reshaping		5					
	Windbreaks			5				
	None	4	4	4				
Horticulture/viticulture specific								
Groundcover between rows	Sown pasture	5	5	5	4	5	6	6
	Volunteer pasture	4	4	4	4	4	5	5
	Other crops	3	3	3	3	3	4	4
	Bare soil	2	2	2	2	2	2	2
	Mulch	4	4	4	4	3	3	4
Method of plant control	Not controlled	5	5	5	5	5	6	6

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	**Gully erosion**	**Wind erosion**	**Structure decline**	**Acidification**	**Salinity and waterlogging**	**Organic carbon decline**
	Cultivation	2	2	2	2	2	3	3
	Chemicals	3	3	3	3	3	3	3
	Grazing	3	3	3	3	3	4	4
	Mowing/slashing	4	4	4	5	4	6	6
Minimum groundcover	>70	5	5	6	6	6	6	6
	51–70	4	4	5	5	5	5	5
	25–50	3	3	4	4	4	4	4
	<25	2	2	3	3	3	3	3
Effective erosion control measures	Tree/vine planting along the contour	4	4	-				
	Erosion control banks	4	4	-				
	Sediment traps and dams	-	4	-				
	Windbreaks	-	-	4				
	Gully reshaping	-	4	-				
	None	3	3	3				
Forestry specific								
Predominant forest type	Exotic plantation (assume pine)	-	-	-	-	4	-	5
	Native hardwood plantation	-	-	-	-	6	-	7
	Native hardwood forest	-	-	-	-	6	-	7
Method of ground preparation	Windrow and burning of residual vegetation	4	4	5	6	5	-	5
	Rip and contour mound soil	5	5	6	4	5	-	4
	Rip and rough stack residue	5	5	6	4	5	-	5
	Rip only	4	4	5	4	5	-	5
	Rip and burn residue	3	3	4	4	5	-	4
	Burn residue only	4	4	5	6	5	-	4
	Remove trash from area	4	4	5	5	5	-	4
	Chip and mulch	6	6	7	7	6	-	6

Land management action	Option	Upper sustainable LSC$_{MGT}$ class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
Method plant growth control in first few years	Plant growth not controlled	7	7	7	6	6	-	6
	Soil cultivation	3	3	4	3	5	-	4
	Herbicides	4	4	5	5	5	-	5
	Grazing	5	5	6	5	5	-	5
	Mowing/slashing	6	6	7	6	5	-	6
Current type of groundcover	Sown pasture	5	5	6	5	5	-	6
	Volunteer plants	5	5	6	6	6	-	6
	Plant leaf litter/mulch	4	4	6	5	5	-	5
	Bare soil	2	3	3	4	4	-	4
Normal groundcover (%)	>70	6	6	7	7	7	-	7
	51–70	5	5	6	6	6	-	6
	25–50	4	4	5	5	5	-	5
	<25	2	3	4	4	4	-	4
Form of harvesting practised	Thinning	5	5	6	7	7	-	7
	Selective logging of mature trees	5	5	7	7	7	-	6
	Extensive logging	4	4	5	6	6	-	5
	Complete vegetation removal	3	3	4	5	5	-	4
Average width between the edge of operations and the top of the drainage line bank (m)	<5	3	3	4	-	-	-	-
	5–10	4	4	5	-	-	-	-
	10–25	5	5	6	-	-	-	-
	>25	6	6	7	-	-	-	-
Water erosion control on roads and tracks	Yes	6	6	6	-	-	-	-
	No	4	4	5	-	-	-	-
Proportion of the total ground surface area is disturbed by heavy vehicle and equipment use (%)	<10	7	7	7	7	7	-	7
	10–25	6	7	6	6	6	-	6
	25–50	5	6	5	5	5	-	5
	50–75	4	5	4	4	5	-	5
	>75	3	4	3	3	4	-	4

Land management action	Option	Upper sustainable LSC_{MGT} class						
		Sheet erosion	Gully erosion	Wind erosion	Structure decline	Acidification	Salinity and waterlogging	Organic carbon decline
Effective erosion control measures	Tree planting along the contour	6	6		-	-	-	-
	Erosion control banks	5	5	-	-	-	-	-
	Sediment traps and dams	-	5	-	-	-	-	-
	Silt fencing	6	6		-	-	-	-
	Gully reshaping	-	5	-	-	-	-	-
	None	4	4	-	-	-	-	-
Wooded Area (non-commercial forestry)								
Extent of livestock exclusion	No exclusion	5	5	6	5	5	6	5
	Partial exclusion	6	6	7	6	6	7	6
	Total exclusion	7	7	8	7	7	8	7
Minimum groundcover for de-stocking (%)	>70	7	7	8	7	7	8	7
	51–70	6	6	7	6	6	7	6
	25–50	5	5	6	5	5	6	5
	<25	4	4	5	4	4	5	4
Significant grazing by wildlife or feral animals	Yes	5	5	6	5	6	6	5
	No	7	7	7	7	7	8	7
Normal groundcover (%)	>70	7	7	8	7	7	8	7
	51–70	6	6	7	6	6	7	6
	25–50	5	5	6	5	5	6	5
	<25	4	4	5	4	4	5	4

\- not applicable

Appendix 3: Overview of land-use versus LSC process

This appendix describes the proposed process of determining the areal extent of LMwC by using land-use as a broad surrogate for land management. It uses existing LSC maps and land-use maps.

Step 1: prepare a digital map of upper sustainable LSC for all land-uses for all hazards assuming best land management scenario (higher range of upper sustainable limits for all typical land management actions).

Step 2: prepare a digital map of upper sustainable LSC for all land-uses for all hazards assuming worst land management scenario (lower range of upper sustainable limits for all typical land management actions).

