3rd Edition

LAND USE CAPABILITY SURVEY HANDBOOK

A New Zealand handbook for the classification of land

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Land Use Capability Survey Handbook 3rd Edition

The renewed interest by land managers in developing sustainable management systems for our productive land has led to the reviewed and updated Land Use Capability Survey Handbook. This handbook replaces the second edition printed in 1971 and reprinted in 1974. It is a welcome addition to the professional training capability available for land managers, as the second edition has long been out of print.

This edition of the handbook remains faithful to the concepts documented in the second edition. However, a systematic review of each component of the classification has been undertaken by a team of scientists, some involved with the preparation of the New Zealand Land Resource Inventory, a country-wide database prepared between 1975 and 1998. This database provided national Land Use Capability assessment standards. A panel of regional council land management advisors experienced in Land Use Capability assessments has participated in the process through workshops and reviews. The combination of science and application has ensured the classification system remains operationally based, contains more quantitative rigour, and as a consequence has ensured the system will remain relevant well into the future.

The first edition published in 1969 was prepared to provide national standards, as these were the basis for central government's financial assistance to farmers for erosion control works. Currently many regional and unitary councils provide financial assistance to farmers to protect their soil resource and biodiversity. Central government is renewing its interest in protecting the national soil resource from the effects of flood and drought. Both these initiatives benefit from a nationally consistent land classification system based on physical sustainability and applied by land managers.

It is gratifying to see the result of a rigorous review of the land use capability system in this third edition of the handbook. The challenge remains to ensure it is used consistently throughout New Zealand as the basis for planning, and advancing sustainable land use.

Garth Eyles

CONTENTS

INTRODUCTION

This handbook introduces the reader to the methods and standards of the Land Use Capability (LUC) system. This system has been used in New Zealand to help achieve sustainable land development and management on individual farms, in whole catchments, and at the district, region, and the national level since 1952.

The **LUC system** has two key components. Firstly, **Land Resource Inventory** (LRI) is compiled as an assessment of physical factors considered to be critical for long-term land use and management. Secondly, the inventory is used for **LUC Classification**, whereby land is categorised into eight classes according to its long-term capability to sustain one or more productive uses.

National and international experience has shown that the classification of land according to its capability for long-term production, based on its physical limitations and site-specific management needs, provides the most reliable basis on which to promote sustainable land management.

The Handbook is divided into five sections. Section 1 provides a concise overview of the LUC Classification. Section 2 outlines the standards and methods for preparing LRI, including significant updates for the five key factors of rock type, soil, slope, erosion and vegetation cover. How to apply the LUC Classification is detailed in Section 3, along with improved discussion on LUC classes, subclasses, units and suites. Existing practitioners should take careful note of the revised LUC class definitions. Section 4 covers survey procedures, while the final section provides farm, district and regional examples of LUC applications, to help demonstrate the practicality and utility of the system.

The importance of robust and objective evaluation of New Zealand's land resources in planning and the promotion of sustainable land management can be emphasised in two important ways. Firstly, the value of New Zealand's annual agricultural and wood exports in 2007 totalled $13.45 billion and $2.25 billion respectively (NZETS 2007). To maintain and increase this productivity requires sustainable land management, the primary objective of the LUC system. Secondly, land management requires an assessment technique that will provide planners, policy developers, and regulatory teams with confidence that their land use and management decisions are based on a transparent robust assessment and good science, and one that is able to withstand close scrutiny through the legal system.

Plate 1: (opposite) Example distribution of Land Resource Inventory and Land Use Capability units on the landscape – lower mid-Awatere Valley, Marlborough (IHL). See page 132 for photo credits.

1. BASIS OF THE LUC CLASSIFICATION

The Land Use Capability (LUC) Classification is defined as *a systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production.* Capability is used in the sense of *suitability for productive use or uses* after taking into account the physical limitations of the land.

Productive capacity depends largely on the physical qualities of the land, soil and the environment. These physical qualities are frequently far from ideal. Differences between ideal and actual may be regarded as limitations imposed by the physical qualities of the soil, and the environment. These limitations affect productivity, the number and complexity of corrective practices needed, and the intensity and manner of land use. Limitations include susceptibility to erosion, steepness of slope, susceptibility to flooding, liability to wetness or drought, salinity, depth of soil, soil texture, structure and nutrient supply and climate.

Assessment of land for long-term sustained production is based on an interpretation of the physical information in a Land Resource Inventory (LRI), which is compiled from a field assessment of rock types, soils, landform and slopes, erosion types and severities, and vegetation cover. Land Resource Inventory is supplemented with information on climate, flood risk, erosion history and the effects of past practices.

1.1 Categories of the LUC Classification

The LUC Classification has three components – **LUC Class**, **LUC Subclass**, and **LUC Unit** – each of which is represented by a number or symbol. Figure 1 illustrates the relationship between the three components of the LUC classification (for specific details see Section 3).

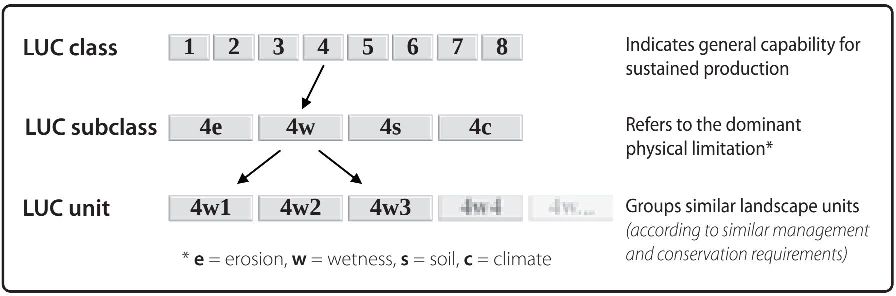


Figure 1: Components of the Land Use Capability Classification.

1.1.1 Land Use Capability Class

The *LUC Class* is the broadest grouping of the capability classification. It is an assessment of the land's capability for use, while taking into account its physical limitations and its versatility for sustained production.

There are eight classes, denoted by Arabic numerals, with limitations to use increasing, and versatility of use decreasing, from LUC Class 1 to LUC Class 8 (Figure 2). Arabic numerals are recommended over traditional Roman numerals (i.e. LUC I, II, III… VIII) to promote consistency and ease of database management.

Increasing limitations to use ↓

Decreasing versatility of use ↓

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
1	High	High	High	Multiple use land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or forestry land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Conservation land

Figure 2: Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8 (modified from SCRCC 1974). † Includes vegetable cropping.

LUC Classes 1 to 4 are suitable for arable cropping (including vegetable cropping), horticultural (including vineyards and berry fields), pastoral grazing, tree crop or production forestry use. Classes 5 to 7 are not suitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry use, and in some cases vineyards and berry fields. The limitations to use reach a maximum with LUC Class 8. Class 8 land is unsuitable for grazing or production forestry, and is best managed for catchment protection and/or conservation or biodiversity.

1.1.2 Land Use Capability Subclass

The *LUC Subclass* is a subcategory of the LUC Class through which the main kind of physical limitation or hazard to use is identified. Four limitations are recognised:

‘**e**’ **erodibility** – where susceptibility to erosion is the dominant limitation.

‘**w**’ **wetness** – where a high water table, slow internal drainage, and/or flooding constitutes the dominant limitation.

‘**s**’ **soil** – where the dominant limitation is within the rooting zone. This can be due to shallow soil profiles, subsurface pans, stoniness, rock outcrops, low soil water holding capacity, low fertility (where this is difficult to correct), salinity or toxicity.

‘**c**’ **climate** – where the climate is the dominant limitation. This can be summer drought, excessive rainfall, unseasonal or frequent frost and/or snow, and exposure to strong winds or salt spray.

1.1.3 Land Use Capability Unit

The *LUC Unit* is the most detailed component of the LUC classification. LUC Subclasses can be subdivided into a number of LUC Units. LUC Units group together areas where similar land inventories have been mapped, which require the same kind of management, the same kind and intensity of conservation treatment, and are suitable for the same kind of crops, pasture or forestry species, with similar potential yields. LUC Units are identified by Arabic numerals at the end of the LUC code. An example of the LUC nomenclature is ‘6e1’, where ‘6’ is the LUC Class, ‘6e’ is the LUC Subclass, and ‘6e1’ is the LUC Unit. Within LUC classifications, LUC Units are arranged (within LUC Subclasses) in order of decreasing versatility for use and increasing degree of limitation to use.

1.1.4 Land Use Capability Suite

The traditional numerical ranking of LUC Units, based on decreasing versatility and capability, as shown in the New Zealand Land Resource Inventory* (NZLRI) LUC extended legends (e.g. Fletcher 1981), gives no indication of the relationships between LUC Units in the landscape. To enable these relations to be better understood, related units can be arranged into groups, called *LUC Suites* defined as a grouping of LUC Units which, although differing in capability, share a definitive physical characteristic which unites them in the landscape (e.g. Blaschke 1985a).

* The NZLRI (NWASCO 1975-79, 1979; NWASCA 1986a, b) is a spatial database and a series of map worksheets that describes Land Resource Inventory and Land Use Capability for New Zealand at regional scales (1:50,000 and 1:63,360).

1.2 Scale of mapping and classification

Scale is an important consideration when mapping LRI, when classifying LUC, and when making use of existing LRI and LUC information.

Mapping scale is usually based on the smallest area of interest. For farm LRI and LUC this is often the smallest area of land that can be managed or treated differently (e.g. two different soils within a paddock, two erosion severities occurring on the same slope). These 'smallest areas' translate to a recommended farm-mapping scale of between 1:5,000 and 1:15,000 depending on management intensity (Table 1).

Table 1: Suggested mapping scales for LRI survey and LUC classification (after Manderson & Palmer 2006).

Smallest area of interest	Corresponding scale*	Common applications
10 m^2	1:500	Horticulture, viticulture, localised riparian studies
0.1 ha	1:5,000	Horticulture, viticulture, arable, intensive pastoral
0.4 ha	1:10,000	Arable, pastoral
1 ha	1:15,000	Pastoral, catchment studies
5 ha	1: 35,000	Extensive pastoral, catchment studies, forestry surveys
10 ha	1:50,000	District and regional studies

** See Table 18 (Page 100) for scales common to large and extensive surveys.*

Detailed scales are less suitable for regional mapping projects that often involve extensive areas. In such cases a 1:50,000 scale is often more appropriate. This is equivalent to a 10 ha 'smallest area', which is sufficient to capture major soils and landform types.

Scale is also important when using LRI and LUC map information in Geographic Information Systems (GIS). Such systems can readily rescale the information beyond its original scale of collection. Significantly enlarging the scale can produce unreliable and misleading results, or result in information that is at best nonsense (Hewitt & Lilburne 2003; Manderson & Palmer 2006).

As a general rule, LRI and LUC information should not be significantly enlarged beyond the scale at which it was originally collected.

2. INVENTORY OF PHYSICAL FACTORS

An understanding of the physical nature of the landscape is a requirement for sustainable land use and water management. However, no single parameter can be used in isolation to adequately describe the limitations and potentials of land.

The LUC system uses Land Resource Inventory (LRI) as a basis for assessing a minimum of five primary physical factors considered to be critical for long-term sustainable land use. The five factors include:

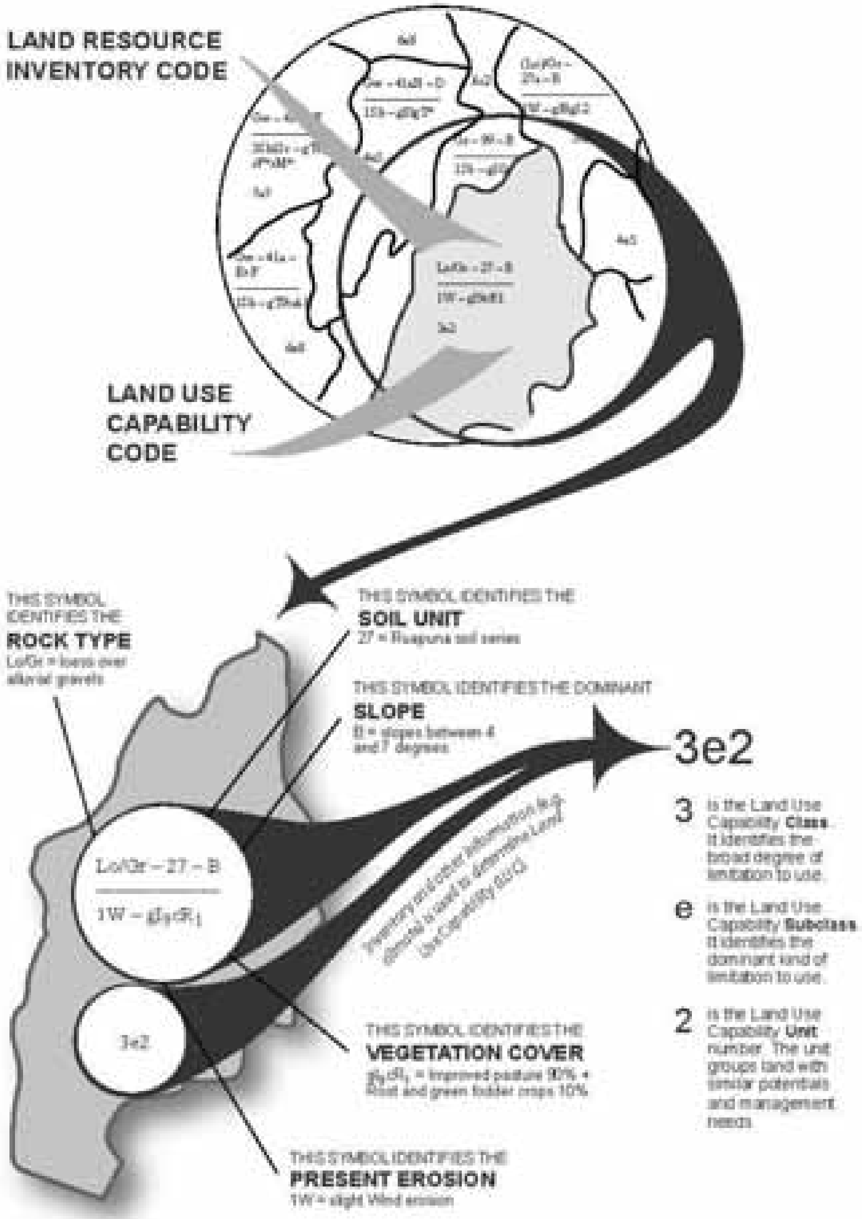
1. Rock type
2. Soil
3. Slope angle
4. Erosion type and severity
5. Vegetation cover

These physical factors vary in their relative importance in different areas, but all have some influence, either individually or in combination, on long-term land use potential. By using these factors, together with an understanding of the climate and the experience gained from past land use, the capability of the land for permanent and sustained production can be assessed.

The five factors are mapped simultaneously within the limitations of scale using a homogeneous map unit method (Eyles 1977). A new map unit is drawn whenever one of the primary physical factors alters significantly, creating a series of interlocking homogeneous areas. A certain level of variability is present within every map unit. The 'art' of this form of appraisal lies in judging the degree of variability that is acceptable. In making this judgement, the impact of this variability on management and outcomes should be considered. For some applications, especially when mapping at farm scales, additional factors like aspect, elevation, and distance to watercourse may also be relevant and would be recorded where appropriate.

Traditionally, LRI is recorded as a code or formula, together with the LUC classification (Figure 3 and Plate 1).

Figure 3: (opposite) Coded Land Resource Inventory recorded as a 'formula', and the accompanying Land Use Capability code (adapted from NWASCO 1979).


LAND RESOURCE INVENTORY CODE
LAND USE CAPABILITY CODE
THIS SYMBOL IDENTIFIES THE
ROCK TYPE
THIS SYMBOL IDENTIFIES THE
SOIL UNIT
THIS SYMBOL IDENTIFIES THE DOMINANT
SLOPE
3e2
3 is the Land Use Capability Class. It identifies the broad degree of limitation to use.
e is the Land Use Capability Subclass. It identifies the dominant kind of limitation to use.
2 is the Land Use Capability Unit number. The unit groups land with similar potentials and management needs.
THIS SYMBOL IDENTIFIES THE
VEGETATION COVER
THIS SYMBOL IDENTIFIES THE
PRESENT EROSION
3e2

2.1 Rock type

Rock type has a major influence on slope, soil stability and natural fertility in New Zealand's hill and mountain lands. Cover deposits such as tephra and loess also influence soil fertility and erosion susceptibility where they occur.

A rock type classification based on erosion susceptibility and physical characteristics that are relevant to soil conservation and land use planning was developed for the NZ Land Resource Inventory (Lynn & Crippen 1991), and provides the standard for this handbook. The classification has four objectives:

1. To group rock types that have similar erosion susceptibilities and characteristics.
2. To concentrate on those rock types that directly influence land surface morphology, and therefore land use.
3. To distinguish rock types that can be recognised and mapped by soil conservators, land managers and earth scientists, with limited formal geological training.
4. To provide information on rock types that can be readily understood and applied by planners and land managers.

Because of these objectives, the definition and use of some terms do not strictly conform to standard geological usage. For example, because many different tephra formations and their component members were considered to have similar erosion characteristics, these were grouped into a manageable number of rock types. At detailed mapping scales the component members may be mapped separately.

The NZLRI rock type classification was developed from separate North and South Island classifications (Crippen & Eyles 1985; Lynn 1985) used in first edition NZLRI mapping. This was later correlated into one classification for second edition mapping (Table 2). Lynn & Crippen (1991) outline the standards and provide detailed definitions for each rock type category.

Plate 2: Limestone rock type exhibiting prominent dip and scarp slopes, Weka Pass, North Canterbury (IHL).

Table 2: Rock type symbols, names and prefixes used in the NZLRI rock type classification.

Igneous rocks			
1. Extremely weak to very weak igneous rocks			
Ng	Ngauruhoe tephra	Kt	Kaharoa and Taupo ashes
Rm	Rotomahana mud	Mo	Ashes older than Taupo ash
Ta	Tarawera tephra	La	Lahar deposits
Sc	Scoria	Vu	Extremely weak altered volcanics
Tp	Taupo and Kaharoa breccia and pumiceous alluvium	Ft	Quaternary breccias older than Taupo breccia
Lp	Pumiceous lapilli		
2. Weak to extremely strong igneous rocks			
Vo	Lavas and welded ignimbrites	In	Ancient volcanics
Vb	Indurated volcanic breccias	Gn	Plutonics
Tb	Indurated fine-grained pyroclastics	Um	Ultramafics
Sedimentary rocks			
1. Very loose to compact (very soft to stiff) sedimentary rocks			
Pt	Peat	Cl	Coarse slope deposits
Lo	Loess	Gl	Glacial till
Wb	Windblown sand	Uf	Unconsolidated clays and silts
Af	Fine alluvium	Us	Unconsolidated sands and gravels
Gr	Alluvial gravels		
2. Very compact (very stiff) to weak sedimentary rocks			
Mm	Massive mudstone	Sb	Bedded sandstone
Mb	Bedded mudstone	Cw	Weakly consolidated conglomerate
Mf	Frittered mudstone	Mx	Sheared mixed lithologies
Me	Bentonitic mudstone	Ac	Crushed argillite association of rocks
Sm	Massive sandstone		
3. Moderately strong to extremely strong sedimentary rocks			
Ar	Argillite	Cg	Conglomerate and breccia
Si	Indurated sandstone	Li	Limestone
Gw	Greywacke association of rocks		
Metamorphic rocks			
Sx	Semi-schist	Gs	Gneiss
Sy	Schist	Ma	Marble
Perennial ice and snow			
I	Perennial ice and snow		

Prefixes

p Rock type is present only in patches, or is of localised significance (e.g. pAf = patchy fine alluvium). Used for alluvium, tephra and loess when coverage is between 20% to 75% of map polygon area (<20% is not recorded; >75% is recorded as totally covered).

w Significant degree and depth of weathering such that the rock's physical characteristics are notably different from its unweathered characteristics (wGw = weathered greywacke).

c The rock type is crushed and sheared (e.g. cGw = crushed and sheared greywacke).

Combining symbols

/ Top rock overlying one base rock (e.g. Lo/Sm = loess over massive sandstone). The top rock is recorded first, and a maximum of two symbols can be used in a single code.

+ Two or more rock types present (e.g. Af+Pt = fine alluvium and peat). The dominant rock type is recorded first, and a maximum of two symbols can be used in a single code.

* a) Top rock overlying two base rocks. Used in conjunction with the '/' symbol (e.g. Lo/Mb*Sb = loess overlying both banded mudstone and sandstone).
  b) Two top rocks overlying one base rock e.g. Af*Lo/Gr = fine alluvium and loess over alluvial gravels.

2.1.1 Assessing rock type

Knowledge of the rock types and geology of the study area should firstly be gained from available geological maps and the NZLRI. Stereoscopic interpretation of aerial photographs can be used to tentatively relate landform and landscape processes to the geology. These should be checked and complemented by field observation. For farm-level mapping, rock types should always be identified in the field.

The main sources of published rock type information include geological maps and the NZLRI. Geological maps have been produced by the Institute of Geological and Nuclear Sciences (www.gns.cri.nz), and its predecessor, the NZ Geological Survey, in particular the *Geological Map of New Zealand* series, at various scales (Table 3). Most are based on special classification systems (e.g. by geological age, stratification, formations), and need to be interpreted into rock types.

Table 3: Sources of rock type maps and information.

Geological and Nuclear Sciences (GNS) map series		
Name	**Scale**	**Coverage**
QMAP	1:250,000	Complete NZ coverage scheduled for 2009
Geological maps	Mostly 1:50,000	Limited coverage
New Zealand Geological Survey (NZGS) maps		
Geological maps of New Zealand (1959–1968)	1:250,000	National coverage
Geological maps (1979–1994)	1:50,000	Limited coverage
Geological maps (1960–1989)	1:63,360	Limited coverage
New Zealand Land Resource Inventory (NZLRI)		
NZLRI Worksheets	1:63,360 1st edition 1:50,000 2nd edition	National coverage except Stewart Island
NZLRI Database	1:50,000	National coverage except Stewart Island

The NZLRI database and published worksheets record rock type at scales of 1:50,000 and 1:63,360. These can be directly applicable to new LRI mapping at an equivalent scale, or as a reference for rock types that are likely to be encountered during more detailed survey.

2.2 Soil

The soil factor is one of the more difficult inventory factors to assess and source information. Much of New Zealand's published soil information is patchy and varies in age, scale and quality. Detailed surveys are generally restricted to the productive lowlands (1:10,000 to 1:63,360 scales), while only reconnaissance maps and general information are available for much of the hill and high country.

The ability to identify, describe and map soils can therefore be an important skill in LRI assessment.