Step 3: compare these maps with a digital map of LSC. If actual LSC is greater than upper sustainable LSC, the land is being managed beyond its capability ie, unsustainably.

Step 4: derive LMwC Index for each pixel (1 to 5) for both the best and worst case scenario maps (see Table 7).

Step 5: compare the LMwC indices (1 to 5) for equivalent pixels on the two maps. Group results into three broad classes that indicate the degree to which land is managed within capability using the following matrix and classes.

Best scenario rating (upper numbers)	Worst scenario rating (lower numbers)				
	5	4	3	2	1
5	A-h	A-m	B-h	B-m	B-m
4	na	A-l	B-m	B-l	B-l
3	na	na	B-m	B-l	B-l
2	na	na	na	C-m	C-l
1	na	na	na	na	C-l

Class	Sub class	Key
A (always managed within capability)	High (extremely good)	A-h
	Medium (very good)	A-m
	Low (good)	A-l
B (sometimes managed within capability)	High (moderate - good)	B-h
	Medium (moderate)	B-m
	Low (moderate - poor)	B-l
C (never managed within or at capability)	High (poor)	C-h

Class	Sub class	Key
	Medium (very poor)	C-m
	Low (extremely poor)	C-l

A preliminary example output of land-use within capability assessment is shown below. The example is strictly proof of concept and data and outputs have not been checked. Water bodies, state forests and national parks have been excluded from this preliminary draft analysis. Colour classes are shown in table above.

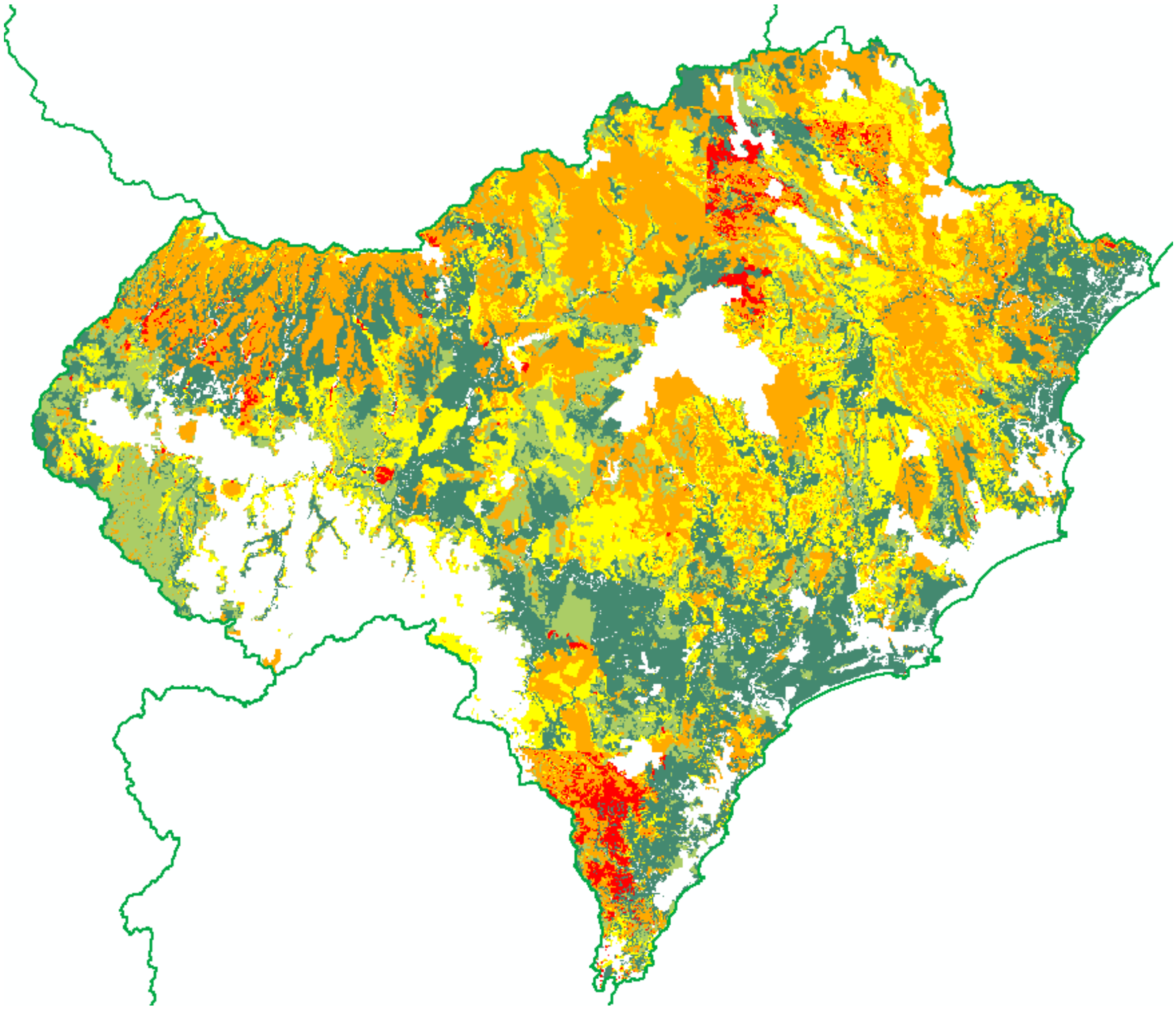


Figure A1: Example output of land-use within capability assessment

Appendix 4: MER land management survey 2008

Department of **Environment & Climate Change** NSW

NSW Monitoring, Evaluation and Reporting Project

Land Management Survey 2008

NSW Monitoring, Evaluation and Reporting Project – Land Management Survey 2008

Introduction

You have kindly allowed one or more soil condition monitoring sites to be placed on your property as part of the NSW Government's Monitoring, Evaluation and Reporting (MER) program for soil and land condition. This program, being administered by the Department of Environment, Climate Change and Water (DECCW), is aimed at reporting on the condition of the State's soil and land resources.

As part of the site monitoring process, it is important to collect detailed information on land management activities being conducted over the monitoring sites. This will allow for the interpretation of any observed changes in soil condition and more generally to understand the role of different land management activities in determining soil and land condition.

Release of Data

Data will be incorporated into the DECCW Land Management Database, which will only be accessible to DECCW staff. For reporting purposes, all results will be aggregated on a regional basis and no personal information will be released.

The Survey

Responses for up to two monitoring sites can be entered on a survey form. If you have more than two sites, please use an additional form. The survey has seven sections:

Section A: General (white); **Section B**: Land and Soil Management (white); **Section C**: Cropping (pink); **Section D**: Grazing (yellow); **Section E**: Horticulture and Viticulture (light blue); **Section F**: Forestry (buff); **Section G**: Wooded Area (light green) plus a page for final comments (white card).

You will only be asked to complete Sections A and B, plus those relevant to the land-use of your site(s). Most questions involve either a multiple choice selection (please choose only one option per column) or entry of a single word or numerical value. Some involve entry of a very brief description. If a question is not relevant to your operation mark it NA (Not Applicable). Additional comments are invited on the final page.

Identifying Paddocks Containing Sites

Enclosed with this questionnaire are two copies of a satellite image of your property. These images show the location of the sites sampled. One copy is a complimentary copy for you to keep. On the other image, could you please mark in the boundary of the paddock containing the sites, and identify 'Site 1' and 'Site 2' (if applicable). Answers to the questionnaire will correspond to these paddocks. Please return this image along with the questionnaire.

Contact Us

If you have any questions in relation to the survey, please contact your regional MER Officer: Name:………………………………………………………………Telephone: …………………………………... or Jonathan Gray: email: jonathan.gray@environment.nsw.gov.au

Office use only			
CMA	SMU	Site 1 No.	Site 2 No.

SECTION A: GENERAL

Please fill in your contact details below.

Name	…………………………………………………………………
Property Name	…………………………………………………………………
Road Address	………………………………………………………………… ………………………………………………………………… …………………………………………………………………
Postal Address (if different to above)	………………………………………………………………… …………………………………………………………………
Telephone Number	…………………………………………………………………
Mobile Number	…………………………………………………………………
Email address	
Lot/DP	
Date Survey Completed	…………………………………………………………………

A1. What are the main farming activities undertaken over your whole property?

	primary	*secondary*	*other*
Cropping (including vegetable and fodder crops)	☐	☐	☐
Grazing	☐	☐	☐
Horticulture (tree crops) or Viticulture	☐	☐	☐
Forestry	☐	☐	☐
Management for natural habitat	☐	☐	☐
Other *(please specify)*			
……………………………………………...	☐	☐	☐

A2. Please provide the name (eg river paddock, home paddock) or a brief descriptor of the paddock containing the monitoring site (to assist in easy identification of each paddock).

Monitoring Site 1 (Area 1)	*Monitoring Site 2 (Area 2)*
…………………………………………………..	……………………………………………………..…

A3. What is the approximate size of the paddock containing the site? Please draw the paddock on the map/image supplied.

Site 1	*Site 2*
…….……………………….. hectares ☐ acres ☐	…………………….…… hectares ☐ acres ☐

A4. What activities are generally undertaken on the area containing the site?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Cropping (including vegetable and fodder crops)	☐	☐	☐	☐
Grazing	☐	☐	☐	☐
Horticulture (tree crops) or viticulture	☐	☐	☐	☐
Forestry	☐	☐	☐	☐
Management for natural habitat	☐	☐	☐	☐
Other *(please specify)*				
………………………………………………...	☐	☐	☐	☐

A5. For approximately how many years has the paddock containing the site been under the current management practices?

Site 1	*Site 2*
………………………………………………	………………………………………………

A6. Please briefly describe the history of the area (include major changes in land-use or management practices, eg approximate date when woodland cleared for pasture, first cropping and first irrigation and how long has the current rotation been in place)

Site 1	*Site 2*
……………………………………………................... ……………………………………………………………..… …………………………………………………………... ……………………………………………………………..…	……………………………………………………..…….... ………………………………………………………………. ……………………………………………………………..... ……………………………………………………………….

A7. Please describe any unusual features that influence management of the paddock containing the site. For example, rockiness may prevent cultivation in the upper ¼ of the paddock. Please draw the relevant section of the paddock on the map/image supplied.

Site 1	*Site 2*
……………………………………………………..…............ ……………………………………………………………….. ……………………………………………………………..... ………………………………………………………………	………………………………………………………..…...... ……………………………………………………..………… ……………………………………………………..………...... …………………………………………………………….…

A8. a) Is management of the monitoring site paddock the same as management over other areas of the property with similar land-use?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

b) If no, please briefly describe the differences.

Site 1	*Site 2*
……………………………………………….....................	……………………………………………….....................
………………………………………………………………..	………………………………………………………………..
……………………………………………………………...	……………………………………………………………...
………………………………………………………………	………………………………………………………………

A9. a) Is land-use or management expected to change in the next five years (eg from set stocking to rotational grazing, or from multiple tillage to no-till, reduced irrigation)?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

b) If yes, please give a brief description.

Site 1	*Site 2*
……………………………………………......................	………………………………………………………………..
………………………………………………………………	……………………………………………………………..…
…………………………………………………………....	………………………………………………………………...
………………………………………………………………	…………………………………………………………………

SECTION B: LAND AND SOIL MANAGEMENT

This section covers general land and soil management issues over the paddocks containing the monitor sites.

B1. How frequently is machinery kept to designated wheel-tracks on the paddock (ie'controlled traffic')?