2.2.1 Published soil information

Published soil information should be used if it can be sourced at an appropriate scale. The main source is the maps and publications of Landcare Research (www.landcareresearch.co.nz) and its predecessor, the Department of Scientific and Industrial Research (DSIR) Soil Bureau. Councils and universities may also maintain their own soil information libraries and databases. Common soil information resources are listed in Table 4.

Table 4: Common soil information resources in New Zealand.

Soil surveys		
Name	**Scale**	**Comments**
Published soil maps	1:2,000 to 1:253,440	Maps printed at different scales from 1930 onwards, which collectively provide partial coverage of NZ. Maps more detailed than 1:100,000 concentrate on lowland areas. National coverage at 1:253,440. Full lists provided in Wallace *et al*. 2000 (South Island) and Clayden *et al*. 1997 (North Island).
Reconnaissance and provisional soil maps	Often 1:63,360	Draft soil maps that may or may not have reached publication. Variable quality, coverage and availability.
Soil Fundamental Data Layers	1:50,000	Nationwide soils database developed from the NZLRI and published soil maps.
S-map	1:50,000	New nationally-consistent soils database currently being developed.
Land inventory surveys		
NZLRI (worksheets and database)	1:50,000 and 1:63,360	Liberal use of existing soil maps and some new mapping. Near nationwide coverage.
Catchment LRI/LUC	1:15,840 to 1:63,360	Occasional catchment surveys. Sporadic coverage within regions.
Farm LRI/LUC	1:5,000 to 1:25,000	Over 6,000 farm plans have been prepared in NZ since the 1950s, most based on LRI/LUC survey. Sporadic coverage, highest in erosion-prone areas. Can be difficult to source.
Other land inventories	1:50,000 to 1:100,000	King Country Land Use Study (NZMS 288), Land Inventory Survey County Series (NZMS 237), NZ Land Inventory (NZ 290). Patchy incomplete coverage.

2.2.2 Soil classification and naming conventions

New Zealand soil information is classified in terms of the old NZ Genetic Classification (Taylor & Pohlen 1962, 1968) or the more recent NZ Soil Classification (Hewitt 1998). General correlations are provided in Table 5.

Table 5: Correlation between NZ Genetic Classification and NZ Soil Classification (adapted from Molloy 1998).

NZ Soil Classification	NZ Genetic Classification	Defining characteristic
Allophanic Soils	Yellow brown loams	Dominated by allophane clay
Anthropic Soils	Anthropic soils	Man-made soils
Brown Soils	Mainly yellow brown earths (except northern YBEs) and some YB sands, BG loams and clays	Distinctive brown colouration due to good aeration characteristics
Gley Soils	Gley soils or gley recent soils	Waterlogged anaerobic soils
Granular Soils	Most brown-granular (BG) loams and clays	Distinctive granular peds and formed from well-weathered volcanics
Melanic Soils	Rendzinas, rendzic intergrades, and some brown-granular loams and clays	Distinctive rich dark topsoils with strong structural development often associated with limestone
Organic Soils	Organic soils	Formed from organic matter (e.g. peat)
Oxidic Soils	Strongly weathered red loams, brown loams, some BG loams and clays	Clayey soils dominated by oxides (rust)
Pallic Soils	Yellow grey earths	Pale and often dense subsoils
Podzol Soils	Podzols	Heavily leached acid soils with a distinctive pale-to-white horizon
Pumice Soils	Yellow brown pumice soils	Dominated by pumice
Raw Soils	Some recent soils, and some unclassed soils	Newly formed soils **without** distinct topsoils
Recent Soils	Recent soils	Young soils **with** distinct topsoils
Semiarid Soils	Brown grey earths	Formed in a semi-arid climate
Ultic Soils	Northern yellow brown earths, some podzols and some YB sands	Strongly weathered soils with clay-rich subsoils

Soil maps may also use the 'regional soil series' approach to grouping soils, where the **Series** describes a local soil (e.g. *Manawatu soils*), the **Soil Type** differentiates the soil by textural class (e.g. *Manawatu fine sandy loam*), and the **Phase** indicates a distinctive characteristic like landscape position, wetness, depth, or stoniness (e.g. *Manawatu fine sandy loam, mottled phase*).

Series and soil type names tend to find common usage amongst farmers and farm advisors, possibly because they represent local and easy to recognise references. However, the approach is not uniform throughout NZ, and should therefore be used with caution. Officially the 'regional soil series' approach is now limited to two components – Series and Phases – whereby the phase includes the textural class.

Series and phases may be superseded by a new soil mapping initiative, **S-map**, described as a revitalised effort in soil survey and soil database development (Lilburne *et al*. 2004, 2006; Hewitt *et al*. 2006). S-map aims to produce a consistent national soils database with a common national legend. The legend seeks to rationalise the many existing soil series into 'Families' and 'Siblings'.

2.2.3 Assessing unmapped soils

New soil assessments are required when there is no published soil information available at an appropriate scale. However, less detailed surveys may be used for reference purposes, and to give an idea of potential soils and soil–landform relationships.

For farm-level mapping, soil descriptions from existing soil surveys, reference to the NZLRI, together with detailed field observation of landform and landscape processes, rock type, regolith composition, and soil profile characteristics, can be used to delineate soil boundaries appropriate to the scale of mapping.

Several New Zealand soil manuals and handbooks are available to help with soil assessment. Taylor & Pohlen (1968) outline 'soil survey method' according to early standards. Milne *et al*. (1995) set out modern standards for describing soil profiles, while Hewitt (1998) provides criteria and standards for classifying soils using the NZ Soil Classification system. Manderson *et al*. (2007) provide an introductory guide to soil mapping for farmers.

Plate 3: The tephra mantle is a significant landscape-forming component in the Central North Island (SNZL).

2.2.4 Recording soil codes

In recognition of past, present and emerging soil naming systems, three alternative methods are recommended for recording the soil factor in LRI code.

1. Use codes from an existing published source, such as a local soil map (Figure 4).

Af – Cl – A
Ø – gI

*Figure 4: Soil code from an existing soil map. In this case the **Cl** represents the Clutha soil series as used in Beecroft et al. (1991).*

2. Use the NZ Soil Classification, ideally classifying soils down to the most detailed *soilform* category (Figure 5).

Af – RFW, Md, z, m – A
Ø – gI

Figure 5: Soil code from the NZ Soil Classification. The code translates to a Weathered Fluvial Recent, (deep) stoneless, silty, moderate permeability soil.

3. Use S-map *families* and *siblings* when they become available (Figure 6).

Af – Waim_9 – A
Ø – gI

*Figure 6: Soil code from S-map. Waim_9 refers to the 9th **Sibling** of the **Waimakariri Family** of soils.*

It should also be noted that some surveyors use their own coding systems while in the field, but later translate their codes for reporting purposes. This can be quicker as much of the referencing and correlation work can be done in the office.

Where no soil exists, or where there is significant bare rock or stone pavement present, the symbol **BR** or **+BR** is recorded. This may also include an estimate of bare rock cover (e.g. **BR**$_2$ indicates that there is a cover of 20% bare rock in the map unit).

2.3 Slope

Slope angle is measured from the horizontal in degrees, and the dominant slope within the map unit area is recorded as one of the following seven slope groups (Table 6).

Table 6: Slope groupings.

Slope Group	Slope angle (degrees)	Description	Typical examples
A	0–3°	Flat to gently undulating	Flats, terraces
B	4–7°	Undulating	Terraces, fans
C	8–15°	Rolling	Downlands, fans
D	16–20°	Strongly rolling	Downlands, hill country
E	21–25°	Moderately steep	Hill country
F	26–35°	Steep	Hill country and steeplands
G	>35°	Very steep	Steeplands, cliffs

Additional symbols that can be used

+	Compound slopes. This is used where more than one major slope group occurs in a unit. For example, D+E slopes means that slopes are mainly strongly rolling but the unit contains a significant area of land with moderately steep slopes.
/	Slopes which are borderline between two slope groupings are recorded in the form D/E, i.e. most slopes are 20–21 degrees.
‘	A dash to the top right of a slope symbol indicates the slopes are dissected. For example A′ indicates that the land is flat to gently undulating but is dissected by narrow entrenched gullies or drainage lines.
$^+$ or $^-$	Superscripts $^+$ and $^-$ are optional symbols to indicate to which end of the slope group the slope actually lies. For example, the symbol F^- indicates that the measured slope is closer to 26°, while F^+ would indicate that the slope is closer to 35°.

In the field the dominant slopes are measured by hand-held Abney level or clinometer, or estimated by eye. Slope angles can be calculated from a Digital Elevation Model (DEM) where one of suitable accuracy and precision is available.

A discussion of the commonly recognised critical slopes for specified activities is given in Appendix 1.

2.4 Erosion

Present and potential erosion are significant factors for land management and the environmental and economic sustainability of large tracts of New Zealand's landscape. Decisions about land use and management are often influenced by the assessment of erosion, and therefore it is important that the method of assessment is consistent and objective. The definitions of erosion types and erosion severity guidelines presented in this edition of the Handbook provide criteria to increase the objectivity and consistency of the assessment procedure.

The classification of erosion types follows closely that outlined in the 1st edition LUC Handbook (SCRCC 1969), which in turn was derived from Campbell (1951). Definitions of erosion types have been adapted from the NZLRI Erosion Classification (Eyles 1985). Both the classification and definitions are based on over 50 years of LUC survey and farm plan mapping, and have been developed to meet the needs of the NZ soil conservation community.

The erosion classification is descriptive and incorporates form and process, rather than a geotechnical, process-based classification. The term *landslide*, although widely used internationally by the geotechnical and scientific communities, is not used in this classification. It is a generic term that includes a wide range of failure processes, materials, sizes, and rates of movement. All of the mass movement erosion types in this classification are forms of landslide.

Table 7: Erosion types and symbols (for definitions see Appendix 2).

Category	Erosion types	Symbol	Optional prefixes (examples)
1. Surface erosion	Sheet	**Sh**	
	Wind	**W**	
	Scree	**Sc**	
2. Mass movement	Soil slip	**Ss**	s = shallow, d = deep, r = riparian
	Earthflow	**Ef**	s = shallow, d = deep, r = riparian
	Slump	**Su**	s = shallow, d = deep, r = riparian
	Rock fall	**Rf**	
	Debris avalanche	**Da**	
	Debris flow	**Df**	
3. Fluvial erosion	Rill	**R**	
	Gully	**G**	s = shallow, d = deep
	Tunnel gully	**T**	
	Streambank	**Sb**	
4. Deposition	Deposition	**D**	

Many factors need to be considered in assessing erosion severity, and these have been listed in order of importance for each erosion type. A new development has been the inclusion of areal extent guidelines in the assessment of mass-movement and fluvial erosion severity (Table 8). Estimates of areal extent provide a preliminary assessment of severity that can be finalized after considering the other listed factors. However, even with these guidelines, the judgement and experience of assessors are still important components in the assessment of erosion severity.

Erosion severity rankings follow the six-part ranking system originally set out in the LUC Survey Handbook and subsequently in Eyles (1985). Assessments of *present erosion* are made by observing erosion in the field and/or interpreting stereo-pairs of aerial photographs. Erosion is defined as 'present' where erosion surfaces are still bare of vegetation. Revegetated erosion scars, while not included in the assessment of present erosion, can indicate *erosion potential*.

Present erosion is assessed for each polygon/map unit, while potential erosion is assessed for each LUC unit. In many cases potential erosion helps to decide Land Use Capability. The assessment criteria used for present erosion are also used to assess potential erosion, but for potential erosion consideration is also given to predominant land use, and the magnitude and frequency of erosion-causing events. For a comprehensive review of various erosion assessment techniques used in New Zealand since 1945, see Lambrechtsen & Hicks (2001). The distribution and severity of present soil erosion as mapped in the NZLRI is summarised by Eyles (1983).

A separate erosion severity is assessed for each erosion type identified within each polygon/map unit. For example, the erosion code **2Ss 1G 1Sh** would read as *moderate soil slip, slight gully and slight sheet erosion.*

2.4.1 Erosion types

Thirteen erosion types and one deposition category are recognised (Table 7). These are grouped into four major categories:

1. **Surface erosion** involves the movement of a thin layer of particles across the ground by water, wind or gravity.
2. **Mass movement erosion** includes a wide range of erosion types where material moves down slope as a more-or-less coherent mass under the influence of gravity.
3. **Fluvial erosion** involves the removal of material by channelised running-water.
4. **Deposition** is a special category concerning the accumulation of waterborne material across large areas (e.g. silt deposition after flooding).

Full definitions for each erosion type are provided in Appendix 2.

2.4.2 Erosion symbol prefixes

Prefixes can be used to more fully describe the type of erosion (Table 7), or to include supplementary information relevant to a specific project. For example, erosion that has an off-site impact by delivering sediment and nutrients directly to watercourses can be identified by a prefix ‘r’ for riparian (e.g. **rSs** indicates riparian soil slip, while **rEf** indicates riparian earthflow).

Prefixes can also be used to denote whether soil slip, earthflow, slump and gully erosion is shallow (s) or deep (d). It should be noted that the ‘earth slip’ erosion type used in previous editions has been superseded by *deep soil slip* erosion (**dSs**). See Appendix 2 for more details.

If required, information such as shape, location or cause (e.g. tracking, earthworks) of features may also be recorded in this way. Examples are given under Additional information (Section 2.4.7).

2.4.3 Erosion severity for SURFACE EROSION

Surface erosion types comprise **sheet**, **wind** and **scree**. Severity ranking of each is partly based on areal extent of bare ground (Table 8) with the option of also including the extent of soil profile loss (see Table 9, p. 42). Other considerations are discussed according to each following erosion type.

Table 8: Guidelines for relating area eroded to erosion severity for each erosion type.

		Sheet, wind & scree	Soil slip	Debris avalanche	Debris flow	Rock fall
Symbol	**Severity**	***Area (%)***	***Area (%)***	***Area (%)***	***Area (%)***	***Area (%)***
Ɵ	negligible	<1	<0.5	<0.5	<0.5	<1
1	slight	1–10	0.5–2	0.5–2	0.5–2	1–5
2	moderate	10–20	2–5	2–5	2–5	5–10
3	severe	20–-40	5–10	5–10	5–10	10–20
4	very severe	40–60	10–20	10–20	10–20	20–30
5	extreme	>60	>20	>20	>20	>30

† Because earthflows, slumps and gullies can be large enough to occupy whole map units, areal extent is best assessed in terms of size (ha).

Table modified from Fletcher et al. (1994), Jessen et al. (1999), and Page et al. (2005).

2.4.3.1 Additional considerations for SHEET EROSION

Assessment of present erosion severity should also take into account:

- The assessed rate of soil profile loss (if known).
- Indicators of erosion such as exposure of tree roots, splash pedestals, build-up of soil upslope behind vegetative barriers and fresh colluvium deposited downslope.
- Slope angle and length.
- Soil properties (structure, texture, slaking, dispersion, etc.).
- The percentage of the area with bare rock resistant to erosion.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 4: Result of extreme sheet and wind erosion, Raglan Range, Marlborough (LCR).

Earthflow & Slump †	Rill	Gully †	Tunnel gully	Stream bank *		Deposition
Size (ha)	***Area (%)***	***Size (ha)***	***Area (%)***	***Reach (%)***	***Lateral (m)***	***Area (%)***
0	<0.5	0	<0.5	<1	<0.5	<1
<0.5	0.5–2	<0.05	0.5–2	1–5	0.5–1	1–10
0.5–1	2–5	0.05–0.5	2–5	5–10	1–2	10–20
1–5	5–15	0.5–1	5–10	10–25	2–3	20–40
5–10	15–30	1–5	10–20	25–40	3–5	40–60
>10	>30	>5	>20	>40	>5	>60

* Estimates of % reach and lateral erosion are made by assessing both banks. Where the proportion of lateral bank erosion and proportion of reach eroded do not match a severity category in the above guidelines, the proportion of lateral bank erosion is used to select the severity category, e.g. lateral bank erosion of >2 m and up to 3 m with >5−10% of reach eroded is classed as severe.

2.4.3.2 Additional considerations for WIND EROSION

Assessment of present erosion severity should also take into account:

- The assessed rate of soil profile loss (if known).
- Indicators of erosion such as exposure of tree roots, build-up of soil behind vegetative barriers and fresh deposition down-wind.
- Soil properties (structure, texture, etc.).
- The percentage of the area with bare rock resistant to erosion.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 5: Active wind erosion of cultivated soil, Strath Taieri Basin, Central Otago (LCR).

Plate 6: Wind-eroded topsoil from a winter feed crop deposited up to 70 cm deep along a fenceline, Maniototo Basin, Central Otago (LCR).

2.4.3.3 Additional considerations for SCREE EROSION

Assessment of present erosion severity should also take into account:

- The assessed rate of soil profile loss (if known).
- Surface microtopography, surface rock weathering colour and its distribution.
- Indicators of erosion such as exposure of tree roots, build-up of materials upslope behind vegetative barriers and fresh colluvium deposited downslope.
- Slope angle and length.
- The percentage of the area with bare rock resistant to erosion.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 7: Extreme scree erosion on LUC Class 8, Whale Stream, Waitaki Basin (IHL).

Plate 8: Scree erosion in the Harper-Avoca catchment, mid-Canterbury. Note the pattern and colour of surface weathering indicating relative activity, the 'armouring' with coarse debris at the base, and that little if any sediment is reaching the stream channel (LCR).

2.4.4 Erosion severity for MASS MOVEMENT EROSION

Mass movement erosion comprises **soil slip**, **debris avalanche**, **debris flow**, **rock fall**, **earthflow** and **slump**. For these erosion types the erosion severity ranking is based on a combination of factors (listed below for each erosion type), together with the areal extent of bare ground (Table 8). Other less common erosion types are not included in this classification, but may be recorded where appropriate.

2.4.4.1 Additional considerations for SOIL SLIP EROSION

Assessment of present erosion severity should take into account:

- Areal extent.
- The size of erosion scars.
- The volume of material removed.
- The nature of the rock and regolith.
- The physical and chemical properties of the soil (fertility, aggregate stability, slaking etc.).
- Slope angle and length.
- Position on hillslope, i.e. connectivity of debris tails with stream channels.
- Likelihood of reactivation, e.g. undercutting by stream.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 9: Very severe soil slip erosion in weakly consolidated sandstone hill country, Pohangina, Manawatu (IGNS).

Plate 10: Shallow soil slip on massive mudstone hill country. Note the shallow scar and the debris tail sliding into the creek (AKM).

Plate 11: Moderately severe, deep soil- slip erosion (previously designated as earthslip). Note the deep scar and the high volume of debris (GH).

2.4.4.2 Additional considerations for DEBRIS AVALANCHE

Assessment of present erosion severity should take into account:

- Areal extent.
- The size of erosion scars.
- The volume of material removed.
- Fluvial characteristics of debris avalanche channels.
- Slope of the debris avalanche walls.
- Physical and chemical properties of the regolith and bedrock.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 12: Very severe debris avalanche erosion in Fiordland (IGNS).

2.4.4.3 Additional considerations for DEBRIS FLOW EROSION

Assessment of present erosion severity should take into account:

- Areal extent.
- The size of erosion scars.
- The volume of material involved.
- Run-out area.
- Nature and size range of debris.
- Fluvial characteristics of debris flow channels.
- Slope of the channel walls.
- Likelihood of reactivation (e.g. undercutting by stream).
- Likelihood of stabilisation if control measures are implemented and/or success of existing measures.

2.4.4.4 Additional considerations for ROCK FALL EROSION

Assessment of present erosion severity should take into account:

- Areal extent.
- The size of erosion scars.
- The volume of material involved.
- The nature of the rock and regolith (e.g. induration, fracture intensity and pattern).
- Likelihood of reactivation (e.g. undercutting by stream).
- Likelihood of stabilisation if control measures are implemented.

2.4.4.5 Additional considerations for EARTHFLOW EROSION

Assessment of present erosion severity should take into account:

- Size of feature(s) (area and depth).
- Evidence of ground disruption as indicator of rate of movement.
- Presence of tension cracks.
- Depth to stable bedrock.
- Slope angle and slope length.
- Rainfall pattern, intensity and duration.
- Wetness of earthflow.
- Physical and chemical properties of the rock, regolith and soil.
- Features likely to affect rate of movement, such as removal of toe by stream, presence of springs, ponds.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 13: Severe earthflow on crushed argillite LUC 7e country (MJP).

Plate 14: Earthflow on Onerahi Chaos breccia, Tauhoa Road, Warkworth, Northland (TC).

Plate 15: Severe earthflow erosion on mudstone, Totangi Road, Gisborne (NT).

2.4.4.6 *Additional considerations for SLUMP EROSION*

Assessment of present erosion severity should take into account:

- Size of feature(s) (area and depth).
- Evidence of ground disruption as indicator of rate of movement.
- Presence of tension cracks.
- Physical and chemical properties of the rock, regolith and soil.
- Depth to stable bedrock.
- Slope angle and slope length.
- Rainfall pattern, intensity and duration.
- Features likely to affect rate of movement, such as removal of toe by stream, presence of springs, ponds.
- Wetness of slump.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 16: Slump erosion, Dannevirke (NT). Note the rotation across the back-wall. Some flow characteristics have developed after the initial slump failure.

Plate 17: Deep-seated slump erosion in soft mudstone hill country, Rangitikei. Note the deep soil slip (earth slip) also evident at the front of the slump (PN).

Plate 18: Large slump off the Maraetotara ridge, Hawkes Bay. Note the backward rotation of blocks and the wetland. Many years of plantings, retirement and pond drainage have not stabilised the slump (GOE).

Plate 19: Large slump in the Whangaehu catchment. Also note the surrounding soil slip erosion (IGNS).

2.4.5 Erosion severity for FLUVIAL EROSION

Fluvial erosion comprises **rill**, **gully**, **tunnel gully**, **streambank** (and **deposition**). As with mass movement, erosion severity is based on a combination of factors (listed below for each erosion type), and the areal extent of bare ground (Table 8).