	Site 1	*Site 2*
Never		
Rarely (less than 10% of the time)	☐	☐
Sometimes (10–50% of the time)	☐	☐
Frequently (51–90% of the time)	☐	☐
Always (greater than 90% of the time)	☐	☐

B2. How frequently do you **avoid** using vehicles and machinery on the paddock if the soil is wet?

	Site 1	*Site 2*
Never		
Rarely (less than 10% of the time)	☐	☐
Sometimes (10–50% of the time)	☐	☐
Frequently (51–90% of the time)	☐	☐
Always (greater than 90% of the time)	☐	☐

B3. Which of the following erosion or sediment control measures **are effective** on the area (tick multiple boxes if required)?

	Site 1	*Site 2*
Cultivation or tree planting all or mostly along the contour	☐	☐
Pasture cropping	☐	☐
Erosion control banks	☐	☐
Sediment traps and dams	☐	☐
Silt fencing	☐	☐
Gully reshaping	☐	☐
Windbreaks	☐	☐
Other *(please specify)*		
……………………………………………………...................	☐	☐
…………………………………………………………………..		

B4. a) Have you undertaken any soil tests on the paddock over the past five years?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

b) If so, please list them.

Site 1	*Site 2*
………………………………………………......................	…………………………………………………………....
…………………………………………………………………	………………………………………………………..…
………………………………………………......................	…………………………………………………….….....

c) If so, would you be prepared to release them to DECCW upon request?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

B5. a) What fertilisers (excluding lime, dolomite and gypsum but including organic fertilisers such as chicken litter, dairy effluent and biosolids) have been applied and what were typical application rates in recent years of 'fair conditions? Record over multiple years if necessary, eg 50kg/ha/2 yrs. Include NPK if known. If no products were applied, please write 'none' in first box.

Type	Site 1 Application rate (kg/ha/yr)	Site 2 Application rate (kg/ha/yr)
……......…………………………		

	……………………………..	:…………………………….
……......…………………………	………………………………..	……………………………….
……......…………………………	……………………………......	…………………………….....
……......…………………………	………………..…………...	………………..…………...
……......…………………………	………………………..…...	………………………..…...

Notes: (eg if once-off application only as in many forestry operations)

Site 1	*Site 2*
……………………………………………................ ………………………………………………………..	……………………………………………………..... ……………………………………………………..

b) How were fertiliser application rates determined?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Landholder assessment	☐	☐		☐	☐

Manufacturer recommendation	☐	☐		☐	☐
Consultant recommendation	☐	☐		☐	☐
Government agronomist recommendation	☐	☐		☐	☐
Set rates	☐	☐		☐	☐
Soil tests	☐	☐		☐	☐
Other *(please specify)*					
……………………………………………...	☐	☐		☐	☐

B6. a) What conditioners such as lime, dolomite and gypsum conditioners were applied and what were typical application rates in recent years of fair conditions? Record over multiple years if necessary, eg 2 tonnes/ha/2 yrs. If no products were applied, please write 'none' in first box.

Type	Site 1 Application rate (tonnes/ha per unit time)	Site 2 Application rate (tonnes/ha per unit time)
……......……………………..…	………………………………….....	……………………………..…...
……......……………………	…………………………………...	……………………………….…
……......……………………	…………………………….........	…………………………….....
……......……………………	………………..…………….....	………………...…………...

……....……………………	………………………..…..	………………………..…..

Notes: (eg if once off application only).

Site 1	*Site 2*
…………………………………………………….... ……………………………………………………..…	……………………………………………….…….... ……………………………………………….………

b) How were conditioner application rates determined?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 2ndary*
Landholder assessment	☐	☐		☐	☐
Manufacturer recommendation	☐	☐		☐	☐
Consultant recommendation	☐	☐		☐	☐
Government agronomist recommendation	☐	☐		☐	☐
Set rates	☐	☐		☐	☐
Soil tests	☐	☐		☐	☐
Other *(please specify)* …………………………………………....	☐	☐		☐	☐

B7. Is this paddock irrigated?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, please go to B12.

B8. For each paddock what was the approximate volume of water used in recent years of fair conditions (and water entitlements) (ML/ha/yr)?

Site 1	*Site 2*
……………………………………………………	…………………………………………………….

B9. What is the primary source of irrigation water for the paddock?

	Site 1	*Site 2*
River	☐	☐
Groundwater (eg bore)	☐	☐
Farm dam	☐	☐
Canal	☐	☐
Other *(please specify)*		
………………………………………………...	☐	☐

B10. a) What is the main method of irrigation used on the paddock?

	Site 1	*Site 2*
Pivot	☐	☐
Travelling	☐	☐
Hand shift piping	☐	☐
Mechanical shift piping	☐	☐
Furrow	☐	☐
Flood	☐	☐
Micro irrigation (including drip)	☐	☐
Other *(please specify)*		
………………………………………………...	☐	☐

b) How are irrigation application rates determined?

	Site 1 primary	Site 1 secondary		Site 2 primary	Site 2 seconda ry
Landholder assessment	☐	☐		☐	☐
Professional recommendation	☐	☐		☐	☐
Set rates	☐	☐		☐	☐
Soil tests/monitoring (eg soil water content)	☐	☐		☐	☐
Water balance calculations (eg Water Use Efficiency program)	☐	☐		☐	☐
Other *(please specify)* ……………………………………………...	☐	☐		☐	☐

B11. Please give the following water quality measurements for irrigation water used on the paddock, if known. Please specify units.

Site 1			*Site 2*	
Salinity (EC)			Salinity (EC)	
Sodicity (SAR, sodium absorption ration)			Sodicity (SAR)	
Alkalinity (pH)			Alkalinity (pH)	
Other if known, eg Boron, N or P concentration …………………………			Other if known, eg Boron, N or P concentration ………………………….	