2.4.5.1 Additional considerations for RILL EROSION

Assessment of present erosion severity should take into account:

- Areal extent.
- Length, width and depth of rills.
- Size of contributing area above rills.
- Fluvial characteristics of rill channels.
- Soil physical and chemical properties.
- Slope of rill walls.
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

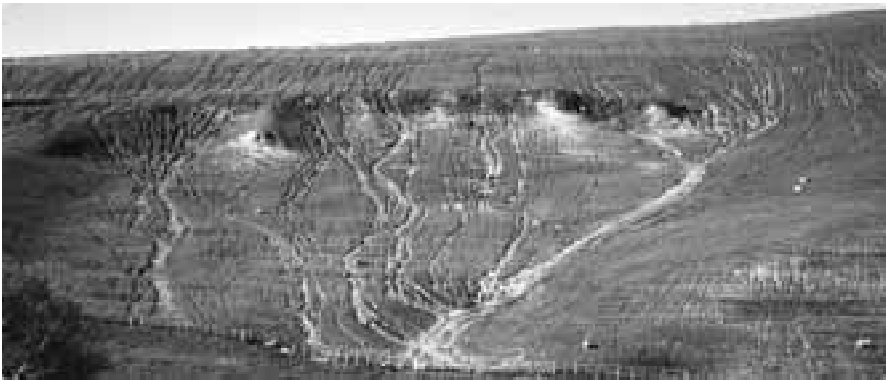


Plate 20: Very severe rill erosion, Esk Valley, Hawkes Bay (MJP).

Plate 21: Extreme rill erosion and severe sheet erosion, Moutere Hills, Nelson (LCR).

2.4.5.2 Additional considerations for GULLY EROSION

Assessment of present erosion severity should take into account:

- Size of feature(s) (area and depth).
- Size of contributing area above gully.
- Presence of tension cracks.
- Physical and chemical properties of the rock and regolith.
- Fluvial characteristics of gully channels.
- Slope of gully walls.
- Active erosion of gully walls (e.g. amount of revegetation).
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 22: Tarndale Gully, Waipaoa catchment, Gisborne. Extreme gully erosion was initiated in 1915 and the gully area had grown to at least 20 ha when last measured (NT).

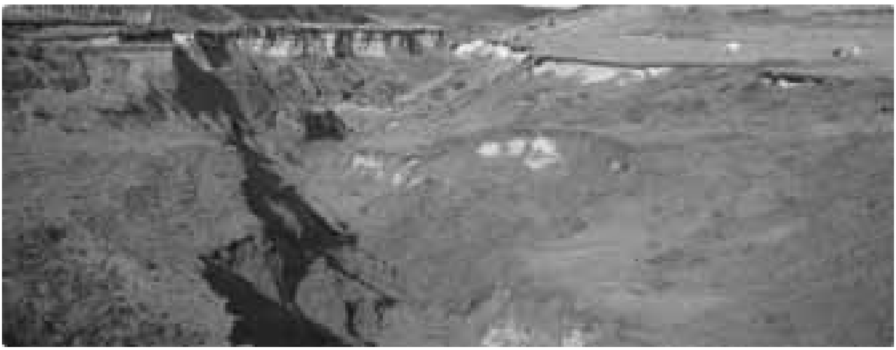


Plate 23: Localised gully erosion in unconsolidated sands. Caused by ineffective management of a water overflow (MT).

Plate 24: Severe gully erosion in mudstone hill country, Gisborne. Note the attempt to limit further enlargement by sparsely planting the upper reaches (GDC).

Plate 25: Characteristic vertical- sided gully system in Taupo breccia (Tp), Poronui Station, Bay of Plenty (GOE).

2.4.5.3 Additional considerations for TUNNEL GULLY EROSION

Assessment of present erosion severity should take into account:

- Areal extent.
- Length, width and depth of tunnel gullies.
- Degree of roof collapse.
- Slope angle.
- Physical and chemical properties of the soil and regolith (e.g. slaking and dispersive characteristics).
- Size of contributing area above tunnel gullies.
- Likelihood of stabilisation if soil conservation and other control measures are implemented (e.g. recontouring) and/or success of existing measures.

Plate 26: Extreme tunnel gully, Wither Hills, Marlborough (LCR).

Plate 27: Moderate tunnel gully erosion on LUC Class 6e, Hawkes Bay (LCR).

2.4.5.4 Additional considerations for STREAMBANK EROSION

Severity of streambank erosion is assessed on a reach basis. A reach is a length of stream course relatively homogeneous in form (bed slope, sinuosity, bars, width, and bank material) and in terms of processes (incision or aggradation, sediment transport characteristics).

Assessment of the severity of streambank erosion should take into account:

- Proportion of reach affected.
- Length of streambank actively eroding.
- Height of streambank actively eroding.
- Physical nature of streambank materials.
- Aggrading or degrading streambed.
- Lateral distance eroded into terrace (if known).
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 28: Moderate streambank erosion south of Tinui, Wairarapa (MJP).

Plate 29: Severe streambank erosion of fine-grained alluvial soils overlying weathered alluvial valley fill gravels of the Sherry catchment in the Nelson region (TDC).

Plate 30: Streambank protection provided by a dense tree root network of poplar and willow species and large rock riprap in the Pigeon Creek catchment (TDC).

2.4.6 Severity for DEPOSITION

Although not an erosion process per se, deposition is a related process and the end product of erosion which disrupts land use and requires restoration. Deposition is defined as material deposited by running water, and as such does not include debris tails of soil slips and other mass movements deposited on hillslopes. These are not normally mapped separately from the scar (source area).

Assessment of the severity of deposition should take into account:

- Depth of the deposits.
- The particle size and physical nature of the materials deposited (silt, sand, gravel or boulder).
- Slope.
- Areal extent of the deposition.
- Nature of underlying material (topsoil or subsoil, compact or loose).
- Likelihood of stabilisation if soil conservation measures are implemented and/or success of existing measures.

Plate 31: Coarse gravel debris deposited in a small active channel of the Eden Valley Stream within the Moutere Gravels in the Nelson region (TDC).

Plate 32: Deposition of fine sediment on river terraces and flats, Gisborne (NT).

Plate 33: Extreme deposition of fine silts to a depth of one metre after flooding associated with Cyclone Bola, Gisborne (GH).

2.4.7 Additional Information

2.4.7.1 Soil profile loss

It may be desirable to record the extent of soil profile loss, and to characterise the residual soil environment (Table 9). This may be of particular relevance when planning extensive revegetation programmes.

Table 9: Guidelines for recording the extent of soil profile loss, especially on sheet and wind eroded areas (SCRCC 1974).

Symbol	Description
0	<5% of topsoil lost
1	5–25% of topsoil lost
2	25–75% of topsoil lost
3	Up to 75% of topsoil lost, subsoil exposed and up to 25% subsoil lost
4	25–75 % subsoil lost
5	>75% subsoil lost

Where these symbols are used they should be placed after the areal severity symbols with a bar, e.g. 3/4Sh, – erosion severity 3 (20–40% bare ground) / soil loss 4 (25–75%) subsoil lost, erosion type – Sh (sheet erosion).

2.4.7.2 Tracks

Farm and forestry tracks can be a significant 'point source' of water, sediment and nutrient input to watercourses through a combination of bare surfaces, high stock and vehicle use, and runoff/discharge that is often diverted into watercourses at numerous stream crossings. Poor maintenance of tracks and crossings can also add to inputs.

Track erosion – Tr (usually a combination of sheet and rill erosion) can be recorded as a prefix to the erosion type symbol. Table 10 gives guidelines for assessing severity of track erosion.

Table 10: Guidelines for recording the severity of track erosion.

Symbol	Severity	Criteria
ϴ	Negligible	Track discharges safely on to land surface.
1	Slight	Track is well grassed, with few stream crossings.
2	Moderate	Track has much bare ground but few rills, and several stream crossings.
3	Severe	Track has high usage and surface disturbance (pugging, wheel tracks), with channelised flow and numerous stream crossings. Track cuttings are eroding.

2.4.7.3 Point sources

Methods for estimating and recording the potential detritus supply-power to channels from point-source erosion forms are documented in Cuff (1974, 1977, 1981), NWASCO (1977), Simpson *et al*. (1980), and Salter *et al*. (1983).

Table 11: NZLRI vegetation cover classification, vegetation class symbols and names.

Grass			
gI	Improved pasture	gW	Snow tussock grassland
gS	Semi-improved pasture	gR	Red tussock grassland
gT	Short tussock grassland	gD	Sand dune vegetation
Crops			
cC	Cereals (wheat, oats, etc.)	cR	Short rotation forage & fodder crops
cM	Maize	cS	Subtropical fruit
cP	Pip and stone fruit	cK	Kiwifruit
cG	Grapes and berry fruit	cV	Vegetables, nurseries
Scrub			
sM	Manuka, kanuka	sW	Sweet brier
sC	Cassinia	sA	Matagouri
sD	Dracophyllum	sV	Mangrove
sF	Fern	sL	Lupin
sS	Subalpine scrub	sH	Heath
sX	Mixed indigenous scrub	sO	Coastal scrub
sB	Broom	sE	Exotic scrub
sG	Gorse	sT	Mixed indigenous scrub with tree fern
sK	Blackberry		
Forest			
fC	Coastal forest	fU	Beech forest, undifferentiated
fK	Kauri forest	fD	Podocarp–broadleaved–beech forest
fP	Podocarp forest	fR	Exotic broadleaved forest
fB	Broadleaved forest	fF	Exotic conifer forest
fO	Lowland podocarp–broadleaved forest	fI	Highland podocarp–broadleaved forest
fW	Lowland beech forest	fN	Kanuka forest (trees >6 m tall)
fG	Highland beech forest		
Herbaceous			
hW	Wetland vegetation	hP	Pakihi vegetation
hR	Rushes, sedges	hM	Semi-arid herbaceous vegetation
hA	Alpine and subalpine herbfield/fellfield vegetation	hH	Hieracium
hS	Saline vegetation		
Unvegetated (bare)			
uV	Unvegetated land		

Other symbols	
Placed before class:	
c	Cutover
s	Stunted
e	Erosion-control trees
n	Naturalised exotic trees
Placed after class:	
*	Scattered

2.5 Vegetation

Vegetation cover is mapped using a national classification adapted from that used in the 1st edition LUC Survey Handbook, and NZLRI mapping (Hunter & Blaschke 1986). Symbols have been changed from the earlier versions to better relate to the vegetation classes (Page 1987).

The classification contains 52 vegetation classes (each NZLRI vegetation class is described in Appendix 3) arranged into five major groups: grass, crop, scrub, forest, and herbaceous (Table 11). Four prefixes are used to further describe specific forest classes.

Where possible a map polygon should contain a single vegetation class. However, due to scale and the patterns of vegetation distribution, this is often not possible, and up to four vegetation classes can be recorded in a map polygon. The distribution of vegetation is recorded as either 'clumped' or 'scattered'.

Clumped refers to discrete areas of continuous cover, and scattered to discontinuous cover. Scattered vegetation is denoted by an asterisk after the class symbol, which indicates it is scattered throughout the preceding non-scattered vegetation class. For example, **gIsM*** is *improved pasture with scattered manuka*, and **gIsM*sG*** is *improved pasture with scattered manuka and scattered gorse*. Clumped vegetation has no additional symbol, e.g. **gIsM**.

Plate 34: In principle, a new polygon is mapped when there is a significant change in vegetation cover. In practice, this is balanced with considerations regarding scale, use of the 'scattered' suffix (*), and an estimate of percent coverage (RG).

For clumped vegetation, where more than a single class is recorded, the area of the polygon occupied by each class is estimated to the nearest 10% and recorded by a subscript in the code, e.g. **gI_7sM_3** records a *70% cover of improved pasture and a 30% cover of manuka scrub*. There is no percentage cover given for scattered vegetation – the area being included within the area of the vegetation through which it is scattered.

Stunted vegetation is represented by the symbol 's' before the class symbol, e.g. **sfE** is *stunted exotic conifer forest*, usually recorded in coastal buffer zones. Erosion control trees are represented by the symbol 'e' before the class symbol, e.g. **efR** is *exotic broadleaved trees planted for erosion control*. Naturalised exotic conifer trees are represented by the symbol 'n' before the class symbol, e.g. **nfF** is exotic conifers, usually self-seeded and growing wild, usually without any form of silvicultural management, and where trees represent a range of ages.

The approximate correlation of the NZLRI vegetation classes to the pasture classes used in the Overseer® nutrient budgets model (AgResearch 2006) is shown in Table 12.

Table 12: Approximate correlation of the NZLRI vegetation classes to the pasture classes used in Overseer®.

NZLRI vegetation classes	Overseer ® pasture classes
Short-rotation forage and fodder crops (cR)	Recently cultivated[1]
Improved pasture (gI)	Highly developed[2] Developed[3]
Semi-improved pasture (gU),	Developing[4]
Short tussock grassland (gT), Semi-arid herbaceous vegetation (hM) & Hieracium (hH)	Developing/Under-developed[4]
Snow tussock grassland (gW), Red tussock grassland (gR), Semi-arid herbaceous vegetation (hM), Hieracium (hH)	Developing/Under-developed[4]

1. Cultivated in the last four years.
2. Soil organic matter is no longer accumulating in the profile.
3. Pasture production is at a pseudo-equilibrium.
4. Pasture production actively increased by pasture renewal, capital fertiliser, irrigation or drainage – applies in agronomically managed situations, otherwise classify as *Undeveloped*.

2.6 Climate

An understanding of climate and its effects on land use and flooding are important factors in determining a site's long-term land use potential. The main sources of climatic information are the publications, maps, records and databases of the New Zealand Meteorological Service (NZMS undated), National Institute of Water and Atmospheric Research (NIWA), regional councils and local records. Mean annual temperature, mean minimum temperature of the coldest month, mean annual solar radiation, winter solar radiation, October vapour pressure, annual water deficit and monthly water balance ratio are national climate layers incorporated in Land Environments of New Zealand (Leathwick *et al*. 2003a, 2003b). Comprehensive climatic records are kept for many farm properties and the farmers are a good source of local climatic information.

3. THE LAND USE CAPABILITY CLASSIFICATION

The Land Use Capability (LUC) Classification has three levels (Figure 7). Firstly, an inventory polygon is categorised into one of eight **LUC Classes** according to its general capacity for sustained production. This can be thought of as a rating of ‘best’ to ‘worst’ land for common productive uses.

Secondly, each class can be further categorised using one of four **LUC Subclasses** based on the dominant limitation. Expressed as a question, *what is the single most important factor that is currently limiting* <u>*sustainable*</u> *production within the map polygon?* Four limitations are used (erodibility, wetness, soil and climate), but it is important to recognise that some limitations cannot be assigned to certain LUC classes (see Section 3.3).

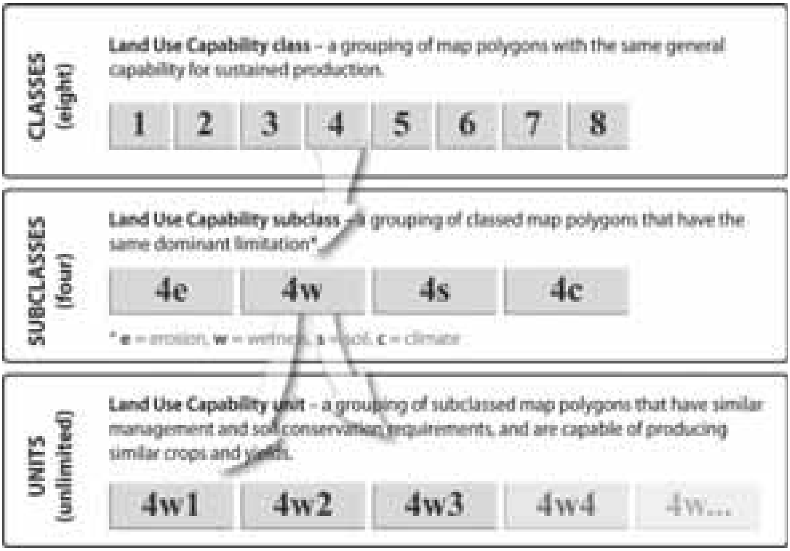


Figure 7: The three hierarchical levels of the Land Use Capability Classification.

Lastly, each Class/Subclass combination can be further differentiated into **LUC Units** (also known as *LUC management units*). LUC Units group areas of land that require similar approaches to management (e.g. fertiliser, drainage, erosion treatment, pugging management), and have similar capabilities regarding yields and crop suitability.

3.1 Land Use Capability Classification definitions

3.1.1 Land Use Capability Class

The Land Use Capability Classification system as used in New Zealand has eight LUC classes. Classes 1 to 4 are classified as arable land, while LUC Classes 5 to 8 are non-arable. The limitations or hazards to use increase, and the versatility of use decreases, from LUC Class 1 to LUC Class 8 (Figure 8).

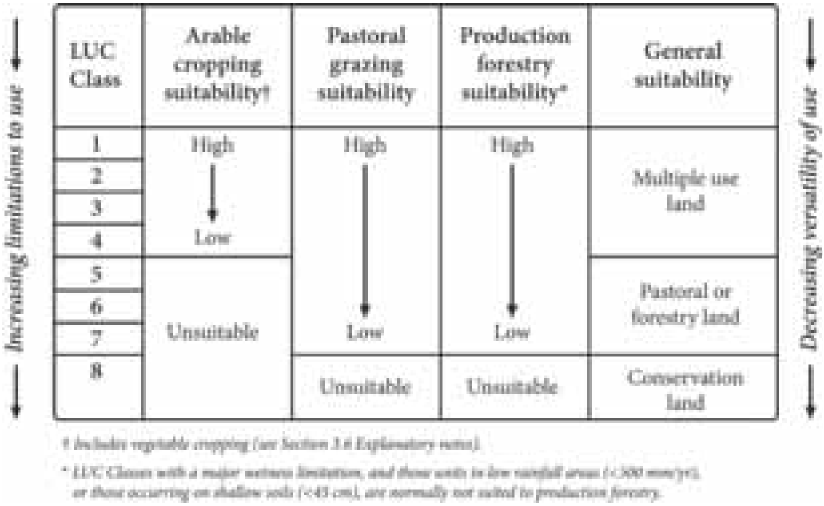


Figure 8: Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8.

New Zealand has only a limited area of high capability classed land (Figure 9), totalling 6.6 million hectares and representing 25% of NZ's total land area. Just under half is classified as LUC Class 6 and 7 (13.2 M ha or 49% of land area), and a sizeable 5.8 M ha has no agricultural value as Class 8 land (22% of NZ).

Under-representation of LUC Class 5 (0.2 M ha or 0.8% of land area) can be attributed both to previous classification criteria, and to NZ's landscape character (limited LUC Class 5 land relative to other LUC classes). Classification criteria have been broadened in this edition of the Handbook (see Section 3.2.4).

The total area of each LUC Class in hectares for both the North and South Islands is tabulated in greater detail as Appendix 4.

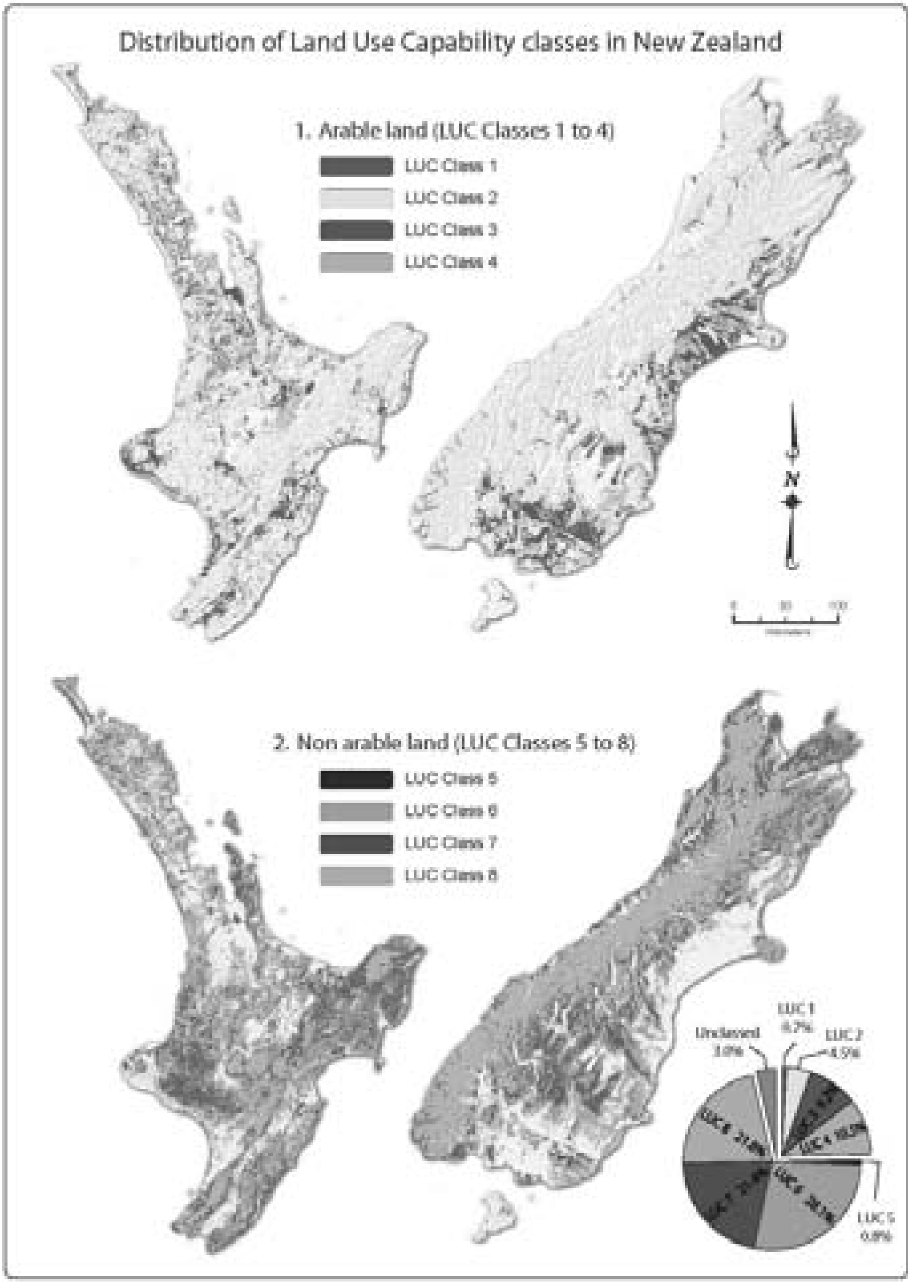


Figure 9: The distribution of LUC Classes in New Zealand as recorded in the NZLRI. Approximately 790 thousand hectares are unclassed (Stewart Island, rivers, towns, quarries, lakes and estuaries).

3.2 Description of Land Use Capability Classes 1 to 8

3.2.1 LUC Class 1

LUC Class 1 is the most versatile multiple-use land with minimal physical limitations for arable use. It has high suitability for cultivated cropping (many different crop types), viticulture, berry production, pastoralism, tree crops and production forestry.

Class 1 land is flat or undulating (0-7°), has deep (>90 cm) resilient and easily worked soils, and there is minimal risk of erosion. Soils are characterised as being fine textured (silt loam, or fine sandy loam), well drained, not seriously affected by drought, well supplied with plant nutrients, and responsive to fertilisers. Climate is favourable for the growth of a wide range of cultivated crops, and for pasture or forest, and does not significantly limit yields.