B12. Is salinity a problem on the paddock or elsewhere on your property?

	Site 1	*Site 2*	*Elsewhere on your property*
Yes	☐	☐	☐
No	☐	☐	☐

B13. Is waterlogging a problem on the paddock or elsewhere on the property?

	Site 1	*Site 2*	*Elsewhere on your property*
Yes	☐	☐	☐
No	☐	☐	☐

If there are no salinity or waterlogging issues on your property, please go to section C: Cropping.

B14. What is the cause of the salinity or waterlogging problems?

	Site 1	*Site 2*	*Elsewhere on your property*
Do not know	☐	☐	☐
Regionally rising water tables	☐	☐	☐
Locally rising water tables	☐	☐	☐
Irrigation water	☐	☐	☐
Poor drainage	☐	☐	☐
Other *(please specify)*	☐	☐	☐
……………………………………………...			

B15. Which of the following measures have been taken to mitigate salinity or waterlogging on the paddock and/or elsewhere on the property (if applicable)?

	Site 1	*Site 2*	*Elsewhere on your property*
Salinity mitigation plan being implemented	☐	☐	☐
Stock exclusion	☐	☐	☐
Revegetation on saline paddocks	☐	☐	☐
Revegetation in potential recharge areas	☐	☐	☐
Engineering solutions (eg sub-surface or surface water drainage scheme)	☐	☐	☐
Increased use of deep rooted perennial pasture species to lower water tables	☐	☐	☐
Other *(please specify)*			
……………………………………………...	☐	☐	☐

B16. Approximately what proportion of the whole property is covered with trees and shrubs (%)?

	Site 1	*Site 2*
>25	☐	☐
15-25	☐	☐
5-15	☐	☐
1-5	☐	☐
<1	☐	☐

SECTION C: CROPPING

C1. Has the paddock been cropped (including vegetable and fodder crops) in the past five years?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to Section D: Grazing.

C2. What is the average frequency of cropping on the paddock containing the site?

	Site 1	*Site 2*
More than 1 per year	☐	☐
1 per year	☐	☐
1 per 1–2 years	☐	☐
1 per 2–3 years	☐	☐
Less than 1 per 3 years	☐	☐

C3. To the **best of your memory**, please indicate the sequence of crop and pasture phases on the paddock over the past 10 years, eg 2008 – wheat, 2007 – pasture, 2006 – oats.

Site 1	
Year	Crop or pasture phase
2008	
2007	

Site 2	
Year	Crop or pasture phase
2008	
2007	

2006	
2005	
2004	
2003	
2002	
2001	
2000	

2006	
2005	
2004	
2003	
2002	
2001	
2000	

1999			1999	

C4. Please record, if known, the approximate yield of the main crops grown on the paddock over the past five years in table (a) below. **Alternatively**, record typical approximate yields in recent years of 'fair' conditions in table (b). Please specify if crops have 'failed', 'not been harvested' or were 'grazed' (if fodder crops) in the yield column.

(a)

Year of Harvest	*Site 1*		*Site 2*	
	Crop	Approx Yield (specify units)	Crop	Approx Yield (specify units)
2008				
2007				
2006				

2005				
2004				

(b)

Site 1		*Site 2*	
Crop	Approx yield/year in recent years with 'fair' conditions (specify units)	Crop	Approx yield/year in recent years with 'fair' conditions (specify units)
……………………………	……………………	…………………………	……………………

……………………………	…………………..…		…………………………	……………………
……………………………	…………………….		…………………………	……………………
……………………………	…………………….		…………………………	…………………..
……………………….….	…………………..…		…………………………	…………………..

C5. If you grow hay, what has been the average number of cuts per year for the past five years?

Site 1	*Site 2*
………………………………………………	………………………………………………

C6. For what proportion of time is the paddock sown to annual legumes?

	Site 1	*Site 2*
None	☐	☐
<10% of time, ie < 6 months each 5 yrs	☐	☐
10–25% of time, ie up to 6 months each 2 yrs	☐	☐
25–50% of time, ie up to 6 months each year	☐	☐
>50% of time, ie more than 6 months each year	☐	☐

C7. Which of the following cropping systems are typically used on the paddock?

	Site 1 primary	*Site 1 seconda ry*		*Site 2 primary*	*Site 2 seconda ry*
Rotational	☐	☐		☐	☐
Continuous	☐	☐		☐	☐
Opportunistic	☐	☐		☐	☐
Other *(please specify)*					
………………………………………..	☐	☐		☐	☐

C8. How are crops typically established on the paddock?

	Site 1	*Site 2*
Single crop	☐	☐
Undersown with pasture	☐	☐
Alternating strips of different crops and/or pasture	☐	☐
Intercropping two or more crop species	☐	☐
Other *(please specify)*		
………………………………………………....	☐	☐

C9. On average, how many cultivations or tillages does the paddock receive prior to sowing?

Site 1: ☐☐ *Site 2:* ☐☐

C10. What equipment is commonly used to cultivate soil on the paddock?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Did not cultivate	☐	☐		☐	☐
Mouldboard plough/rotary hoe	☐	☐		☐	☐
One-way disc	☐	☐		☐	☐
Two-way disc	☐	☐		☐	☐
Tined implement (narrow spacing < 20cm)	☐	☐		☐	☐
Tined implement (wide spacing ≥ 20cm)	☐	☐		☐	☐
Other *(please specify)*					
……………………………………………...	☐	☐		☐	☐

C11. How often, if at all, would you rip the paddock (in years)?

Site 1	*Site 2*
………………………………………………	………………………………………………

C12. How do you control weeds on the paddock prior to sowing?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Did not control weeds	☐	☐		☐	☐
Soil cultivation	☐	☐		☐	☐
Burning	☐	☐		☐	☐
Herbicides	☐	☐		☐	☐
Grazing	☐	☐		☐	☐
Mechanical slashing	☐	☐		☐	☐
Other *(please specify)*					
…………………………………………...	☐	☐		☐	☐

C13. What is the average number of days between first soil cultivation and sowing (ie the length of bare fallow)?

Site 1	*Site 2*
………………………………………………	………………………………………………

C14. What equipment is commonly used to sow the crop(s)?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Disc seeder	☐	☐		☐	☐
Tine (narrow point)	☐	☐		☐	☐
Tine (broad point)	☐	☐		☐	☐
Other *(please specify)*					
	☐	☐		☐	☐
…………………………………………					

C15. What is the typical row spacing of crops?

Site 1	*Site 2*
………………………………………………	………………………………………………

C16. What percentage of the crop land's surface area is disturbed during sowing?

	Site 1	*Site 2*
Less than 5%	☐	☐
5–20%	☐	☐
20–50%	☐	☐
50–100%	☐	☐

C17. Following a crop harvest, how many weeks is the paddock typically rested before being grazed (excluding stubble) or cropped again?

Site 1	*Site 2*
………………………………………………	………………………………………………

C18. What methods of stubble management are applied?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Left intact	☐	☐		☐	☐
Left intact with chemical treatment of weeds	☐	☐		☐	☐
Slashed/mulched	☐	☐		☐	☐
Removed by baling	☐	☐		☐	☐
Lightly grazed (partial removal, < 50)	☐	☐		☐	☐
Heavily grazed (removal of majority)	☐	☐		☐	☐
Ploughed in	☐	☐		☐	☐
Cold burn	☐	☐		☐	☐
Hot burn	☐	☐		☐	☐
Other *(please specify)*					
………………………………………………...	☐	☐		☐	☐

C19. Overall, what is the minimum groundcover you aim to maintain over most of the year (more than 90% of the time)? (*NB: If no target, circle 'No target'*.)

Site 1: ☐☐☐ *Site 2:* ☐☐☐

No target *No target*

SECTION D: GRAZING

D1. Have you grazed the paddock in the past five years?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to Section E: Horticulture and Viticulture.

D2. What type(s) of stock are grazed on the paddock?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Beef cattle	☐	☐	☐	☐
Dairy cattle	☐	☐	☐	☐
Sheep	☐	☐	☐	☐
Fat lambs	☐	☐	☐	☐
Horses	☐	☐	☐	☐
Other *(please specify)* ……………………………………	☐	☐	☐	☐

D3. Over the past 12 months, how many head of stock have been grazed on the paddock, and for how long (ensure stock type is consistent with C2)?

Site 1			*Site 2*		
Type of stock	Number of stock	Days grazed on paddock	Type of stock	Number of stock	Days grazed on paddock

D4. Which grazing systems best describes paddock use over the past 12 months?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Rotational grazing based on time (not cell)	☐	☐	☐	☐
Cell grazing (high intensity, short duration, small paddocks, often temporary fencing)	☐	☐	☐	☐
Set (continuous)	☐	☐	☐	☐
Rotational grazing based on pasture growth	☐	☐	☐	☐
Other *(please specify, eg grazed as part of a forage cropping system)* ……………………………………………...	☐	☐	☐	☐

D5. What is the average groundcover maintained in the paddock, in normal (fair) years (*NB: If not known in percentage terms, tones/ha can be indicated underneath*)?

Site 1: ☐☐☐ *Site 2:* ☐☐☐

…………..t/ha ..………….t/ha

D6. What is the average pasture height maintained in the paddock, in normal (fair) years?

Site 1	*Site 2*
………………..cm	*..…………..cm*

D7. How frequently does pasture condition determine stocking rates on the paddock?

	Site 1	*Site 2*
Never	☐	☐
Rarely (less than 10% of time)	☐	☐
Sometimes (10–50% of time)	☐	☐
Frequently (51–90% of time)	☐	☐
Always (greater than 90% of time)	☐	☐

D8. a) Does groundcover determine total destocking of the paddock?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

b) If yes, at what percentage of groundcover is the paddock completely destocked?

Site 1: ☐☐☐ or …… ……..t/ha *Site 2:* ☐☐☐ or ……… …..t/ha

D9. How frequently is the paddock destocked if the soil is wet for extended periods (ie, several days)?

	Site 1	*Site 2*
Never	☐	☐
Rarely (less than 10% of time)	☐	☐
Sometimes (10–50% of time)	☐	☐
Frequently (51–90% of time)	☐	☐
Always (greater than 90% of time)	☐	☐

D10. How frequently is the paddock destocked during periods of grass seeding or bud formation of pasture?

	Site 1	*Site 2*
Never		
Rarely (less than 10% of time)	☐	☐
Sometimes (10–50% of time)	☐	☐
Frequently (51–90% of time)	☐	☐
Always (greater than 90% of time)	☐	☐

D11. Please list up to five of the main pasture species currently in the paddock:

Site 1	*Site 2*
1.………………………………………...	1.………………………………………...
2.………………………………………...	2.………………………………………...
3.………………………………………...	3.………………………………………...

4.………………………………………... 5.………………………………………...	4.………………………………………... 5.………………………………………...

D12. Currently, what proportion (by area) of pasture species on the paddock are native?

Site 1	*Site 2*
☐☐☐ Native	☐☐☐ Native

D13. Currently, what proportion (by area) of pasture species on the paddock is perennial?

Site 1	*Site 2*
☐☐☐ *Perennial*	☐☐☐ *Perennial*

D14. How has pasture on the paddock been renovated over the past five years?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Sowing with multiple cultivation	☐	☐	☐	☐
Direct drill seeding	☐	☐	☐	☐
Broadcast seeding	☐	☐	☐	☐
Renovation not required or natural regeneration	☐	☐	☐	☐
Not renovated (but may be desirable)			☐	☐
	☐	☐		
Other *(please specify)* ………………………………………………...	☐	☐	☐	☐

D15. If the paddock has been sown with pasture species, when did this last occur?