Land which has a slight limiting physical characteristic such as wetness, risk of flooding, or drought can be included in LUC Class 1, where that limitation is removable by permanent works. The Subclass denotes the physical limitation. Waterways associated with Class 1 land may have slight streambank erosion.

The extent of Class 1 land is limited (Figure 9), and confined almost entirely to areas of deep, well-drained alluvial soils, located mostly on the flood plains of the larger rivers, or tephric and recent loess soils on terraces, or inland in frost-free localities where climatic conditions are favourable for good crop growth. Class 1 land normally occurs below 200 m (South Island) or 350 m (North Island), and where annual rainfall is between 650 and 1500 mm. Irrigation and windbreaks may be required for optimum production.

Plate 35: Market gardening on LUC Class 1 land (1w) at Marshlands, Canterbury (LCR).

Plate 36: LUC Class 1 land (1s) under intensive use in the Riwaka Valley (Nelson) on deep Typic Fluvial Recent Riwaka soils (6e in the background and 7e in the immediate foreground) (IHL).

Plate 37: Process tomatoes on LUC Class 1 land (1s) with Manawatu silt loam soils, Palmerston North (MJP).

Plate 38: LUC Class 1 (1c) under horticulture in Southern Hawkes Bay, on Twyford soils (KN).

3.2.2 LUC Class 2

This is very good land with slight physical limitations to arable use, readily controlled by management and soil conservation practices. The land is suitable for many cultivated crops, vineyards and berry fields, pasture, tree crops or production forestry. The most common physical limitations which may occur include:

- Slight susceptibility to erosion under cultivation.
- Moderate soil depth (45–90 cm).
- Slight wetness after drainage.
- Occasional flood overflow.
- Unfavourable soil structure and difficulty in working.
- Very weak to weakly saline.
- Slight climatic limitations.

Plate 39: Cropping on Class 2 land with Pukekohe soils (2e). Sheet and rill erosion is evident in the foreground (LCR).

Most Class 2 land is flat or undulating (0-7^0). When cultivated there may be a slight susceptibility to wind erosion, and sheet and rill erosion on slopes of 3-7 degrees. Slight streambank erosion may be apparent around waterways. Unfavourable soil characteristics include loamy sand and clay-textured soils.

Class 2 land is more widespread than Class 1 (Figure 9). Soils are derived mainly from alluvium and recent loess, although some in the North Island have developed on fine-textured, andesitic and basaltic ash. Class 2 land normally occurs below 400 m (South Island) or 500 m (North Island), and where annual rainfall is between 800 and 2000 mm in the North Island or <1500 mm in the South Island. Common uses include dairy pasture, high performance sheep or beef, and there are extensive areas used for cropping.

Plate 40: Bean cropping on Class 2 land with Pakowhai soils (2w), Hawkes Bay (LCR).

Plate 41: Class 2 land with Temuka soils (2w) being used to grow garlic at Riverlands, Blenheim. Note the tunnel-gullied Wither Hills in background (LUC 6e and 7e) (IHL).

Plate 42: Viticulture on LUC Class 2 land with Wairau soils (2s) in the Wairau Valley, Marlborough (IHL).

Plate 43: Intensive horticulture and neighbouring pastoralism on LUC Class 2 land (2s) near Kerikeri, Northland. Kerikeri soils on flat to undulating slopes (GH).

Plate 44: Cultivated Class 2 land with Kiwitea silt loam (2c) near Shannon, Horowhenua (MJP).

3.2.3 LUC Class 3

Class 3 land has moderate physical limitations to arable use. These limitations restrict the choice of crops and the intensity of cultivation, and/or make special soil conservation practices necessary. Class 3 land is suitable for cultivated crops, vineyards and berry fields, pasture, tree crops or production forestry. The most common limitations that may occur include:

- Moderate susceptibility to erosion under cultivation.
- Rolling slopes (8-15°).
- Shallow (20–45 cm) or stony soils.
- Wetness or waterlogging after drainage.
- Occasional damaging overflow.
- Low moisture holding capacity.
- Moderate structural impediments to cultivation.
- Low natural fertility.
- Weak salinity.
- Moderate climatic limitations.

Most Class 3 land occurs on undulating to rolling country (4-15°). When cultivated there may be a moderate susceptibility to wind erosion, and to sheet and rill erosion. Class 3 land also occurs on shallow and/or stony flats and terraces with low water holding capacities that may also be susceptible to wind erosion. Areas adjacent to waterways can exhibit moderate streambank erosion. Moderately unfavourable soil characteristics typically include clay and sandy loam textures, and moderate stoniness (15–35% stones or gravels in the upper 20 cm).

The distribution of Class 3 land is extensive (Figure 9). It is commonly classed on rolling country, flat pumice country, slow-draining soils, and across extensive areas of shallow and stony plains. Distribution is generally confined below 650 m

(South Island) or 750 m (North Island), and where annual rainfall is between 800 and 2500 mm in the North Island or below 2400 mm in the South Island.

Plate 45: Grain harvesting on rolling Class 3 land with Timaru soils formed from loess (3e). Timaru, Canterbury (SNZL).

Plate 46: Viticulture on Class 3 land with well-drained Rapaura soils (3s) on undulating channel and stony gravel-bar topography in the Wairau Valley, Marlborough (IHL).

Plate 47: Class 3 land (3c) mapped on the gently sloping floor of Kaituna Valley, Marlborough. LUC 7e foothills in the background (IHL).

3.2.4 LUC Class 4

Class 4 land has severe physical limitations to arable use. These limitations substantially reduce the range of crops which can be grown, and/or make intensive soil conservation and management necessary. In general, Class 4 land is suitable only for occasional cropping (e.g. once in 5 years or less frequently) although it is suitable for pasture, tree crops or production forestry. Some Class 4 land is also suited to vineyards and berry fields. The most common limitations which may occur include:

- Moderate to high susceptibility to erosion under cultivation.
- Strongly rolling slopes (16- 20°).
- Very shallow (<20 cm) and/or stony, or very stony soils.
- Excessive wetness after drainage.
- Frequent flooding.
- Very low moisture holding capacity.
- Severe structural impediments to cultivation.
- Low fertility difficult to correct (e.g. Al toxicity).
- Moderate salinity.
- Severe climatic limitations.

Class 4 land ranges from flat to strongly rolling (0-20°) country. When cultivated there may be a severe susceptibility to wind erosion, and to sheet, rill and gully erosion. Class 4 land also occurs on very shallow (<20 cm) and/or stony or very stony flats and terraces with low water holding capacities. Waterway areas may exhibit slight to moderate streambank erosion. Erosion is the most common limitation assigned to Class 4 land (4e). Unfavourable soil characteristics include clay, loamy sand and sand textures, and very stony soils (35–70% stones or gravels in the upper 20 cm) on terraces.

Distribution is extensive (Figure 9) and normally occurs below 800 m (South Island) or 1000 m (North Island), or where annual rainfall is between 800 and 3,000 mm in the North Island or below 3,000 mm in the South Island.

Direct drilling of crops and pasture can be used to significantly reduce the erosion risk on land limited for cropping by steepness, and on flat and rolling land susceptible to wind erosion. In Northland and Westland some Class 4 land is limited by excessive wetness, and/or low natural fertility. Class 4 also occurs on the shallower stony soils of the river terraces and outwash surfaces where cultivation is marginal, and on flat and rolling land in Central Otago where cropping is limited by low rainfall.

Plate 48: Pastoral use of Class 4 land in the loess downlands of North Otago. LUC 4e is classed for the rolling to strongly rolling cultivated slopes and LUC 4w for the poorly drained valley floor. Moderately steep to steep LUC 6e in the middle ground, with the Kakanui Ranges in the background (IHL).

Plate 49: Cultivated Class 4 land (4e) associated with shallow loess in the Waitaki Valley, South Canterbury. LUC 6e in the background (IHL).

Plate 50: Contour cultivation on loess Class 4 land (4e) in the southern Hawkes Bay (MSR).

Plate 51: Wet Class 4 land on Hauraki clay soils (4w). Note the 'hump and hollow' drainage. Hauraki Plains, Waikato (MRJ).

Plate 52: Class 4 with stony Ruapuna soils (4s) of the Canterbury Plains. Predominantly used for pasture grazing, with occasional cereal and short-rotation fodder cropping (IHL).

Plate 53: High rainfall Class 4 land (4c) located in the upper Taramakau catchment (6,400 mm/yr rainfall), West Coast (IHL).

3.2.5 LUC Class 5

This is high-producing land with physical limitations that make it unsuitable for arable cropping, but only negligible to slight limitations or hazards to pastoral, vineyard, tree crop or production forestry use. In this Handbook the class has been revised to include slight erosion, and consequently subclass ‘e’ erodibility is applicable. The most common limitations which preclude arable use include.

- Moderately steep slopes (21-25°).
- Erosion risk.
- Stoniness and/or the presence of boulders or rock outcrops.
- Excessive wetness after drainage.
- Frequent flooding.

Originally the Class 5 definition followed the United States Department of Agriculture’s concept of flat to rolling land, ‘which, because of limitations impracticable to remove, was not suitable for cultivation for cropping’ (Norton 1939; Klingebiel & Montgomery 1961).

The definition was widened in New Zealand to include non-arable sloping land which although cultivable in some instances, had virtually no erosion hazard under grazing or forestry use (SCRCC 1974). This additional land was of two kinds:

1. Land that is cultivable for development (pasture or forestry) or for pasture renewal.
2. Land that is too steep for cultivation, but is stable, fertile and capable of high production.

Under this definition (SCRCC 1974; NWASCO 1979), only 0.1M ha was mapped in the North Island and just over 0.1M ha in the South Island (0.8% of the country – see Figure 9). This land was confined to very stable hill country, localised areas of bouldery river flats and fans, karst and some basaltic landscapes.

In this Handbook, the Class 5 definition has been expanded to include non-arable land with a slight sheet, and/or soil slip, and/or rill, and/or tunnel gully erosion limitation, or hazard under permanent vegetation cover. Previously this highly productive land with a slight erosion limitation under permanent vegetation would have been mapped as Class 6 land.

Plate 54: Example of LUC 5 land (5e) previously classed as LUC 6 (6e), north of Waipawa in the Hawkes Bay. Strongly rolling downlands with Te Aute soils. Cultivation for pasture renewal masks the results of past erosion, but there is evidence of past activity on the mid-slope and in the background (NF).

Plate 55: Class 5 land with a wetness limitation that makes it unsuitable for arable uses even after drainage (5w) (MJP).

Plate 56: Class 5 land in the Waikato, where topography is easy and soils are productive, but the presence of limestone outcrops and boulders create a severe soil limitation for cropping (5s) (GOE).

Plate 57: Intensive grazing and dairying use of bouldery Class 5 land (5s) on the Hapuka Fan, Kaikoura (IHL).

Plate 58: Class 5 land with a climate limitation (5c) associated with low seasonal rainfall (830 mm) and fertile yet droughty Matapiro soils (dense subsoils reduce plant-available water storage), Puketapu, Hawkes Bay (MJP).

3.2.6 LUC Class 6

Class 6 land is not suitable for arable use, and has slight to moderate physical limitations and hazards under a perennial vegetative cover. Suitable uses include grazed pasture, tree crops and/or forestry, and in some cases vineyards. Erosion is commonly the dominant limitation, but it is readily controlled by appropriate soil conservation and pasture management. Common limitations include:

- Moderate erosion hazard under perennial vegetation.
- Steep and very steep slopes (>26°).
- Very stony (35–70%) or very shallow (<20 cm) soils.
- Excessive wetness.
- Frequent flooding.
- Low moisture holding capacity.
- Moderate to strong salinity.
- Moderate climatic limitations.

Class 6 is extensively mapped in New Zealand. The majority is stable productive hill country, a large proportion of which has a moderate erosion potential. Also included are flat to gently undulating stony and shallow terraces and fans, rolling land with a significant erosion risk, or a wetness or climatic limitation too great to allow sustainable arable cropping. It is not unusual for more than one of these limitations to be present.

Although not suitable for arable uses, some Class 6 land may be cultivated infrequently for pasture establishment or renewal (e.g. <1 yr in 10). Class 6 is distinguished from similar Class 5 land by having a greater erosion risk.

Soil conservation applicable to Class 6 hill country includes space-planted trees, conservation fencing (e.g. dividing strongly contrasting aspects), water control structures, oversowing and topdressing, and appropriate winter cattle management.

Plate 59: LUC class 6e with mixed grazing and production forestry land use on the foothills surrounding Whangapoua Harbour, Coromandel Peninsula (CJP).

Plate 60: Class 6 hill country, North Canterbury. Background landscape is formed from indurated greywacke (6e), with the easier slopes being cultivated from previously oversown and topdressed short tussock grassland with matagouri scrub. The foreground is soft sandstone partially mantled with loess (6e), with a degree of soil slip evident (IHL).

Plate 61: Class 6 land in the Waikato (6e), with minor soil slip erosion (MRJ).

Plate 62: LUC Class 6 land on steep to very steep slopes with moderate soil slip and sheet erosion on volcanic loams developed from Franklin Basalt (6e), Waikato (SW).

Plate 63: Limestone Class 6 land characteristic of the Puketoi Ranges, Tararua. Elevation and exposure convey a dominant climate limitation (6c) (LCR).

Plate 64: Classes 6, 4 and 3 on estuarine soils and reclaimed land, Kaipara Flats, Northland. The slightly saline Takahiwai and gley Kaipara soils are classified as 3w and 4w where drained, and 6w for the undrained soils nearest the estuary (GH).

Plate 65: Stone-picked and rolled Class 6 land with stony Takapau soils (6s), Southern Hawkes Bay. Significant topsoil stones and gravels still remain, and these soils have low soil-water storage capacities making them particularly prone to droughtiness (KN).

Plate 66: Moderately steep Class 6 hill country (6s) near Tikokino, Hawkes Bay. Gwavas and Mangatahi soils formed from patches of loess over gravels and unconsolidated sands. Note the brown drier areas where loess is no longer prevalent (KN).

3.2.7 LUC Class 7

Class 7 land is unsuitable for arable use, and has severe physical limitations or hazards under perennial vegetation. Consequently it is high-risk land requiring active management to achieve sustainable production. It can be suited to grazing provided intensive soil conservation measures and practices are in place, and in many cases it is more suitable for forestry.

The limitations of LUC Class 7 are of a similar nature to those affecting LUC class 6, but are more severe and its versatility is significantly less. The most common limitations that may occur include:

- Severe erosion hazard or severe effects of past erosion.
- Very steep slopes, including land >35°.
- Very low moisture holding capacity.
- Very frequent damaging flooding.
- Extreme wetness of soils.
- Very shallow (<20 cm) or stony (35–70%) soils.
- Very erodible rock types.
- Low natural fertility difficult to correct (e.g. Al toxicity).
- Strong salinity.
- Severe climatic limitations.

Because of the relationships between climate, topography, and soils, more than one of these limiting features is usually present.

The 5.7 M ha of Class 7 land is widely distributed throughout New Zealand. The majority is steep and very steep hill or mountain country where adverse climate, steep slopes, and low soil fertility combine to give a high risk of erosion and low productivity.

Significant areas of the erodible soft rock hill country in the North Island have high-fertility parent material coupled with a high potential for soil slip, slump, earthflow, and gully erosion. Despite a high present or potential stock carrying capacity this land is classed as LUC 7 due to the severe erosion hazard. Class 7 is also extensive in the South Island high country where climate and low fertility severely limits productive potential. Class 7 is also mapped on steep low-elevation slopes where loess overlying a range of rock types has a high susceptibility to sheet, wind and tunnel gully erosion when the vegetative cover is depleted.

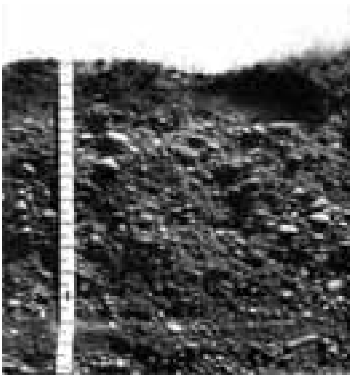


Plate 67: Typical very shallow (<20 cm) and/or stony (35–70%) Class 7s type soil profile (very shallow and droughty Lismore soils of the Canterbury Plains) (SNZL).

Plate 68: Typical 'hard' dry and cold inter-montane Class 7 steeplands on greywacke rocks with moderate to severe sheet erosion and slight gully erosion (7e), Awatere Valley, Marlborough. High altitude Class 8e land in the background (IHL).

Plate 69: Very severe soil slip erosion on LUC Class 7 (7e) hill country after Cyclone Bola (1988). Devil's Elbow, Northern Hawke's Bay (MJP).

Plate 70: Class 7 land with acidic and infertile Okarito silt-mantled Perch-gley Podzol soils on the Craigieburn Pakihi, Grey Valley. In this location soils represent the dominant limitation (7s) (SNZL).

Plate 71: Foreground. Flat Class 7 land with a wetness limitation for pasture and forestry (7w) at the head of Lake Brunner, Westland (LCR).

3.2.8 LUC Class 8

Class 8 land has very severe to extreme physical limitations or hazards which make it unsuitable for arable, pastoral, or commercial forestry use.

Erosion control, water management and conservation of flora and fauna are the main uses of this land. The most common limitation is extreme actual or potential erosion, often combined with severe climatic and/or soil fertility limitations.

Class 8 land is mainly very steep mountain land although it also includes very steep slopes at low elevations such as deep gully sides and cliffs, and highly erodible areas like unstable foredunes, large active slumps and gullies, and braided gravel floodplains. Class 8 land has been classified for 5.8 M ha of NZ's land area.

Classification criteria for Class 8 are similar to those for Class 7 land (Section 3.2.7), but with all limitations or hazards being rated as very severe to extreme for all agricultural land uses. Specific regional variations are given in the respective published NZLRI regional legends.

Plate 72: Rolling Class 8 land (8s) with coarse gravels and boulders from alluvial gold-dredge tailings (all fine material has been removed), Taramakau River, West Coast (IHL).

Plate 73: Flat to undulating Class 8 land (8c) with scab weed and subalpine vegetation, on the summit of the Old Man Range, Otago (1,600 m above sea level) (IHL).

Plate 74: A range of Class 8e in middle and background, with debris cones and valley fill of Class 7e, Freds Stream, Ben Ohau Range, Waitaki Basin (IHL).

Plate 75: Class 8 mountain land (8e). Looking south-east at the south-facing slopes of Mukamuka Stream, Orongorongo catchment, Wellington (NT).

Plate 76: Very steep (>35^0) Class 8 greywacke slopes with moderate scree and gully erosion (8e), Mount Hector, Tararua Ranges, Wellington (MJP).

Plate 77: Coastal Class 8 land on the dunes and storm beach deposits (8s) between Baring Head and Turakirae Head, Wellington coast (MJP).

3.2.9 Classification checklist

Generalised class guideline criteria are provided as a quick reference for assigning or checking classifications at the LUC class level (Table 13). Users should refer to the full class descriptions (Sections 3.2.1 to 3.2.8) if the criteria are too generalised (e.g. borderline classifications).

3.3 Description of Land Use Capability Subclasses

The Land Use Capability Subclass identifies the main kind of physical limitation or hazard to use. Four kinds of limitation or hazard are recognised.

3.3.1 Erodibility limitation

'e' **erodibility** – where susceptibility to erosion and/or past erosion damage is the dominant limitation or hazard to use.

Arable land (LUC Classes 1–4) is susceptible to wind, sheet, and rill erosion when cultivated. The degree of erosion risk is a complex function involving the following characteristics:

- Slope – steepness, length, and aspect.
- Rock type – cohesiveness, mineralogy (e.g. clay type) and consolidation.
- Soil – texture, aggregate size and stability, permeability and prior soil-moisture conditions.
- Weather – rainfall intensity and duration, wind strength and direction.

The timing of cultivation to minimise the exposure of bared soil, and the retention of a coarse tilth and rough soil surface of strong stable aggregates, reduces the risk of wind erosion. Direct drilling, minimal tillage and no-till techniques to establish crops and pastures can also significantly reduce the erosion susceptibility and risk.

On non-arable land (LUC Classes 5–8) the factors that determine erosion type, severity and susceptibility, include rock type characteristics (competence, joint, fracture, and bedding plane patterning), the location of fault and crush zones, regolith and soil characteristics, elevation, vegetation cover history, and climatic factors.

Table 13: Summary of generalised LUC class guideline criteria.

LUC Class	Physical limitations	Arable suitability	Slope	Soil stoniness, depth & workability	Soil texture & drainage	Erosion severity & erosion types	Salinity	Elevation & annual rainfall ranges* South Is.	North Is.
				Arable land					
1	Minimal limitations for arable use.	Suitable for a wide range of crops.	0- <7°	Deep, >90 cm, easily worked & resilient.	Fine textured, silt loam, fine sandy loams, well drained.	Minimal erosion risk (negligible W, Sh under cultivation)	Nil	<200m 650–1500mm	<350m 650–1500mm
2	Slight limitations for arable use.	Suitable for many crops.	0- ≤ 7°	Moderately deep 45–90 cm, slightly difficult to work.	Wide range, loamy sand & clay textures are less favourable, well to imperfectly drained.	Slight erosion risk under cultivation, W, Sh, R.	Very weak to weak	<400m <1500mm	<500m 800–2000mm
3	Moderate limitations for arable use. Soil conservation measures required.	Restricted range of crops, intensity of cultivation is limited.	0- ≤ 15°	Shallow 20–45 cm &/or stony (5-35% in upper 20 cm), often difficult to work.	Wide range, clay loam, & sandy loam textures are less favourable, well to imperfectly drained.	Slight to moderate erosion risk under cultivation, W, Sh, R.	Weak	<650m <2400mm	<750m 800–2500mm
4	Severe limitations for arable use. Intensive soil conservation measures required.	Occasional cropping but reduced range of crops and intensity of cultivation.	0- ≤ 20°	Very shallow <20 cm) &/or stony or very stony (35-70% in upper 20 cm), often difficult to work.	Clay, loamy sand, sand, & very stony textures are less favourable; well to poorly drained.	Severe erosion risk under cultivation, W, Sh, R, G.	Moderate	<800m <3000mm	<1000m 800–3000mm
				Non-arable land (assessed under perennial vegetative cover)					
5	Negligible to slight under perennial vegetation cover.	Non-arable, high producing.	0- ≤ 25°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Negligible to slight, Sh, Ss, R, T	Moderate	<950m[a] & 1050m[b] 600-4000mm	<1000m 3000-4000mm
6	Moderate, soil conservation measures desirable.	Non-arable, suited to grazing, tree crops, & forestry.	0- ≤ 35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Moderate, Sh, Ss, Sc, T etc	Moderate to strong	<950m[a] & 1050m[b] <600-4000mm	<1000m 3000-4000mm
7	Severe, requires active soil conservation measures.	Non arable, with soil conservation measures suited to grazing and forestry in some cases.	0- >35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Severe, Sh, Ss, Sc, G etc	Strong	<950m[a] & 1500m[b] <4000mm	<1100m[c] & <1300m[d] 4000-6000mm
8	Very severe to extreme – conservation or protection uses.	Unsuitable for arable, pastoral or commercial forestry use.	0- >35°	Variable, deep to very shallow (<20 cm) &/or stony or very stony.	Variable texture, well to poorly drained.	Very severe to extreme Sh, Ss, Sc, G etc	Strong	<3700m 420–10000+	<2800m 750–7000+

** Regional variations occur.*

[a] Southland, [b] Marlborough, [c] Wellington, [d] Gisborne.