Site 1	*Site 2*

SECTION E: HORTICULTURE AND VITICULTURE

E1. Is the paddock containing the site used for horticulture (tree crops) or viticulture (if vegetables are grown, refer to section C: Cropping)?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to Section F.

E2. Please record if known, the approximate yield of the main products grown on the paddock over the past five years in table (a) below. Please specify if products have 'failed' or 'not been harvested', in the yield column. **Alternatively**, record typical approximate yields in recent years with 'fair' conditions in table (b).

(a)

Year of Harvest	*Site 1*		*Site 2*	
	Product	Approx Yield (specify units)	Product	Approx Yield (specify units)
2008				
2007				

2006				
2005				
2004				

(b)

Site 1		*Site 2*	
Crop	Approx yield in recent years with 'fair' conditions	Crop	Approx yield in recent years with 'fair' conditions

	(specify units)		(specify units)
………………………	………………	………………………	………………
………………………	………………	………………………	………………
………………………	………………	………………………	………………
………………………	………………	………………………	………………
………………………	………………	………………………	………………

E3. What is the predominant method of harvesting?

	Site 1	*Site 2*
Hand picked	☐	☐
Mechanical (vibration)	☐	☐
Other *(please specify)*		
………………………………………………...	☐	☐

E4. What is the type of groundcover between rows?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Sown pasture	☐	☐	☐	☐
Volunteer plants	☐	☐	☐	☐
Other crops	☐	☐	☐	☐
Bare soil	☐	☐	☐	☐
Mulch	☐	☐	☐	☐
Other *(please specify)*				
………………………………………………...	☐	☐	☐	☐

E5. How is plant growth between rows controlled?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Plant growth is not controlled	☐	☐	☐	☐
Soil cultivation	☐	☐	☐	☐
Herbicides	☐	☐	☐	☐
Grazing	☐	☐	☐	☐
Mowing/slashing	☐	☐	☐	☐
Other *(please specify)*				
………………………………………………...	☐	☐	☐	☐

E6. What is the minimum percentage of groundcover you aim to maintain between rows?

	Site 1	*Site 2*
Less than 25%	☐	☐
25–50%	☐	☐
51–70%	☐	☐
Greater than 70%	☐	☐

SECTION F: COMMERCIAL FORESTRY

F1. Is the site being used for commercial forestry operations?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to Section G.

Please note: if the site is primarily a windbreak, tree lot within a farm paddock, a mine site regeneration area, a natural forest maintained for non-commercial reasons or regrowth go to Section G.

F2. What is the predominant forest type?

	Site 1	*Site 2*
Exotic plantation	☐	☐
Native hardwood plantation	☐	☐
Native hardwood forest	☐	☐
Other *(please specify)*		
………………………………………………...	☐	☐

F3. For plantations, in what year was the current rotation established?

Site 1	*Site 2*

F4. What was the method of ground preparation for the latest rotation of the forestry operation?

	Site 1 primary	*Site 2 secondary*	*Site 2 primary*	*Site 2 secondary*
Windrow and burning of residual vegetation	☐	☐	☐	☐
Rip and contour mound soil	☐	☐	☐	☐
Rip and rough stack residue	☐	☐	☐	☐
Rip only	☐	☐	☐	☐

Rip and burn residue	☐	☐	☐	☐
Burn residue only	☐	☐	☐	☐
Remove trash from area	☐	☐	☐	☐
Chip and mulch	☐	☐	☐	☐
None	☐	☐	☐	☐
Other *(please specify)*				
…………………………………………………	☐	☐	☐	☐

F5. How is plant growth between trees controlled in the first few years after site preparation?

	Site 1 primary	*Site 1 secondary*	*Site 2 primary*	*Site 2 secondary*
Plant growth not controlled	☐	☐	☐	☐
Soil cultivation	☐	☐	☐	☐
Herbicides	☐	☐	☐	☐
Grazing	☐	☐	☐	☐
Mowing/slashing	☐	☐	☐	☐
Other *(please specify)*				
………………………………………………....	☐	☐	☐	☐

F6. What is the current type of groundcover between trees?

	Site 1 primary	*Site 2 secondary*	*Site 2 primary*	*Site 2 secondary*
Sown pasture	☐	☐	☐	☐
Volunteer plants	☐	☐	☐	☐
Plant leaf litter/mulch	☐	☐	☐	☐
Bare soil	☐	☐	☐	☐
Other *(please specify)*				
………………………………………………....	☐	☐	☐	☐

F7. What is the normal groundcover percentage over the area?

	Site 1	*Site 2*
>70%	☐	☐
51–70%	☐	☐

25–50%	☐	☐
<25%	☐	☐

Note: for fertiliser and conditioner use, refer to Section B.

F8. What form of harvesting is practiced?

	Site 1	*Site 2*
Thinning	☐	☐
Specify thinning type eg,1 row in 4 or selective	………………………………….	………………………………...
Selective logging of mature trees	☐	☐
Extensive logging in compartments or coups	☐	☐
Clear felling of compartments or coups	☐	☐
Other *(please specify)* …………………………………………………	☐	☐

F9. What harvesting methods/equipment are used?

	Site 1 primary	*Site 1 secondary*		*Site 2 primary*	*Site 2 secondary*
Chain saw	☐	☐		☐	☐
Harvester	☐	☐		☐	☐
Forwarder/skidder	☐	☐		☐	☐
Snigged to log landing or dump	☐	☐		☐	☐
Other *(please specify)* …………………………………………………	☐	☐		☐	☐

F10. What is the average width (m) between the edge of operations and the top of the drainage line bank?

Site 1	*Site 2*

F11. Do you have a harvest management plan in place?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

F12. Were the tracks designed by a forest/road engineer?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

F13. Are rollover banks (eg water bars or 'whoa boys') and other water erosion control management items in place as recommended?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

F14. What is the maximum spacing of rollover banks (m)?

Site 1	*Site 2*

F15. What proportion of the total ground surface area is disturbed by heavy vehicle and equipment use during harvesting operations (including log dumps, roads and tracks)?

Site 1: ☐☐☐ *Site 2:* ☐☐☐

F16. a) Is the area being grazed by livestock?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to F17.

b) If yes, for what purpose?

	Site 1	Site 2
Uncontrolled access	☐	☐
Light supplementary feed	☐	☐
Stock shelter	☐	☐
Fire hazard reduction	☐	☐
Reduce competition for tree seedlings	☐	☐
Other *(please specify)*		
…………………………………………………	☐	☐

c) Does the factor of groundcover influence destocking of the site?

	Site 1	Site 2
Yes	☐	☐
No	☐	☐

d) If yes, at what percentage of grass cover is the site destocked?

Site 1: ☐☐☐ *Site 2:* ☐☐☐

e) Extent of stock exclusion during plantation rotation?

	Site 1	Site 2
No stock exclusion	☐	☐
During plant establishment (1 to 3 years)	☐	☐
Duration of rotation	☐	☐
Other *(please specify)*		
	☐	☐

F17. Is there significant grazing or disturbance by native wildlife (kangaroos, etc.) and/or feral animals (rabbits, pigs, etc) to the extent of significantly impacting on groundcover?

	Site 1	Site 2
Yes	☐	☐
No	☐	☐

F18. a) When was the last wildfire through the area (year)?

Site 1	*Site 2*

b) When was the last controlled burn?

Site 1	*Site 2*

Note: other questions of relevance to forestry are in Section B: Land and Soil Management (B2, 3, 5, 6)

SECTION G: WOODED AREA

This refers to areas with extensive tree and/or shrub cover with generally low intensity use, but not commercial forests. They may be managed entirely as natural habitat with full exclusion of stock or they may be accessible to stock for shelter or camps, but contain little formal pasture.

G1. Does the monitoring area belong in this category?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to final comments at the end of the survey.

If yes, but is managed for: Pasture for formal grazing purposes (ie, more than stock shelter) please return to Section D: Grazing.

Forestry purposes, please return to Section F: Commercial Forestry

G2. Which of the following best describes the native vegetation of this area?

	Site 1	*Site 2*
Natural remnant	☐	☐
Revegetated	☐	☐
Regrowth	☐	☐
Mixture	☐	☐
Other *(please specify)* ……………………………………………...	☐	☐

G3. What is this land used for?

	Site 1 primary	*Site 1 secondary*	*Site 1 other*	*Site 2 primary*	*Site 2 secondary*	*Site 2 other*
Maintaining biodiversity	☐	☐	☐	☐	☐	☐
Stock shelter	☐	☐	☐	☐	☐	☐
Windbreak	☐	☐	☐	☐	☐	☐

Salinity control	☐	☐	☐	☐	☐	☐
Timber for farm use	☐	☐	☐	☐	☐	☐
Aesthetic	☐	☐	☐	☐	☐	☐
Restoration of disturbed site (eg mined areas)	☐	☐	☐	☐	☐	☐
Unused/no purpose	☐	☐	☐	☐	☐	☐
Other *(please specify)* ………………………………..	☐	☐	☐	☐	☐	☐

G4. Is the area fenced? If no, go to G7.

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

G5. How effective is exclusion of livestock and feral animals from the area (by fencing)?

	Site 1	*Site 2*
No exclusion	☐	☐
Partial exclusion	☐	☐
Total exclusion	☐	☐

G6. How frequently are fences inspected and maintained?

	Site 1	*Site 2*
More than once per year	☐	☐
Once per 1 to 2 years	☐	☐
Less than once per 2 years	☐	☐

G7. If the area has been planted, in which year(s) did this occur?

Site 1	*Site 2*

G8. a) Do you allow grazing on the area for specific purposes?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

If no, go to G9.

b) If yes, for what purpose?

	Site 1	*Site 2*
Light supplementary feed	☐	☐
Stock shelter	☐	☐
Fire hazard reduction	☐	☐
Other *(please specify)*		
…………………………………………………	☐	☐

c) Does groundcover determine destocking of the area?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

d) If yes, at what percentage of groundcover is the area destocked?

Site 1: ☐☐☐ *Site 2:* ☐☐☐

G9. a) Is there significant grazing or disturbance by native wildlife (kangaroos, etc.) or feral animals (rabbits, pigs, etc.) to the extent of significantly impacting on groundcover?

	Site 1	*Site 2*
Yes	☐	☐
No	☐	☐

b) If yes, what are the main animals?

Site 1	Site 2

G10. What is the normal groundcover percentage over the area?

	Site 1	Site 2
>70	☐	☐
51–70%	☐	☐
25–50%	☐	☐
<25%	☐	☐

G11. a) When was the last wildfire through the area?

Site 1	*Site 2*

b) When was the last controlled burn?

Site 1	*Site 2*

Do you have any further comments relating to management or condition of the area containing the site?

(eg impacts from recent bushfires or locust, grasshopper or other insect plagues; any innovative practices that are unusual for your type of land-use)

…… …… …… …… …… …… …… ………………………………

Do you have any comments relating to this survey or the MER program?

…… …… …… …… …… ……

Thankyou for your contribution.

If survey has not been collected by a field team member, please return to:

MER Monitoring Team
Soil Science Section
NSW Department of Environment, Climate Change and Water
PO Box 3720
PARRAMATTA NSW 2124

www.environment.nsw.gov.au