3.3.2 Wetness limitation

'w' **wetness** – where either a high water table, slow internal drainage, and/or frequent flooding or ponding, from streams or coastal waters, represent the major limitation or hazard to use by limiting plant growth through a lack of soil aeration.

Soil-related wetness limitations are assessed by examining visual features of the site and the associated soil profile. These include:

- The presence or absence of *hydromorphic features*. These are observable features of the soil profile associated with oxygen availability. Examples include gleying (grey-coloured horizons caused by extended periods of saturation), mottling (usually as brown, yellow or orange patches of colour that suggest a seasonally fluctuating water table), and pale horizons associated with perched water tables (e.g. sitting on an iron or clay pan).
- The presence or absence of *accumulated water*, either as a watertable at depth, or as free-standing water (e.g. ponding). Shallow watertables can be assessed by digging a hole and waiting until the hole stops filling with water (Plate 78). Where the level stops indicates the height of the water table. Surface water accumulation is self-evident, and can be assessed on an extent basis.

Water accumulation can be a seasonal feature, and should therefore be assessed in conjunction with hydromorphic features (Table 14). This is an idealised relationship originally developed for the Marlborough area (Lynn 1996), and regional variations may occur.

Table 14: Relationship between the wetness subclass and depth to hydromorphic features, water table depth, and the presence of standing water (adapted from Lynn 1996).

LUC subclass	1w	2w	3w	4w	5w	6w	7w	8w
Depth to hydromorphic* feature (cm)	>90 cm	45–90 cm	45–90 cm	<45 cm	<45 cm	<30–45 cm	<30 cm	<30 cm
Water table (WT) depth and standing water	Not applicable	Seasonally high water table†	Moderately high WT for 0.5 yr	Moderately high WT for 0.5 yr	High WT, limited standing water	WT at or within 30 cm limited, standing water	Significant standing water	Extensive standing water

** Hydromorphic features: low chroma colours, gleying or mottling.*

† High water table at or within >45 cm of the ground surface.

Wetness caused by flooding is assessed using different criteria. This includes flood duration (inundation), frequency of flooding, and the degree of damage to crops, pasture and trees (Table 15). Damage can occur through physical destruction, drowning of vegetation, and deposition (including sand, silt, stones and debris).

Table 15: The relationship between LUC classes with a 'w' limitation and inundation and effects of floodwaters (adapted from Fletcher et al. 1994). Specific criteria vary regionally.

LUC subclass	Description	Days of continuous inundation
1w	Not applicable	
2w	Inundation lasting 1–2 days, not more frequently than once in 2 years. Yield of sensitive crops is affected but survival is not.	1
3w	Inundation lasting 1–2 days on average once per year; or lasting 2-3 days once every 2 years. Some crops do not survive. Others have reduced yield.	1-2
4w	Inundation lasting 2–4 days on average once per year. Cropping of annual ground crops is marginal, tree crop yields are reduced.	2-4
5w	Inundation lasting 4–8 days on average once per year, or 1-4 days on average 2–3 times a year. All ground crops are killed and tree crops have reduced yield. Flood-sensitive pasture may be affected.	4-8
6w	Inundation lasting 8–15 days on average once per year, or 4-8 days on average 3–4 times a year. Pasture yields are reduced but do not need resowing. Some trees are killed.	8-15
7w	Inundation lasting more than 15 days (often > 20 days) on average once per year, or lasting 8–15 days on average more than once per year. Pasture needs resowing and pastoral farming is marginal.	15-30
8w	Inundation lasting more than 15 days on average once per year. Pasture cannot be maintained.	>30

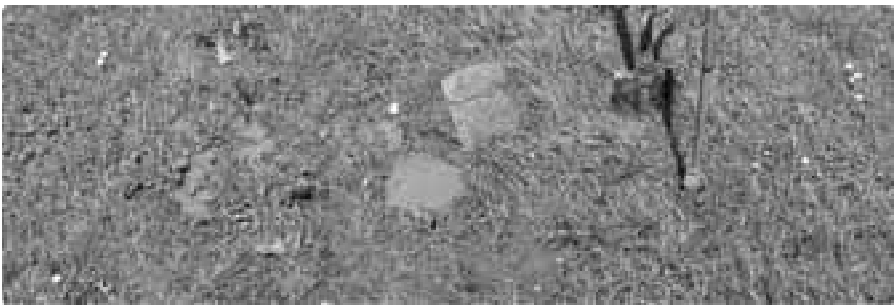


Plate 78: Fluctuating water table that is at the surface during winter, but drops below 90 cm in summer. Mottles appear at 50 cm depth, making this 3w land (AKM).

3.3.3 *Soil limitation*

's' **soil limitation** – where the major restriction or hazard to use is a limitation within the rooting zone. This can be a shallow soil profile, stoniness throughout the profile, subsurface pans, rock outcrops, low soil water holding capacity, low fertility (where this is difficult to correct), poor soil texture and structural conditions, salinity or toxicity.

Land with a soil limitation is widespread in New Zealand (Figure 11), particularly in the pumice lands, areas of stony terraces and plains, and where soils are notably coarse or shallow, or have a pan impeding root development. Stoniness, pans and soil texture are three of the most important characteristics.

Stoniness is assessed by the number and size of stones present in the soil profile (Figure 10), the incidence of stones or boulders at the surface, and a consideration of soil texture. For example, a coarse stony soil will usually have a greater soil limitation relative to a stony soil with a finer texture fraction (e.g. see Plates 52, 67, 72 and 79). Also note that Figure 10 is a stylised depiction, and is provided as a guide only.

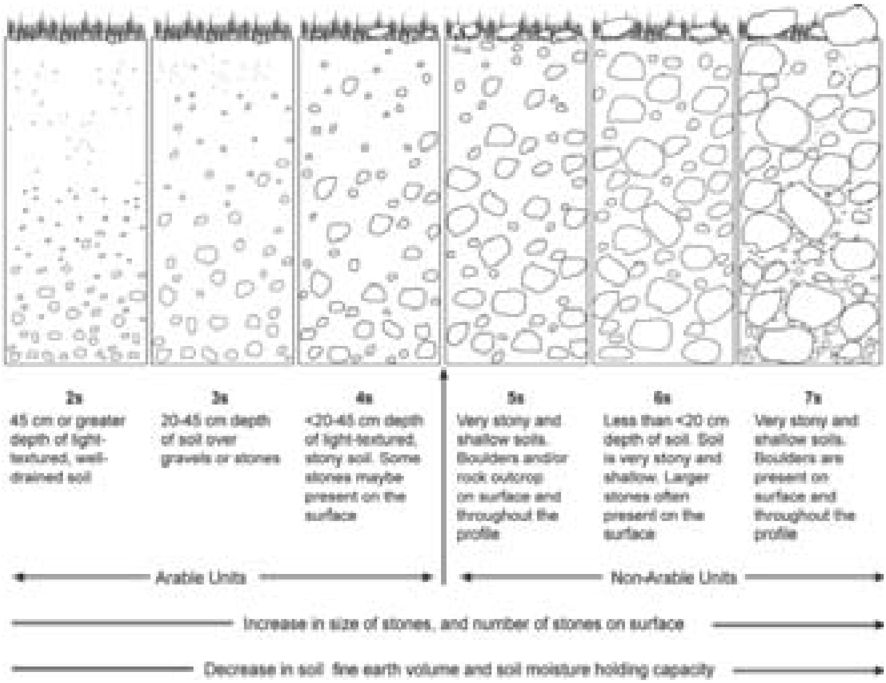


Figure 10: A diagrammatic representation of the relationship between LUC class, soil depth, and degree of stoniness (adapted from Noble 1985).

Plate 79: Moderate streambank erosion exposing stony Kopua soils in the Tararua district. Gravels at 45 cm (LUC 3s) and an appreciable size and number of stones occur in the profile and often at the surface (stone picking is common). Also note the slight deposition (1D) of fine gravels from a previous flooding event (AKM).

The degree of limitation imposed by a pan is assessed by depth, whereby a deeper pan has less impact on root development relative to a shallow pan (Table 16). Similarly, soil limitations related to texture often tend to increase as clay or sand becomes dominant (Table 16).

Table 16: The relationship between arable LUC classes with an 's' limitation and (a) depth to subsurface pans, (b) typical fine earth textures.

LUC subclass	1s	2s	3s	4s
(a) Depth to subsurface pan	>90 cm	45–90 cm	20–45 cm	<20 cm
(b) Typical fine earth soil textures	silt loam, loamy silt, silt, sandy loam, clay loam.	silt loam, loamy silt, silt, sandy loam, clay loam, sandy clay loam, loamy clay.	silt loam, loamy silt, silt, sandy loam, clay loam, sandy clay loam, silty clay, loamy clay, loamy sand, sand, clay.	silt loam, loamy silt, silt, sandy loam, clay loam, sandy clay loam, silty clay, loamy clay, loamy sand, sand, clay.

3.3.4 Climate limitation

'c' **climate** – where the climate is the major limitation or hazard to use.

The climate limitation can be a short growing season, inadequate or excessive rainfall, a rainfall distribution such that a suitable maturing/drying period is lacking, unseasonable or frequent frost and/or snow, and exposure to strong winds or salt spray.

The influence of climate, especially temperature and rainfall, can be significant when assessing Land Use Capability. This is particularly evident with some coastal areas, semi-arid zones, mountain lands, and other high altitude zones like the high country (Figure 11). It is also the default classification when no other limitation is particularly dominant (see Section 3.3.5), and can therefore be used on high capability land (e.g. see Taranaki in Figure 11).

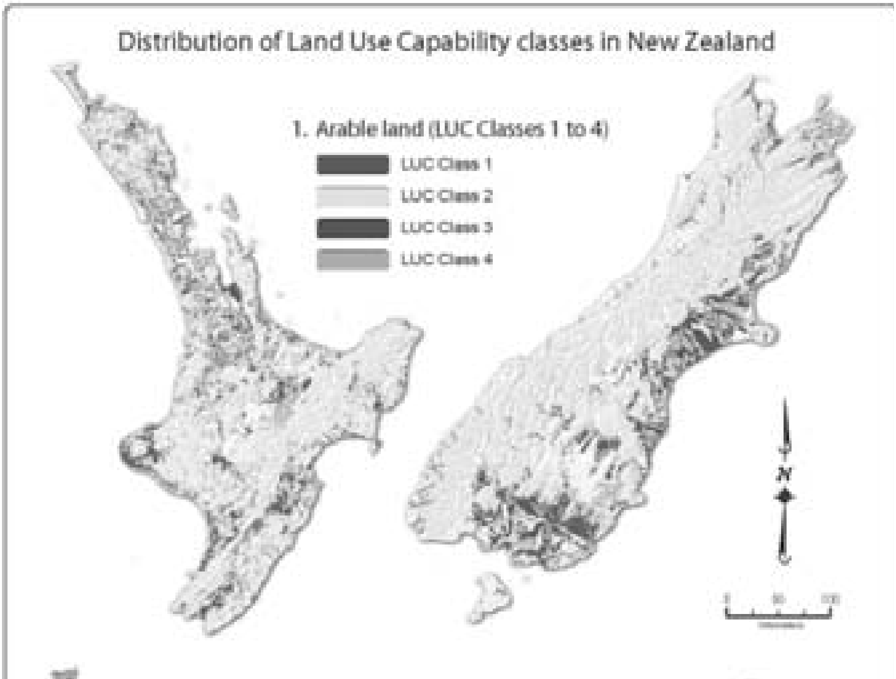


Figure 11: Distribution of LUC subclasses in New Zealand (from the 1:50,000 NZLRI).

Altitude-related bioclimatic zones (Burrows 1967; Wardle 1991) provide a useful framework for relating LUC classes to climate gradients in high elevation areas (Table 17). This demonstrates how temperature and growing degree days (GDD –

number of days that have temperatures high enough for crop growth and development) influence potential productivity, and therefore the degree of climatic limitation.

For example, Cossens (1983b) demonstrated significant decreases in crop and pasture performance with successive increases in altitude (e.g. productivity declines of 90 and 45 kg DM/ha/yr per 100 m increase for pasture and oversown tussock).

Given sufficient soil water, montane pastoral lands are environmentally suited to forests. Although *Pinus radiata* is poorly represented above 600 m because of frost-tenderness, growth rates for Douglas Fir, European Larch, Corsican Pine and Ponderosa Pine in the moist western zone of the Canterbury high country are among the highest recorded anywhere for the species (Ledgard & Belton 1985).

Reflecting these potentials and constraints, where other factors are non-limiting, arable LUC Class 4 land is the highest class in the lower montane zone (<750 m), and LUC Class 6 is the highest class in the upper montane zone (Table 17).

Table 17: Guidelines for LUC class according to altitudinal (temperature) limits applicable in the central South Island (adapted from Lynn et al. 1987, and Hunter 1992).

Max altitude (m)	Bio-climatic zone	Mean temp. (°C)	Selected GDD* >5°C[1]	Pasture yield[2] kgDM/ha/yr	Highest LUC class	Potential primary productivity
200	Lowland	9.9–12.6			1	Wide range of crops, pasture and trees.
400		9.4–10.6	1,253 @450m	10,000 @400m	2	
600	(lower)				3	Development of semi-improved to highly improved pasture generally feasible (rainfall dependent). Suitable for forestry, though restricted to cool-climate tree species above 700 m.
750	Montane (8-1000m)	6.6–9.1	854 @750m,		4	
950–1000	(upper)		648 @ 1,050m	3,800 @ 1000m	5, 6	
950–1350	(sub) Alpine	3.3–5.2		Up to 3,000m	7	Very limited scope to establish exotic pasture or tree species (high risk, low production). Some scope for cocksfoot, tall fescue, white, red, alsike clover, Maku lotus.
>1200 No limit	Nival	<3.0			8	No potential for plant introductions. Indigenous vegetation unlikely to sustain grazing off-take.

**Growing degree days.*

[1] Cossens (1983b).

[2] From sown ryegrass/white clover/cocksfoot; Cossens (1983a).

The midslope subalpine zone has its upper limit defined by the altitudinal limit of trees and woody shrubs at about 1,300 m in the central South Island. Mean annual temperatures are typically in the range 5.3 to 7.7°C. The growing season is relatively short and production levels from exotic pasture species occupying favourable sites is below 3,000 kg DM/ha/yr (Cossens 1983b; Floate *et al*., 1985). Land use options for production are less diverse than for montane lands although production forestry is likely to be feasible on accessible sites in the lower subalpine zone. The highest possible LUC class in the subalpine zone is LUC 7 (Table 17).

The upper-slope alpine zone extends from the potential upper limit of indigenous woody species to the gradational zone of sparse herbaceous vegetation, rock and scree. Mean annual air temperatures are typically in the range of 3.9 to 5.2°C. Climatic extremes and the very short growing season preclude the establishment of known exotic plant species. Agricultural production is confined to low intensities of extensive grazing in late summer and autumn. There is no significant potential for production forestry. Reflecting these constraints, the highest possible LUC class in the upper alpine and nival zones is LUC Class 8 (Table 17).

Bioclimatic zones decline from north to south. For example, the upper subalpine limit, in humid, beech-forested areas is about 1,500 m in the Wairau Valley, Marlborough (Latitude 42°S), 1,350 m in the Harper Valley, mid-Canterbury (43°S) and 1,150 m in the lower Dart Valley, Otago (45° 45’S). Altitude-related guidelines for LUC Class need to be adjusted to reflect this latitudinal trend.

Rainfall and associated soil water availability also influence land use capability. In semi-arid areas of Central Otago and the Waitaki Basin, soil water levels remain below wilting point for much of the potential growing season. Droughts impose severe constraints on plant establishment and growth, and result in persistent exposed bare ground which is vulnerable to degradation by wind erosion, and during high-intensity storms. By contrast, in super-humid western areas the soils are strongly leached and have high rates of erosion.

Although guidelines for rainfall are applied to arable LUC classes, in practice they are generally over-ruled by the predominant temperature, erosion and soil limitations on hill and steep lands.

3.3.5 Discussion on subclasses

Only the dominant limitation is recorded for each map unit. All four subclasses are applicable to each LUC class, with the exception of subclass ‘e’, which is not used with LUC Class 1. Note that subclass ‘e’ is now applicable for the redefined LUC Class 5.

Conventions are observed in determining the subclass. The limitations imposed by erosion, excess water, and soil factors listed previously can be modified or partially overcome by management and are therefore given precedence over climate in the determination of subclasses. The dominant limitation or hazard determines which of the subclasses 'e', 'w', or 's' is used.

Subclass limitation 'c' is used where climate is the only limitation.

In practice several limitations may affect the map unit. It may therefore be difficult to decide which should be the subclass, especially on non-arable land, particularly where soil limitations and erosion risk are closely related. Where two kinds of limitation are essentially equal, the limitations are given the following priority, 'e', 'w', 's', and 'c'. That is, 'e' is given precedence over 'w' and 's', and w is given precedence over 's', and so on (Figure 12).

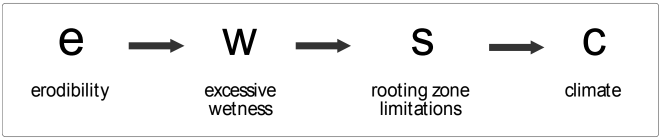


Figure 12: Subclass allocation priority when more than one kind of limitation is considered equal.

3.3.5.1 LUC class and subclass assumptions

When assessing and allocating LUC classes and subclasses the following assumptions are made:

- The permanent physical limitations of the land remain.
- The rectifiable limitations may be removed.
- An above-average level of land management is practised.
- Appropriate soil conservation measures will be applied and maintained.

Where it is feasible to either remove or significantly reduce the physical limitation (e.g. installing drainage or permanent irrigation, improving soil fertility, removing surface gravel, stones or boulders, or minimising erosion), then the land is assessed as if the limitation has already been removed or managed. For example, stoney Kopua soils (Plate 79) may be classified as LUC 3s even before stone picking has taken place.

3.3.5.2 Physical limitations

'Physical limitations' refer to land characteristics which have an adverse effect on the capability of land. These limitations can be permanent, removable, or modifiable.

Permanent limitations cannot be removed. It is neither practical, nor economic, nor technologically possible to remove the limitation. Examples include:

- Rock type attributes.
- Adverse climate (e.g. frequency of extreme events).
- Excess wetness even after drainage.
- Overflow from major river systems that cannot be controlled.
- Slope angle.
- Soil attributes, such as plant rooting depth (presence of subsoil pans or other rooting impediments), texture, structure, water holding capacity, type of clay minerals.

Removable limitations are those that can be removed, but removal is not easy and often involves a sizeable investment in land development. Removal depends on economics and the availability of appropriate technology, relative to the degree of limitation. Examples include:

- Gravel and boulders on the land surface and brought to the surface by cultivation (stone picking or piling).
- Soil wetness (drainage, water diversion, land reclamation).
- Flooding risk (through large community flood control schemes).
- Soil moisture deficit (through large irrigation schemes).

Modifiable limitations can be removed, but only through ongoing management and investment. Examples include:

- Erosion.
- Nutrient deficiencies.
- Soil moisture deficit.

The difficulty of removing or modifying limitations depends on their type and severity. The key words 'reasonable', 'feasible' and 'economic' are considered when deciding on the practicability of removing or modifying limitations. Soil conservation measures, irrigation, farm drainage, stone removal, and fertiliser applications are examples where technology can be used to modify or remove existing physical limitations on individual farms. The Land Use Capability assessment assumes that such improvements have been carried out.

LUC assessment can also be adjusted by major schemes that permanently change the degree of the limitation, such as large scale irrigation, drainage or flood control schemes.

For land where permanent irrigation has been installed (e.g. a centre pivot, border dykes) the classification is made on the basis that the soil moisture limitation has been permanently removed.

Where permanent drainage has been installed or is part of an approved scheme, the classification is made on the degree of limitation that will exist after drainage.

Where major community-based flood control schemes designed with protection levels to the 50–100 year return event are in place, the classification is made on the basis that the flood risk has been removed.

The type and severity and/or effective removal of the above physical limitations should be documented in the LUC unit descriptions.

Where works are beyond the ability of individual farmers and require a community scheme the land is classified according to the nature of its present limitations. If in time a large scheme such as irrigation becomes operative, the land can be reclassified into a higher LUC class.

The classification of LUC is independent of such factors as location, distance from markets, processing facilities, land ownership, or the skills of individual farmers.

3.4 Description of Land Use Capability Units

The Land Use Capability Unit is the most detailed component of the Land Use Capability classification. LUC Units group together land inventory units which require essentially the same kind of management, the same kind and intensity of conservation treatment, and are suitable for the same kind of crops, pasture or forestry species with similar potential yields.

The LUC Unit is the 'management' level in the classification, and the degree of detail specified depends on the scale of mapping and the purpose of the survey. LUC Units are identified by Arabic numerals at the end of the LUC code. An example of LUC unit nomenclature is '4e1', where '4' is the LUC Class, '4e' is the LUC Subclass, and '4e1' is the LUC Unit. Within *LUC extended legends* (see next paragraph), LUC units are arranged (within LUC Subclasses) in order of decreasing versatility and increasing degree of limitation to use (e.g. 7e5 would have a higher use capability than 7e8, but not as high as 7e2).

Information relevant to each LUC Unit is documented in an 'extended legend'. The legend describes the general nature of each LUC Unit, including a summary of land resource inventory, climate, land use and other factors influencing land use capability. Soil conservation and land management requirements are outlined together with its suitability for cropping, pastoral use, production forestry and watershed protection (see Figure 23 as an example, Page 124).

Regional LUC Units have been defined in the extended legends of the NZLRI (Trustrum 1974; Page 1975, 1976, 1995; Walsh 1977; Prickett 1978; Steel 1979; Noble 1979; Fletcher 1981; NWASCO 1983; Jessen 1984; Harmsworth 1996; Lynn 1996; Jessen *et al*. 1999).

3.5 Description of Land Use Capability Suites

The traditional numerical ranking of LUC Units, based on decreasing versatility and capability, as shown in the regional New Zealand Land Resource Inventory (NZLRI) LUC extended legends, gives no indication of the relationships between LUC Units in the landscape. To enable these relationships to be better understood, and to aid interpretation of maps and extended legends, related LUC Units can be arranged into groups, called Land Use Capability Suites.

An LUC Suite is defined as groups of LUC Units which, although differing in capability, share a definitive physical characteristic which unites them in the landscape. These definitive physical characteristics may vary between suites and regions, and are documented in the NZLRI regional bulletins (e.g. Blaschke 1985a; Lynn 1996). The factor used to delineate LUC Suites is usually a principal determinant of the ‘physical character’ of a landscape (e.g. rock type) with slope typically being the factor used to distinguish LUC Units within LUC Suites. The combination of rock type and relief immediately gives LUC Suites a geomorphic unity in the landscape. Other factors which may be used to distinguish LUC Suites, for example rainfall, altitude or surficial soil-forming materials such as volcanic deposits or loess, all give their resulting LUC Suites geographical distinctiveness.

In the Bay of Plenty – Volcanic Plateau Region the primary factor used to delineate LUC Suites is soil parent material as determined by tephra or other volcanic deposits (Blaschke 1985a). Four of the eight LUC Suites are directly related to one of four tephra groups (recent tephras, Kaharoa Ash, Taupo Pumice, or tephras older than 5000 years), three have soil parent materials that are wholly or significantly tephric in origin, while one is defined by the absence of significant tephric soil parent materials. Depth and texture of tephra deposits, climate and underlying rock type are used to further subdivide the suites.

In contrast, for the South Island and Marlborough LUC regions the hierarchical structural framework of the extended legends is used to distinguish the LUC Suites. The factors used include environment, landform, rainfall zone, soil depth and degree of stoniness, the presence or absence of loess, underlying rock type, or rainfall and temperature zones related to elevation and indigenous treeline.

The use of LUC Suites as a tool in landscape assessment is further discussed by Blaschke (1985b).

3.6 Explanatory notes

3.6.1 Cultivation for cropping – 'Arable Use'

'Suitable for cropping' means, that under good management, the land is capable of growing at least one of the common, annual field crops normally grown in that region without any permanent adverse soil effects, and with average yields justifying the growing of that crop.

These crops include wheat, oats, barley, maize, peas, lupins, field-grown vegetable crops and potatoes, linseed, meadow foam, fodder beet, swedes, turnips, kale, choumoellier, rape and canola. In the warmer districts crops such as soyabeans, sunflower, rice, sorghum, Sudan grass hybrids, sugar cane, and the fibre plants ramie and kenaf may become common, with increased global warming (Lynch 1967; MFE 2004). Other crops new to New Zealand may be added in the future. The list of common crops does not include grass or lucerne although much arable land is used for these purposes. Predicted changes in climate and carbon dioxide levels have the potential to exacerbate regional differences in cropping practices and productivity (Hennessy *et al*. 2007). For example, temperatures in New Zealand in the 2030s are predicted to be 0.1 to 1.4^{o}C higher than 1990 levels (Wratt *et al*. 2004), with consequent opportunities for greater use of and variety of warm-season crops in more northern parts of the country. The effects of climate change on weeds, pests and diseases, and their impacts on crops, are uncertain.

'Cultivation for cropping' and 'arable use' implies that the land is capable of producing one of these crops at least once in every 4 or 5 years. In many districts it is a common practice to leave such areas in pasture for 5 to 10 years, or longer. Direct drilling, minimal tillage and no-till techniques to establish crops and pastures can significantly reduce erosion susceptibly and risk.

The erosion risk or some other soil limitation prevents much land from being regarded as arable, when it is cultivated out of scrub, fern or poor grass in order to establish permanent pasture. When establishing or renewing pasture, common practice is to sow a forage crop and either undersow with grass, or cultivate and resow after the forage crop is fed off. This is not sufficient to justify the land being classed as suitable for cultivation for cropping.

4. SURVEY GUIDELINES

Previous sections have focused on criteria and standards for assessing Land Resource Inventory (LRI), and for classifying Land Use Capability (LUC). This section concentrates on the practical and fieldwork aspects of undertaking an LRI survey and its subsequent refinement into an LUC classification.

The purpose is to outline recommended LRI and LUC procedures for producing maps, databases, and extended legends **to a consistently high standard**. Use of survey results is discussed more fully in the Applications section (Section 5).

Procedures can vary between surveyors, so guidelines are provided both for farm surveys and for extensive surveys (district, regional, national). Practising surveyors may tailor these guidelines based on their experience and individual project requirements. Novices should adhere closely to the guidelines, ideally under the mentoring of an experienced practitioner.

4.1 Guidelines for farm LRI/LUC surveys

Farm-level LRI/LUC surveys are undertaken predominantly for 'farm planning', where LRI and LUC form the basis of developing a programme for improved resource use and management. Other increasingly common applications include nutrient budgeting and farm development projects. Five steps are recommended for a farm-level survey (Figure 13).

4.1.1 Step 1: Project start

Each project should be scoped to determine if a quality job can be achieved within a given time-frame, budget and available resourcing. Availability of aerial photography should be checked, and some thought given to the best time for undertaking fieldwork. There may be calendar periods that are unsuitable for the farmer (e.g. lambing), and periods that are unsuitable for fieldwork from a weather perspective.

Info box 1: Tips on being an efficient surveyor

- ⇨ Be well-versed in LRI/LUC survey and classification techniques. Study this Handbook.
- ⇨ Develop the ability to interpret landscapes and work out terrain complexity. Learn landscape formation, soil development, and geology fundamentals. Study local geology and soil reports.
- ⇨ Maintain an active level of fitness for traversing uneven terrain and/or long distances.
- ⇨ Refine your own mapping style and survey kit to better suit the types of projects and landscapes you encounter most often.
- ⇨ Learn to adjust survey intensity and technique to project purpose (see discussion on scale and 'lumpers and splitters').

Farm LRI/LUC survey

1. Project start
- *Survey is requested*
- *Project scoped*
- *Confirmation*

2. Preparation
- *Project planning*
- *Survey kit and mapping materials*
- *Background investigation*
- *(Draft land units)*

Effective preparation will ensure:
- That the work of other resource investigations will not be repeated, but will be built upon.

- That a basic understanding of the local landscape will be gained, and an expectation of what will be encountered can be developed.

- An organised approach to survey to minimise the potential for wasting time in the field.

3. Field survey
- *Farmers' knowledge*
- *Land Resource Inventory mapping*
- *(Proposed Land Use Capability)*

Field survey is a physical activity that requires good fitness levels particularly in hill and steepland terrains.

Be prepared for variable weather conditions and extended exposure to the elements (e.g. all day in the sun).

Be aware of farm remoteness - help or contact may not be immediately available, particularly on larger properties.

Access to private land is a privilege. In all cases respect farm visitation protocols (see Info box 6).

4. Office work
- *Map draughting/digitising*
- *Land Use Capability Classification*
- *Extended legend*

Start office work immediately after the survey. Delaying the write-up increases the risk of forgetting important details, and may lessen confidence when seeking to clarify map unit boundaries and inventory descriptions.

One technique is to spend an hour at the end of the day redrafting map units onto a clean base map, reviewing notes, and expanding on inventory descriptions.

5. Applications
- *Farm planning*
- *Nutrient management*
- *Etc.*

Figure 13: Overview of recommended steps for undertaking farm-level LRI/LUC survey. Core steps are highlighted in blue boxes, and each step is equally important as the next.

4.1.2 Step 2: Preparation

Fieldwork can be physically tiring, constrained by time (particularly if travel distances are long), and the degree of support available in the office will not be available in the field (e.g. reference material, an experienced surveyor). Preparation is important to ensure that the survey is organised, efficient, and effective in terms of producing a quality result.

4.1.2.1 Project planning

Special considerations when planning a farm survey include defining a purpose, working out logistics, setting project scale, and arranging input from other people.

Define purpose: A purpose statement provides direction and boundaries. It should be clear, specific and practical. For example, *produce a farm LRI/LUC map and extended legend to identify areas of erosion risk and best options for management, before June 30.*

Logistic arrangements: Where is the farm? How do I get there? How long will it take? Is a 4WD vehicle required?

Scale: LRI/LUC farm surveys are typically undertaken at around a 1:10,000 scale (Tables 1 and 18). However, scale may also be influenced by practical limitations (see Info box 2). Special surveys that require particularly high standards may be undertaken at half the publication scale (e.g. field survey at 1:5,000 and publication at 1:10,000).

Input from others: This may involve talking with experienced surveyors; working with a GIS person to obtain a base map and arrange map production; and contacting the farmer to arrange meetings, survey dates, and finding out about potential farm hazards.

4.1.2.2 Mapping materials

Mapping materials essentially refer to a ***base map***, which in most cases should be an orthophoto (a digitally corrected aerial photo that has had camera and terrain distortions removed, and georeferenced against a coordinate system). Use of uncorrected raw aerial photos and topomaps is increasingly uncommon. Also note that high-resolution satellite imagery is an excellent resource for mapping (when available for a particular farm). A useful base-map size that balances a decent coverage with manageability is the A3 page (297 x 420 mm).

Info box 2: Practical considerations regarding the choice of mapping scale

Ideally scale is determined by the smallest area of interest (see Section 1.2). In practice, several other factors can influence the actual scale of mapping:

⇨ Aerial photo resolution. Mapping at detailed scales requires high resolution imagery or photography. If this is not available, scale needs to be adjusted to match the resolution of the imagery/photo that is available.

⇨ Survey extent (farm size). It may not be practical to map a large farm at a detailed scale for normal farm planning purposes. In this case a less detailed scale would be more suitable.

⇨ Manageability. A base map that is a single page of manageable size is far easier for fieldwork than either a large poster-type map, or an overlapping collection of several small pages or photos.

4.1.2.3 Survey kit

Many items can be of use in the field, but a balance is required to ensure a comfortable pack weight and easy access to key items.

Exactly what is included will vary with the type of landscape, survey purpose, and personal preference. However, some items are essential (see Info box 3). A more comprehensive list of recommended items is included in Section 4.2.2.

One particularly useful item is a laminated quick-reference 'LRI code sheet', which summarises the codes and descriptions of local inventory factors (from Tables 2, 6, 7, 8 and 11). Alternatively, the new edition Handbook can be used.

Occasional or special-purpose items can be left in the vehicle. It is also important to have robust footwear (boots with ankle support), sun hat, and at least a lightweight wind/rain-proof jacket.

Info box 3: What's in a surveyor's kit?

Items included in field kits vary with individuals. Below is a list of items found in one surveyor's backpack.

- Clinometer (see Info box 4)
- Clipboard with base map
- Notebook
- Pens and markers
- LRI code sheet
- Spade
- Knife
- Cellphone
- Camera
- Drink bottle
- Sunscreen
- Lunch
- Lightweight wind/rain jacket

The following is a 'base kit' generally left at the vehicle.

- LUC Handbook
- Soil handbooks
- Reference material (e.g. local soils, geology, NZLRI).
- Auger

4.1.2.4 Background investigation

Generalised land, soil and geology information is available for most agricultural areas. Relevant information should be sourced and reviewed to gain an insight and expectation of the type of resources and capability classifications that may be encountered in the field. This information can also be a rich source of *description criteria* for local soils, geological feature types, and regional LUC units.

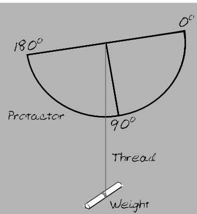
Sources of published and unpublished information are discussed in Section 2. Of particular relevance is the NZLRI database, worksheets, extended legends and regional bulletins where available (see Section 4.3.1). Local 'farm plans' can also be useful but may vary in terms of quality and availability.

Info box 4: Clinometers (inclinometers)

Clinometers are tools for measuring slope angle. They can be sourced from suppliers of technical instruments.

Common clinometer

Compass clinometer (Geological or Brunton compass)

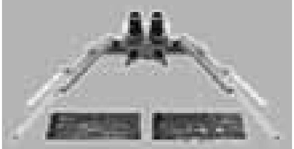


Home made clinometer

Info box 5: Stereoscope mapping

A stereoscope is used to create an illusion of landscape depth from two overlapping aerial photos. They are powerful mapping tools if paired photos are available. Not everyone can use a stereoscope.

Pocket stereoscope for field use



Mirror stereoscope for use in the office

4.1.2.5 Draft land units

Deciding where to draw a unit boundary in the field can be difficult. Likewise, exactly where the line is drawn may be changed several times as a surveyor moves around the landscape and sees the unit from different locations and perspectives.

Fieldwork can be assisted by preparing a preliminary map of land units using remote techniques. Field mapping then becomes an exercise of validating boundaries and infilling LRI code.

A map of draft units is prepared by interpreting aerial photos, images and maps. At its simplest, dominant landforms can be distinguished using aerial photography, provided the photos have sufficient landscape contrast and definition (e.g. older black and white photos). High-resolution satellite imagery can also be useful.

Some insight may be inferred from hill-shaded digital elevation models, but at the time of writing few models are available at a level of detail useful for farm mapping. Similarly, automated landform classification has potential but still requires development for regular application.

Stereoscopic mapping is especially useful (Info box 5). A stereoscope creates an illusion of terrain depth, which makes landforms very distinctive (exaggerated) and easy to recognise. Similarly, digital photogrammetry allows for on-screen 3D digitising, but high set-up costs generally limit use to larger survey projects (see Section 4.2).

Info box 6: Farm visitation protocols

- ⇨ Never access a farm without an invitation, or without telling the farmer.
- ⇨ Always tell the farmer where you are likely to be on the farm each day. Likewise, inform a co-worker of your surveying intentions for the day, and report back when finished.
- ⇨ Use gates where possible. If scaling fences is unavoidable, climb over at posts or strainers.
- ⇨ Leave gates as you find them (i.e. open or shut).
- ⇨ Treat all farm animals as dangerous, particularly stags, bulls and dogs.
- ⇨ Don't intervene in farm management unless a problem is encountered that needs immediate attention (e.g. a cast ewe). In all other cases, report suspected problems to the farmer as soon as possible.
- ⇨ Make a point of asking the farmer if there are any hazards or health and safety issues that you need to be aware of.
- ⇨ Do not 'borrow' or use farm machinery or equipment without prior permission.

4.1.3 Step 3: Field survey

Field survey involves a farm visit to physically map and describe the land resource. Farm visitation protocols should be observed at all times (Info box 6), and a simple vehicle sign can help offset any potential 'neighbourhood watch' issues.

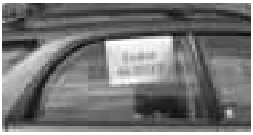


Plate 80: Rural neighbourhood watches can be particularly vigilant. A simple sign informs people why there happens to be a strange vehicle parked on the side of the road (AKM).

4.1.3.1 Farmer's knowledge

An astute surveyor will take the time to find out what a farmer knows about their land. Farmers tend to have a practical working knowledge gained through years of cultivating, digging post holes, and observing how land and soils change in response to seasons and management.

A short informal interview is recommended, whereby the farmer is invited to sketch a resource map of their farm. The aim is to identify general differences in land type by prompting with relevant questions (e.g. which areas are wetter… dry out first in summer… grow the most grass… have the worst erosion?).

4.1.3.2 Land Resource Inventory mapping

Either a reconnaissance or systematic approach can be used to map a farm. The reconnaissance technique involves quickly traversing the property to produce a draft map, and then selectively returning to areas that require further investigation. The systematic technique involves starting at one end of the farm, and systematically mapping in a regular pattern until the survey is complete.

A survey should aim for even coverage; each part of a farm should be investigated. Complete coverage of easy country can be achieved using a grid pattern or regularly spaced traverses. Mapping paddock-by-paddock is an alternative if electric fences are a barrier. Hill country survey patterns are often influenced by landscape access, whereby mapping routes are determined by ridge lines and valley floors. Larger grid patterns (quadrants) are useful, particularly for extensive hill country surveys.

Inventory units can be mapped by starting with major landform types (e.g. flats, hills, terraces) and gradually refining them down into smaller units. In principle, any significant change in a single LRI factor (rock type, soil, slope, erosion or vegetation) requires the mapping of a new inventory unit. However, this should be balanced with considerations of scale and a thorough understanding of how codes can describe within-unit variation (e.g. see Plate 34 and Info box 7).

Assess each inventory factor using the guidelines and criteria presented in this Handbook (Section 2). Code may be recorded directly on the map, and auxiliary notes taken in a notebook. If codes will not fit within the drawn unit, use a numerical legend (1, 2, 3, 4…) and record the code in the notebook.

4.1.3.3 Proposed Land Use Capability

Directly inferring LUC in the field without having first prepared a physical inventory is discouraged. Without LRI there is limited justification or evidence to back up the classification. However, it is fully acceptable to make inferences about LUC while mapping LRI. The proposed LUC should then be confirmed back at the office.

Info box 7: 'Lumpers and splitters'

'Lumping and splitting' refers to how different surveyors delineate mapping units. 'Lumpers' tend to map large general units by focusing on the dominant or most important landscape characteristic. The advantage is quick surveying and a 'big picture' overview of the land resource.

'Splitters' attempt to delineate a wider range of landscape characteristics to produce smaller units and more detailed inventories. LRI units may later be aggregated during LUC classification if necessary. The advantage is a more descriptive inventory and classification, and the level of detail allows for more targeted recommendations. However, mapping times can be longer, and the result can be too complicated for practical farm management purposes.

4.1.4 Step 4: Office work

Office work should be undertaken soon after the survey to avoid forgetting important details. The aim is to refine the inventory, classify LUC, and produce maps, legends and reports to a quality standard.

4.1.4.1 Map draughting/digitising

Prepare for digitising: Redraw the field LRI units as a tidier version ready for map production. At this stage do not add the inventory codes, but rather assign each unit a unique number (1, 2, 3… etc.).

Digitising: Most modern digitising is undertaken using a Geographic Information System (GIS), although farm mapping software can also be used. A common procedure is to scan the redrafted map(s), georeference them within a GIS, then digitise the farm boundary followed by the LRI units.

Create an attribute database: Digitising within a GIS will produce a default attribute database or table file. Add a new field/column and manually input the 'unique numbers' that were assigned for each LRI unit earlier.

Either add more fields/columns and manually enter the full LRI code for each GIS polygon, OR create a more easily managed spreadsheet using the same ‘unique numbers’ and then later link the spreadsheet back to the GIS database using a 1:1 relational join.

Info box 8: Map reference information (metadata)

A well prepared map includes reference information that describes the map itself (see Section 5 for examples). Considerations include:

- ⇨ Authorship and date of map preparation.
- ⇨ Data used in the map, particularly aerial and ortho-photography (date of photo, image resolution, accuracy, source, copyright).
- ⇨ Field work particulars including survey intensity (survey scale or number of observations per unit area) and who undertook the survey.
- ⇨ Copyrights and disclaimers.
- ⇨ Farm particulars (owner, address, contact, office reference details).

Map design and output: Several map design options are presented in Section 5. Designs range from objective and minimalist, through to ‘rich maps’ where colour, layout and overlays are used to help with map interpretation. Aerial photo overlays can help orientate the map user, while colour can be used to distinguish LUC classifications (Info box 9) or indicate importance, severity or risk. Note that the use of transparent overlays can change colours, particularly with coloured aerial photos, and that on-screen colour separations may not be reproduced accurately by printers. A well-prepared map:

- ⇨ Has legible text (a reasonable font size).
- ⇨ Includes a title, north arrow, scale, legend and appropriate metadata (Info box 8).
- ⇨ Clearly conveys the intended information. The use of colour, aerial photo overlays and transparency does not confuse or mute the intended information.

Info box 9: LUC map colours

The previous handbook edition recommended a standard national set of colours for presenting LUC Classes on maps. Uniformity allows quick recognition by map users throughout the country. However, the colours were not particularly well coordinated (see below), and some farm-scale applications resulted in mono- or duotone coloured maps (i.e. only one or two LUC classes present).

Considered use of colour is recommended in this Handbook edition. For example, lighter to stronger colours may be used to portray LUC rank.

LUC 1	Sap green	$_{R}80\ _{G}125\ _{B}42$
LUC 2	Yellow	$_{R}255\ _{G}255\ _{B}0$
LUC 3	Crimson lake	$_{R}206\ _{G}0\ _{B}64$
LUC 4	Light blue	$_{R}120\ _{G}200\ _{B}220$
LUC 5	Hookers green	$_{R}0\ _{G}70\ _{B}30$
LUC 6	Chrome orange	$_{R}250\ _{G}150\ _{B}30$
LUC 7	Raw umber	$_{R}135\ _{G}90\ _{B}50$
LUC 8	Mauve	$_{R}224\ _{G}176\ _{B}255$

LUC class colours from the 2nd edition handbook with approximate system RGB values.

Map extract from a 1960s LUC survey.

4.1.4.2 Land Use Capability Classification

How to interpret inventory into Land Use Capability is detailed in Section 4.3. Briefly, the classification is applied by hierarchy (i.e. firstly allocate classes, then subclasses, then lastly the LUC Unit) according to the criteria and standards set out in this Handbook (Section 3).

It is important to note that farm LUC classifications are made using existing regional LUC units where possible, or correlated with the regional equivalents to produce two levels of classification (a farm and regional classification). Regional classifications provide more information (e.g. production indices and special management considerations by LUC Unit), and ensure that the LUC system is applied consistently and uniformly throughout the country. The use of regional classifications is discussed more fully in Section 4.3.1.

However, preparing a farm-particular classification is a useful exercise for novices, and is generally a more intuitive and easy-to-understand ordering of information for the end user (e.g. 6e1, 6e2, 6e3… conveys more immediate meaning than the regional equivalent of 6e2, 6e4, 6e23…). Assign farm LUC units by ranking subclass sets (e.g. all 3s land on a farm) according to relative capability and management needs.

4.1.4.3 Extended legend

An ‘extended legend’ is an extension of the map legend. It summarises inventory descriptions by each LUC unit, and typically provides supplementary information regarding land qualities and management considerations in a form easily understood by users (see Figure 23, Page 124).

4.1.5 Step 5: Farm applications

Rarely is a farm LRI/LUC survey undertaken solely to provide a map and description of land use capability. How farm LRI/LUC survey can be applied is discussed in Section 5.

Info box 10: The importance of training and experience

Adhering to the standards, criteria and methodology outlined in this handbook will help ensure a robust survey and LUC classification. However, repetition and experience is required to promote self-confidence and quicker assessments. This process can be accelerated by:

- ⇨ Studying this Handbook in detail.
- ⇨ Obtaining assistance and guidance from experienced surveyors, and mentoring if possible.
- ⇨ Attending training courses and workshops.
- ⇨ Self-calibrating. For example, a common novice error is rating erosion severities too high because truly severe or extreme erosion has yet to be encountered in the field. A degree of self-calibration can be achieved by studying erosion severity examples, and by using published surveys to guide or tune how erosion severity will be rated during a farm survey.

4.2 Guidelines for extensive LRI/LUC surveys

Large and extensive surveys are undertaken at district, regional and national levels. They typically cover large areas, use less detailed scales, and have a general rather than specific resource management purpose (i.e. they are used for many different applications). Survey size necessitates high levels of preparation, organisation and coordination, and often justifies the use of more demanding survey techniques, technologies and quality assurance protocols.

The main steps recommended for undertaking extensive LRI/LUC surveys can be arranged into four broad categories of *preliminary investigation*, *mapping (field survey)*, *synthesis* and *implementation*.

4.2.1 *Preliminary investigation*

Once the LUC survey has been commissioned the following procedures need to be undertaken. The size and detail of these individual tasks depends on the objectives of the survey, the extent of the area, and the types of country.

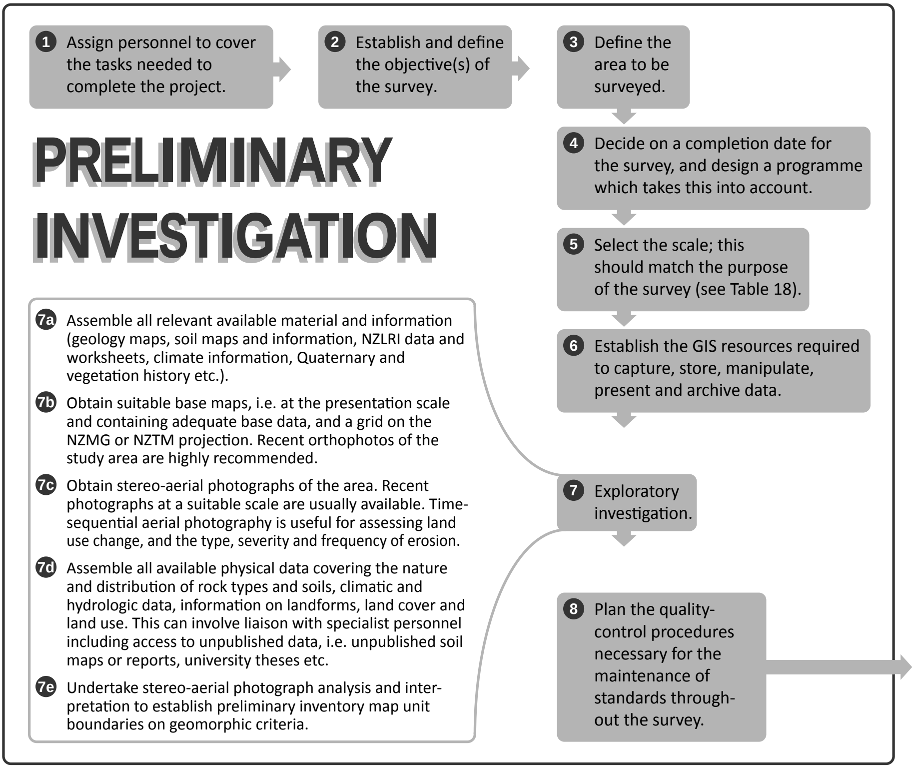


Table 18: Guidelines to the selection of appropriate scales for extensive LRI/LUC surveys (modified from McRae & Burnham 1981 and Jessen 1987).

Scale level[1]	National	Regional	District and catchment	Farm
Scale[2]	1:250,000 to 1:100,000	1:100,000 to 1:50,000	1:50,000 to 1:15,000	1:<15,000
Scale size[3]	Small	←	→	Large
Map detail[3]	General	←	→	Detailed
Smallest area[4]	40–250 ha	10–40 ha	1–10 ha	≤ 1 ha
LUC level	Dominant capability class or subclass	LUC unit (regional)	LUC unit (regional)	LUC unit (regional and farm[5])
Common application examples	Strategic overview, broad planning, prioritising or targeting projects for detailed investigations.	Land use planning, targeting of regional priorities and projects, reference for more detailed survey.	Catchment projects, small district/community projects, farm planning for large properties.	Farm planning (detailed), nutrient budgeting, farm development projects, precision agriculture.

1 Scale levels are subjective. Meaning is often dependent on context (e.g. a 'detailed' scale in a farming context is different from a 'detailed' scale in a regional context).

2 Recommendations are based on common NZ scales used in soil, geology and LRI/LUC surveys.

3 Large and small scale terminology is confusing. A 'large' scale (e.g. 1:5,000) is actually more detailed than a 'small' scale (e.g. 1:500,000). Scales are essentially fractions, and fractions with large denominators are smaller numbers (e.g. 1:5,000 is the same as 1/5000 or 0.0002, which is a larger number than 1:500,000 = 0.000002).

4 The smallest area of interest represents the minimum legible area (MLA) that can be displayed on a paper map at a given scale. Any smaller and labelling becomes illegible, and line boundaries become disproportionate. Modern digital printing can accommodate a minimum legible area as small as 0.4 cm^2 (after Forbes *et al*. 1982).

5 Occasionally regional LUC Units may require adaptation at the farm scale (see Section 4.4).

4.2.2 Inventory and mapping (survey)

The main steps involved in mapping are presented opposite. Special consideration should be given to remote techniques and technologies, both of which are particularly useful for large and extensive surveys.

Remote mapping is particularly feasible because large areas can be mapped quickly at relatively low costs. Set-up can therefore be justified, and appropriate-resolution imagery is often already available. Useful techniques and technologies include stereoscopic mapping, satellite classifications of land cover, digital photogrammetry, and potentially automated landform classification.

However, remote mapping can only provide predictions. It does not replace the need for fieldwork. ***Predictions still need to be checked, truthed and refined with ground survey.*** Likewise, some inventory factors cannot yet be predicted remotely (e.g. rock type), and a ground survey adds context to certain assessments (e.g. erosion severity, present management, recommended management).

INVENTORY AND MAPPING

1 Carry out reconnaissance field investigations.

2 Draft land units.

- **2a** Establish primary inventory map unit boundaries on geomorphic criteria (combinations of rock type, landform and slope angle). Stereo-aerial photograph analysis and interpretation backed up with field confirmation is critical. Stereo-aerial photographs enable you to 'see' all the terrain in one 'view', and 'see' each component in context with respect to the surrounding terrain.
- **2b** Separate flat and rolling areas from hill and steeplands, and then break each of them down further as required.

3 Carry out the main body of the fieldwork.

- **3a** Confirm the map unit boundaries originally determined by stereo-aerial photograph analysis and interpretation.
- **3b** Make comprehensive notes about all inventory factors. These notes will constitute a major database for the inventory map units, and are essential for report writing. Take numerous photographs, especially of important and characteristic soil and rock exposures, erosion types and severities, landforms and land use attributes.
- **3c** Any additional soil information should be collected using standard soil description procedures and terms such as those in Milne et al (1995), Hewitt (1998).
- **3d** Give consideration to LUC Class and Subclass guidelines and limitation criteria. This includes linking characteristics in the inventory to certain types and degree of limitations (e.g. soil depth and texture characteristics) LUC Class limits etc, thereby establishing standards to assist limitation evaluation.
- **3e** If applicable fit existing NZLRI LUC Units to the inventory units mapped. If appropriate subdivide existing LUC Units on relevant characteristics such as aspect or slope length. Establish 'new' LUC Units as required.
- **3f** Liaise with local professionals and the landholders to gather local knowledge.

4 Compile secondary inventory map units and establish a data listing.

- **4a** Compilation involves:
  1. Interpretation of stereo-aerial photographs.
  2. Interpretation of existing data gathered from preliminary investigations.
  3. Interpretation of data obtained from fieldwork.
  4. Translation of the inventory to Land Use Capability (see Section 4.3).
- **4b** Compilation results in:
  1. Inventory map units delineated on aerial photographs and/or a base map.
  2. Inventory codes, LUC class and subclass assessments and codes recorded in a data listing and linked to map units with unique numbers.
  3. Inventory map unit boundaries, unique numbers and LUC assessments all recorded on a base map. This is a draft Land Use Capability map.

5 Audit the draft LUC survey data. Auditing involves intensive field and office checks of the data. A principal auditor should be selected for their knowledge in LUC mapping. Personnel with specialist skills can be involved in checking as required.

Auditing invariably results in improvements to the draft data, and these are usually made by returning to the compilation step. If problems uncovered by the audit have their origins in an earlier step in the survey programme, then the programme is re-entered at that step. Amendments are checked and approved by the principal auditor before synthesis can begin.

LRI/LUC surveys do not normally entail detailed testing and sampling, consequently the required field equipment is neither sophisticated nor too heavy to carry in the field. However, more items are generally required relative to farm-level LRI/LUC surveys (Table 19).

Table 19: Suggested checklist of items to include in a kit for extensive LRI/LUC surveys.

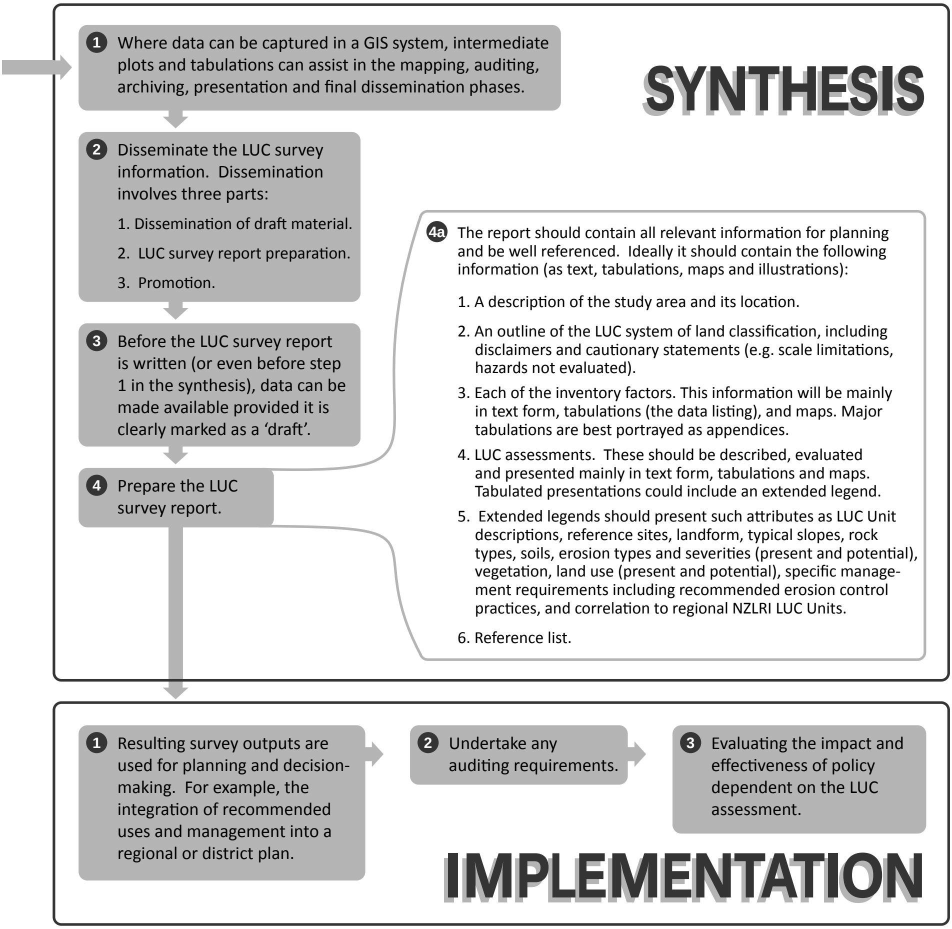
Documentation	
• Aerial (ortho-) photographs on which the primary map units are delineated. • Base map (topomap or orthophotograph). • LUC Handbook incorporating tables depicting classifications for rock type, erosion type and severity, vegetation cover etc. • Relevant geological and soil maps and associated information.	• Soil profile description guides e.g. Milne *et al.* 1995; Hewitt 1998. • Munsell soil colour charts. • Waterproof notebook or PDA/Laptop.

Equipment	
• Clipboard. • Pencils (including a chinograph type), waterproof pen, eraser. • Pocket stereoscope. • Digital camera. • GPS. • Binoculars. • Knife.	• Measuring tape with clearly marked scale. • Spade. • Soil auger. • Geological hammer. • Compass and clinometer, or combination compass with clinometer. • Plastic bags for soil and rock samples.

4.2.3 Synthesis (write-up)

Synthesis focuses on collating survey results for reporting and publication. Recommended steps and considerations are presented opposite.

Traditional outputs include a publication with maps (or worksheets), extended legends, and perhaps even a classification bulletin. More recently the GIS database has become a standard output. Publication or release of GIS databases should be paired with a metadata report that explains geographic characteristics, methods of collection, information quality, and other considerations to ensure the data are used within their limits.



4.2.4 *Implementation / Evaluation*

Implementation refers to the use or integration of survey results to assist with planning and decision-making.

The full LRI/LUC survey process should be reviewed and evaluated for extensive survey projects. Unforeseen inefficiencies may have been encountered no matter how well the preparatory steps were undertaken. Review and evaluation leads to the improved delivery of future projects.

4.3 Translation from inventory to Land Use Capability

When the physical inventory has been recorded, the next step is an interpretive translation of these data into the LUC system, following the framework established for the various LUC Classes, LUC Subclasses, and LUC Units (Section 3).

The initial primary classification according to the degree of physical limitations establishes the LUC Class; the dominant kind of limitation is indicated by the LUC Subclass; and then the LUC Unit is established.

Subclasses can be subdivided into LUC Units by grouping those inventory units with a particular and unique set of inventory characteristics such as rock type, slope, and landform, which require the same management.

This orientates the classification towards management and potential production. Both facets of conservation – protection and production – have to be considered in accordance with the concept of 'use and risk'. Two methods are recommended:

1. Making classifications when regional classification descriptions are available.
2. Making classifications in the absence of quality regional classifications.

4.3.1 Using an existing regional classification

The New Zealand Land Resource Inventory (NZLRI) provides an interlinked LUC classification for New Zealand. The classification is divided into 12 'LUC regions', each of which uses its own slightly different classification at the unit level (e.g. 2w1 in one region may not be the same as a 2w1 from another region). These are referred to as 'regional classifications' (see Section 4.5).

LUC Unit descriptions for each regional classification are available as extended legends and bulletins. ***New LUC classifications should be based on existing regional classifications where possible***. This is achieved by sourcing the relevant extended legend or bulletin for the region of interest. Bulletins are generally more comprehensive, but are only available for eight of the 12 regions (Figure 14). Regional classifications also vary in quality and description. See Section 4.3.2 if an appropriate extended legend or bulletin cannot be sourced.

Bulletins and extended legends provide a framework for the consistent allocation and ordering of LUC into units and suites (e.g. Table 20). Each framework follows a series of steps, commencing with an understanding of landforms, rock types and soils. The main landforms, rock types and soils are often used to develop LUC Suites (Section 4.5) and component LUC Units within a hierarchy. These frameworks will then guide the selection of LUC Units based on the inventory. Frameworks, and final LUC Units, are continually refined as the mapping progresses to completion.

Some of the more recent bulletins also provide a clear ordering and simplification of the classification process by using regional decision-tree pathways (e.g. Harmsworth 1996; Lynn 1996; Jessen *et al*. 1999).

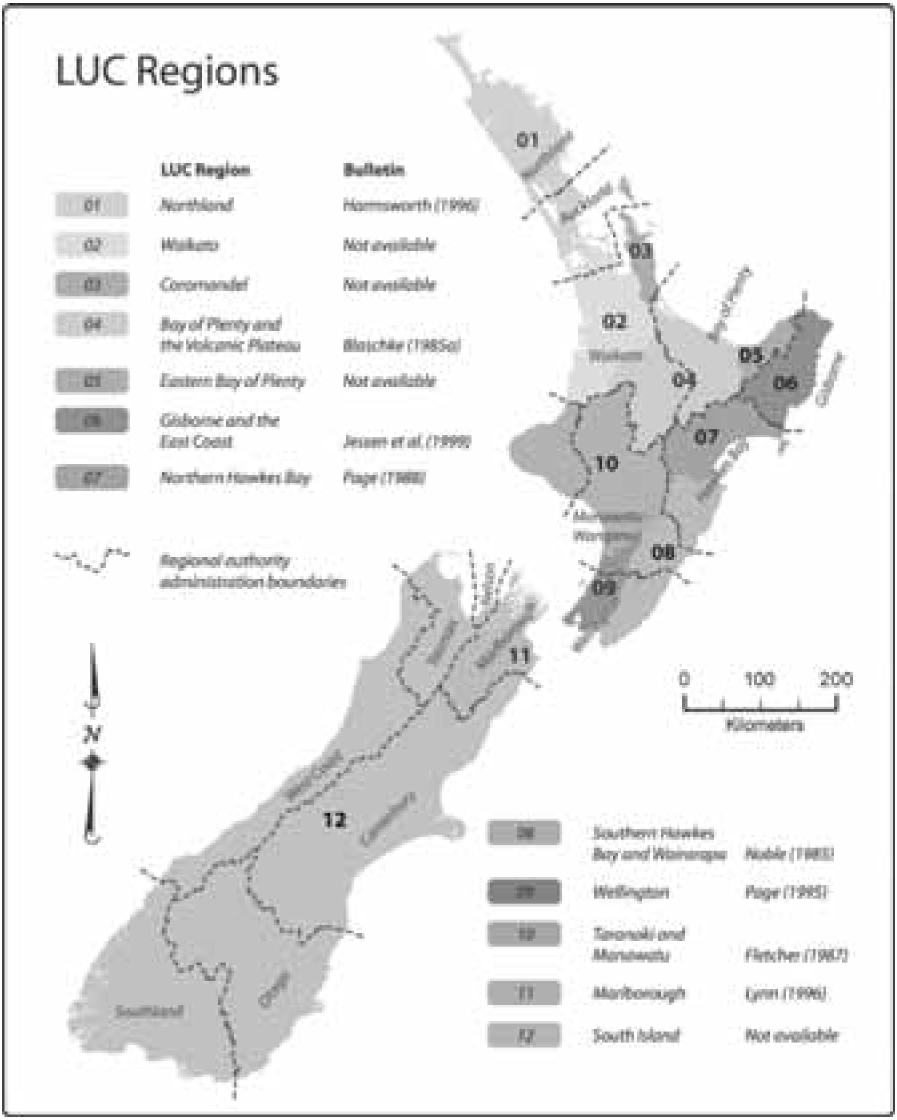


Figure 14: Land Use Capability regions and published bulletin availability. Dotted grey lines represent administration boundaries of regional and unitary councils.

Table 20: LUC Suites, Sub-suites and component LUC Units in the Northland Region (Harmsworth 1996).

LUC Suite	Sub-suite		Component LUC Units
1. Coastal sand country			
	(a)	Young unstable sand dune complex.	6e15, 7e10, 8e1
	(b)	Old stable sand dunes on unconsolidated to compact sands.	3e5, 3s4, 4e9, 6e6, 7e9
	(c)	Old stable podzolised terraces and escarpments on unconsolidated to compact Pleistocene sands.	4e10, 4s5, 6e14, 6s4, 7e9
2. Alluvial and estuarine plains and low terraces			
	(a)	Well-drained floodplains and low terraces.	2w1, 3w1
	(b)	Alluvial and estuarine plains with gley soils.	2w2, 3w2
	(c)	Poorly drained floodplains and low terraces.	4w1, 6w1, 7w1
	(d)	Mudflats with saline soils.	3w3, 4w2, 6w2
	(e)	Peats.	3w4, 4w3, 6w3, 7w2
3. Quaternary terraces with complex soils			
		-	2e2, 2w3, 2s2, 3e2, 3s3
4. Sedimentary rock terrain excluding greywacke			
	(a)	Interbedded and massive sandstone and mudstone.	3e3, 4e5, 6e1, 6e8, 7e4
	(b)	Older shattered and sheared argillites and sandstone.	4e6, 6e7
	(c)	Sheared mixed lithologies.	4e8, 6e12, 7e2
	(d)	Crushed argillite.	6e19, 7e8
	(e)	Limestone.	3s5, 4e1, 5c1, 6s3, 6e3, 7e3
	(f)	Limestone complexed with sedimentary deposits.	3e4, 4e4, 6e5
	(g)	Podzols on sedimentary rock.	4e12, 4s4, 4w4, 6s5
5. Greywacke terrain			
		-	4e7, 6e9, 6e10, 6e17, 6c1, 7e5, 7e6
6. Young basalt volcanic terrain			
		-	1c1, 2e1, 2s1, 3e1, 3s1, 3s2, 4e2, 4sl, 4s2, 5s1, 6s1, 6e4, 8s2
7. Old volcanic terrain			
	(a)	Landforms on old stable basalt-andesite volcanics with brown granular loams and clays.	4e3, 4s3, 5c2, 6e2, 6e16, 6c1, 7e1
	(b)	Landforms on volcanic/sedimentary complexes.	6s2, 6e11, 6e13
	(c)	Acid to intermediate igneous volcanics and plutonics.	4e11, 6e18, 7e7
8. Cliffs and precipitous slopes			
		-	8e2, 8e3, 8s1

Summary *information sheets* for each LUC Suite or specific LUC Unit can be developed outlining the characteristic rock types, landforms, soils, erosion severity and types, potential land uses and recommended soil conservation management practices and techniques (Figure 15).

Sandstone units – 7e11

Sustainable Land Management Programme

TARANAKI REGIONAL COUNCIL

7e11

Introduction

Land use capability unit 7e11 (Fletcher 1981, 1987) comprises steep to very steep (26°->35°) slopes formed from sandstone on the inland hill country east of Stratford. Ridge crests are usually sharp and narrow and the streams or watercourses at the base are often deeply entrenched. Sandstone bluffs are also present. Rainfall averages 1600 – 2400 mm p.a.

Figure 1. Typical LUC unit 7e11.

The dominant soils are Whangamomona steepland soil on silty sandstone and Moumahaki steepland soil on coarse sandstone. Both these soils have low natural fertility.

Production potential

Under improved pasture 7e11 is capable of growing between 4,300 and 5,000 kg dm / ha per annum, falling to 2,200-2,500 kg on steep eroded slopes. The *Pinus radiata* site index is 25-28m for the lower slopes. Upper slopes are unsuitable for forestry.

The preferred land use option is scrub regeneration or bush retirement on the upper slopes, and extensive grazing or forestry on the lower slopes.

Environmental limitations

- Potential for severe soil slip and debris avalanche erosion.
- Low soil fertility.
- Scrub reversion.

Environmental recommendations

If to be kept in pasture:

- Lightly graze lower slopes – do not expect high pasture yield.
- On upper slopes, allow scrub to regenerate to reduce slip damage.

If to be planted in woodlots:

- Plant lower slopes where soil depth favours tree growth and slope angle facilitates silviculture.
- Avoid planting upper slopes and gullies - these areas have low timber yield.
- Leave existing scrub along watercourses, or allow to regenerate, so that it controls bank erosion and traps silt.
- Use low-impact logging methods e.g. cable hauler or skyline, to minimise soil loss.
- Site tracks and landings away from watercourses to minimise sediment discharge and channel blockage by slash.

If already in scrub or bush:

- Leave indigenous vegetation – avoid clearance for pasture or forestry.
- Control animal pests that damage canopy (possums) or ground cover (goats, deer).

For further advice and assistance contact:

The Land Management Section
Taranaki Regional Council
Private Bag 713
Stratford
Ph: 06 7657127

Figure 15: Example of an LUC unit information sheet used by Taranaki Regional Council.

An alternative method of grouping LUC Units is through the use of a hierarchical *environmental framework*, as used in the Marlborough regional classification (Lynn 1996). Two decision tiers are used. Firstly, inventory units are allocated into one of 33 LUC Suites according to environment, landform, rainfall zones, soils and rock type characteristics (Figure 17). A more explicit decision-tree is then used to allocate the LUC Unit within the suite structure.

For example, the inventory code below (Figure 16) falls within the L4 LUC Suite according to the pathways of Figure 17. Once the suite has been identified, the inventory unit can be further classified down to the LUC Unit level according to limitations and management needs. For example:

- If soil depth is within 15–30 cm, then the classification would likely be 4s4 (severe root zone limitations for cropping).
- If soil depth is between 30–45 cm (fewer rooting limitations) but strong north-westerly winds make erosion a problem, then the classification would likely be 3e2 (root zone limitations are present but erosion is the dominant limitation for cropping).
- If the soil depth is within 30–45 cm and the mapping unit was in a sheltered location, then the classification may be 3s2 (a moderate rooting zone limitation for cropping).

At the farm scale, LUC Units could be further differentiated by topsoil stoniness. For example, a 3s2 unit may be further classified as 3s2a when topsoil stones are <5%, and 3s2b when stones are >5%. See Section 4.4 for refining regional classifications at detailed scales.

Inventory unit

$\frac{\text{Lo/Gr – 27 – B}}{\text{1W - gl}_9\text{cR}_1}$

Rock type =	Loess overlying alluvial gravels
Soil =	Ruapuna silt loam
Slope =	Undulating
Erosion =	Slight wind erosion
Vegetation =	Improved pasture (90%) + root and green fodder crops (10%)

Classified into the L4 LUC suite using Figure 17

L4

LUC suite

Environment =	<400m above sea level =	LOWLAND
Landform =	Undulating terrace ($0\text{-}7^0$) =	FLAT TO GENTLY SLOPING TERRACE, FLOODPLAIN AND FAN LANDFORMS
Drainage =	No mottles within 45cm =	WELL AND MODERATELY WELL DRAINED
Rainfall zone =	Annual rainfall of 1000mm =	MODERATE
Other features =	<45cm silt loam over gravels =	SHALLOW

Figure 16: Inventory classified into the L4 suite of the Marlborough regional classification.

Figure 17: Marlborough LUC suite classification structure (Lynn 1996).

Environment	Landform			Rainfall zone[1]	Other features[2]	Suite
Lowlands	Flat to gently sloping terraces, floodplains and fans (0-7^0)	Well and moderately well drained		Low	Deep soils	L 1
					Shallow soils	L 2
				Moderate	Deep soils	L 3
					Shallow soils	L 4
		Low-lying drainage impeded	Non-saline	Low	Alluvial soils	L 5
				Moderate	Alluvial soils	L 6
			Saline	Low to moderate	Saline gley recent soils	L 7
		Coastal sandflats and dunes		Low to moderate	Yellow-brown sand soils	L 8
	Moderately sloping land mainly downland (7-20^0)			Low	On loess	L 9
					On calcareous or basaltic rock	L10
				Moderate	On loess	L11
					On indurated rocks	L12
					On calcareous or basaltic rock	L13
	Hills and steeplands (>20^0)			Low	On loess overlying weakly indurated rocks	L14
					On strongly indurated rocks	L15
					On calcareous or basaltic rock	L16
				Moderate	On weakly indurated rocks	L17
					On strongly indurated rocks	L18
					On calcareous or basaltic rock	L19
				High	On strongly indurated rocks	L20
High country	Flat to gently sloping terraces, outwash plains, floodplains and fans (0-7^0)			Low	Shallow soils	H 1
				Moderate	Deep soils	H 2
					Shallow soils	H 3
				Moderate	Alluvial soils	H 4
	Moderately sloping land (7-20^0) moraine and fans			Low	Organic soils	H 5
				Moderate	Alluvium and colluvium	H 6
	Exposed uplands >950 asl			Moderate to high	Alluvium and colluvium	H 7
	Hills and steeplands (>20^0)			Low	Colluvium on strongly indurated rocks	H 8
					On strongly indurated rocks	H 9
				Moderate	On basaltic rocks	H10
					On strongly indurated rocks below indigenous treeline	H11
				High	On strongly indurated rocks above the indigenous treeline	H12
					On strongly indurated rocks above the indigenous treeline	H13

[1] *Rainfall zones: LOW = <800 mm, MODERATE = >800 mm to <1600 mm, HIGH = >1600 mm*

[2] *Soil depth: DEEP = >45 cm, SHALLOW = <45 cm*

4.3.2 If no regional classification is available

Regional classifications may not be available because the appropriate publication cannot be sourced, or a regional classification has not been prepared. For example, the only regional legend in the South Island is for Marlborough, the balance being covered by a single island-wide legend.

4.3.2.1 Modal classifications

In the absence of a quality regional classification, a listing of the soils and/or rock types in the area can be used to establish a modal LUC Class and Subclass from the first principles outlined in this Handbook, and adjusted for any anomalous soil unit/rock types.

These can then be modified, either upgraded or downgraded according to the soil phase, slope, aspect, degree of erosion, etc., or any other relevant factors shown by the inventory or relevant to the map units' geomorphic location.

An example of 'setting' modal LUC standards using soil sets representative of the South Island eastern mountain lands is given in Table 22 opposite. The soil sets are drawn from NZ Soil Bureau Bulletin 27 (New Zealand Soil Bureau 1968).

Although less comprehensive, the broad-scale South Island extended legend can also be used to establish a range of units for regional and more detailed studies.

Table 21: Selecting LUC units for the soils depicted in Table 22 using the hierarchical structure of the NZLRI Marlborough Regional extended legend (Figure 17).

mLUC Suite[1]	mLUC Units[1]	Soil set[2]
L1	2e1, 2e2	93a
L4	3e2, 3s2, 4s4, 5s2	27, 27a
L12	4e5	41aH
L18	6e8, 7e7	41aH, 41a
L20	6e18, 7e18	prt 65
H2	4c1, 4e8, 4e9	99
H3	4s9, 4s10, 5s3, 6s2, 7s3, 8s1	prt 99, prt 52
H6	6c2, 6e20	prt 52
H10	6e17, 7e22, 7e24, 8e9	57a
H11	7e25, 8c1, 8e11, 8e13	57
H12	8e16	prt 65
H13	7e25, 8c1, 8e12, 8e13	58

[1] Lowercase 'm' = Marlborough *[2] Codes from NZ Soil Bureau (1968)*

4.3.2.2 Adapting neighbouring classifications

The structural framework of the Marlborough regional classification (previous Figure 17) can be used to identify potential LUC Units for the same soils as used in Table 22. The most appropriate LUC Unit is identified from the specific characteristics and conditions of each site, matched to those specified in the LUC Suite distinguishing criteria (examples as Table 21 on previous page).

Table 22: An example of 'setting' modal LUC standards using soil sets (New Zealand Soil Bureau, 1968) representative of the South Island eastern mountain lands.

Representative soil sets [soil code]	Example map unit inventories	Modal LUC class and subclass	Modification criteria
Alpine Steepland [100]	Gw-100+BR-F+G/4Sc-gW*	8e	none
Spencer Steepland [58]	Gw-58+BR-F/3Sc-gW_4sS* Gw-58-F/3Sc-gW_5sD_1	8e	none
Lewis Steepland [65]	Gw-65-F/2Sh2Sc1Da-fG_6 Gw-65-F/2Sh-fG_8	8e	6e if <1000m and <3 erosion 7e if <1200m and not >3 erosion
Kaikoura Steepland [57]	Gw-57+BR-F/2Sh1Sc-gW_6sS_1 Gw-57+BR-F/3Sc-gW_5sS* Gw-57+BR-F/4Sc-gW_2sS*	7e or 8	7e if < 1400m and not >3 erosion
Tekoa Steepland [57a]	Gw-57a-E/2Sh2Ss-gT_6hH_2sM* Gw-57a-F/2Sh2Ss-gT_6sM_2 Gw-57a-F+G/4Sh2Ss-gT_3sM_3	7e or 8e	8e if > 1400m or 4 erosion 6e if >1000m, E slope, and 2 or less erosion
Hurunui Steepland [41a]	Gw-41a+BR-F/2Sh1Ss-$gTgS_6sF$*sM* Gw-41a-F+E/1Sh1Ss-gT_7gS_2hH*	6e	7e if 3 erosion or > 1000m
Hurunui Hill [41aH]	Gw-41aH-E+D/1Sh-gT_9sA_1 Gw-41aH-D/1Sh-gT0	6e	4e on cultivatable areas, C and D slopes
Craigieburn [52]	Lo/Gr-52-A/1W-gl0 Lo/Gr-52-A+B/2W-gS_6hH_2	4e	6e if shallow, stony or > 800m
Ashwick [27a]	(Lo)/Gr-27-B/1W-gl_9cR_1 (Lo)/Gr-27a-B/1W-gl_0	4 or 3e	3e where >30cm stone free over gravels, lower altitude (<600m), and more sheltered
Ruapuna [27]	Lo/Gr-27-B/1W-gl_8gS_2 Lo/Gr-27-B/1W-gl_9cR_1	3e	4e, s where shallower or bouldery phase
Tasman [99]	Af/Gr-99-A/1Sb-gS_5gl_5sA* Gr-99-A+B/1Sb1D1W-gS_7hH_3	3s, 4s, 5s, 6s	According to depth, structure, texture, stoniness, moisture holding capacity etc.
Kowai [93a]	Lo/Gr-93a-A+B/1W-gl_0	2e to 3s	According to depth, structure, texture, moisture holding capacity etc.

4.4 Modifying regional LUC Units for farm surveys

Regional LUC Units are occasionally too generalised for application at detailed farm scales. Either the regional units lack sufficient detail, or the unique component parts of these units may be individually mapped and even reclassified. Regional LUC Units may be split at the farm scale for management reasons, or for a more specific classification of existing units.

4.4.1 Splitting regional LUC Units for management

Regional LUC Units may be modified if opportunities for more targeted conservation or management can be identified through detailed mapping. For example LUC 6e8 from the Marlborough regional classification can be further divided according to shady and sunny hill aspects to become 6e8a (sunny) and 6e8b (shady) classifications. Soil, erosion severity and type, present and potential land use, and productivity indices as well as the soil conservation management recommendations and comments can then be specifically tailored to the varying needs of each contrasting aspect.

4.4.2 Deconstructing regional LUC Units

Scale determines the level of variation that can be captured within a mapping unit. Occasionally two or more LUC units may be present, but unit size is too small or complicated to map as separate units at the regional scale. In such cases either the dominant or least capable LUC unit is assigned.

At the farm scale these units can be deconstructed to their component classifications. If the component units have never been classified, then a new LUC Unit may be created.

For example, the 6e2 LUC Unit used in the Southern Hawkes Bay and Wairarapa regional classification (Noble 1985) is described as moderately steep to strongly rolling, fertile mudstone and siltstone hill country in higher rainfall areas with a moderate potential for shallow earthflow erosion. Strongly rolling landforms are not distinguished from the moderately steep landforms at the regional scale. However, at the farm scale, the strongly rolling landforms are of sufficient size and extent to be mapped separately. They are less susceptible to erosion and can therefore be managed differently.

Currently there is no existing regional LUC Unit that adequately describes these particular strongly rolling landforms in the Southern Hawkes Bay and Wairarapa regional classification. In this case a new 5e(*x*) LUC Unit could be classified according to the criteria outlined in this Handbook (Section 3.2.5). The (*x*) designates the as yet unspecified LUC Unit number.

4.5 Regional LUC correlations

4.5.1 North and South correlations

Twelve regional classifications were created during compilation of the 1:50,000 NZ Land Resource Inventory (see Section 4.3.1). Each regional classification is different, and neighbouring classifications are generally incompatible (although there is often a degree of overlap and similarity). In some cases the same type of land has been classified using several different LUC Units.

The 10 North Island regional classifications have been correlated to produce a single North Island LUC classification at a 1:50,000 scale (Page 1985). The South Island is represented by a single regional classification that was prepared under 1st Edition NZLRI mapping (NWASCO 1983). However, 2nd Edition mapping has been undertaken to produce the Marlborough regional classification (Lynn 1996), which is more detailed and is designed to cover all of the Marlborough District, but has yet to be mapped in the Marlborough Sounds.

4.5.2 Compatibility with regional administration boundaries

Regional LUC boundaries were created before the current regional and unitary council boundaries were established. These two types of boundaries only occasionally match and some modern regional administration boundaries can encompass several LUC regions (see previous Figure 14). This can complicate the use of regional LUC classifications for informing policy and planning.

Classifications that conform to regional administration boundaries can be developed by selective correlation of regional LUC classifications. Two examples following standardised methods are given below.

Example 1: Five regional LUC classifications occur in the Environment Bay of Plenty (EBOP) Region. The LUC units from the five LUC classifications were correlated and reclassified into one single EBOP classification. Both the original and the new LUC unit descriptions were presented together in an extended legend (Harmsworth & Page 1991, 1993). The new ordered EBOP LUC Units are called NBOP LUC Units or ‘new’ BOP LUC Units.

Example 2: As part of 3rd Edition LUC Handbook revision, the five LUC regional classifications found in the Hawkes Bay administrative region were listed, correlated, and classified into one single classification using the same methodology as used in Bay of Plenty. This work will provide a useful LUC correlation for future farm plan and LUC mapping.

4.6 Productivity indices

Regional productivity indices were created for LUC Units as part of the NZLRI mapping project. Indices include three levels of stock carrying capacity for pastoral use, and a *Pinus radiata* site index for forestry.

4.6.1 Stock carrying capacity indices

Stock carrying capacities have been estimated for each LUC unit recorded in the 1st Edition NZLRI. Carrying capacities are based on sheep stock units (su) where one stock unit is equivalent to a 55 kg ewe rearing one lamb. Representative LUC Units were evaluated by Ministry of Agriculture and Fisheries (MAF) Advisory Officers together with NZLRI survey staff. Three types of carrying capacity were assigned to each LUC Unit:

1. Present Average – The number of stock units per hectare (su/ha) which the 'average farmer' was typically carrying on a particular LUC Unit.
2. Top Farmer – The number of stock units per hectare that the farmer with the highest level of stocking rate, with at least average stock performance, was carrying on a particular LUC Unit.
3. Attainable Physical Potential - the number of stock units per hectare capable of being carried on a particular LUC Unit, assessed within the limits of present technology and given favourable socio-economic conditions (Table 23).

NZLRI stock carrying capacities only apply to 'typical sheep and beef farming systems'. They do not apply to dairying or cropping systems (LRG, 1981).

Table 23: Potential stock carrying capacity rankings (significant regional variations occur).

Stock carrying capacity ranking	Potential stock units per ha[1]
Very high	>25
High	21-25
Moderately high	16-20
Moderate	11-15
Low	6-10
Very low	1-5
Sparse	<1

[1] *One stock unit is equivalent to a breeding ewe (55 kg at mating) rearing one lamb.*

For national consistency the following criteria were adhered to:

- The land was assumed to be managed exclusively for livestock grazing.
- On-farm feed cropping only was considered.
- Is was assumed that the stock were carried all year (i.e. winter carrying capacity in most instances) except for high country where stock were carried for part of the year only. In this case, seasonal figures were converted to an annual stocking rate.
- It was assumed that each LUC unit was managed as a discrete entity.

4.6.2 Pinus radiata site index

Site index, defined as the mean height in metres of the 100 tallest 20-year old trees in a sampled hectare, provides an index of site quality for growing radiata pine in New Zealand (Table 24). *Site index* was determined for each NZLRI LUC Unit using the combined expertise of land resource scientists, New Zealand Forest Service advisors, commercial forest companies and forestry consultants. *Pinus radiata* was chosen as the indicator species because of its importance and widespread production.

Site index has largely been superseded by the *300 Index* in New Zealand, which uses modelling to predict mean top height, basal area and stocking annually through a rotation.

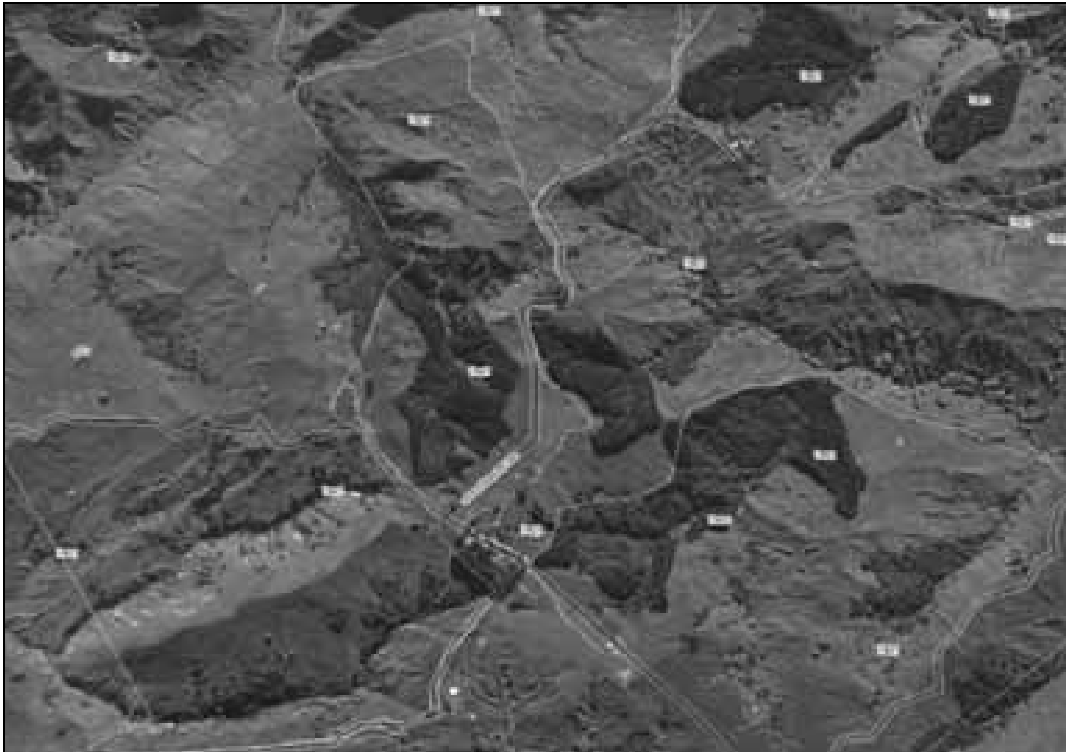
Table 24: Site index rankings for Pinus radiata.

Site index (metres)[1]	Site index ranking	Forest productivity[2]
>35	Very high	Highly productive
30-35	High	Highly productive
25-29	Moderate	Moderately productive
20-24	Low	Poorly productive
<20	Very low	Poorly productive

[1] Mean top height in metres of a stand of *Pinus radiata* aged 20 years

[2] These terms are used in the LUC unit descriptions to broadly define potential forest productivity

Figure 18: Works plan template for the Gisborne East Coast sustainable hill country programme.



(Please mark on this map and link back to this legend where appropriate)

Legend *Add map symbol*

Relevant existing fences	------------
Relevant paddock names	------------
Plant material types	------------
Establishment boundaries	------------
Fences to exclude some or all stock	------------
Overlay 3A areas already treated	------------
Overlay 3A areas that are untreatable	------------
Additional land areas next to 3A areas to be planted	------------
Proposed thinning or tree harvesting	------------

For office use only:
Recommended by:
Approved by:
Date:

Key

Overlay 3A targeted land

Land parcels

Legal roads

GISBORNE DISTRICT COUNCIL

Produced by the Gisborne District Council. Contains Crown Copyright data sourced from LINZ. Ortho-photography from Terralink Ltd.

SUSTAINABLE HILL COUNTRY WORKS PLAN

Farm name:
Address:

Other information:

Scale = 1:10,000 (A3 map size)

390 195 0 390 Metres

N

5. APPLICATION EXAMPLES

Potential applications of the LUC system are wide and varied. Several examples are presented in this section to illustrate how the analysis of physical factors can be used in the systematic planning of land use, and the design and implementation of targeted management (particularly soil conservation measures).

The examples are deliberately varied in order to convey the flexibility of the system and differences in the form of presentation which caters for differing physical conditions. Examples have been prepared using 2nd edition Handbook standards, so LUC Classes are described using Roman rather than Arabic numerals.

5.1 Regional planning for targeted land use change

Gisborne and the East Cape have a well-founded history of using LUC to help plan and implement sustainable land use at several application scales. Approximately 40–45% of the Gisborne District has been mapped at 1:5,000 to 1:15,840 scales, and 2nd Edition NZLRI mapping is available at a 1:50,000 scale.

The East Coast Forestry Project provides a district/regional application example of the LUC system. The project was established to address widespread and severe erosion. It aims to achieve sustainable land management across 60,000 ha of severely eroding land by 2020. The project uses LUC to firstly identify *target land* that requires special management or land use change to achieve erosion control, and secondly to rank landholder eligibility for grants assistance.

Targeted land is defined to include regional LUC 8e (units 3–9) and the worst of LUC 7e (units 18, 19, 21-25). These targeted LUC Units have been amalgamated as priority-weighted overlays, which can be placed over orthophotos to identify which parts of a farm may be eligible (Figure 18).

In 1999 Gisborne District Council was advised that the Government-funded East Coast Forestry Project would only continue if greater land controls were introduced through rules in the District Plan. This resulted in Overlay 3A being placed within the District Plan, and it is now a legal requirement to establish and maintain effective erosion-control tree cover on targeted LUC Units before 2020.

Whereas policy and rule development were undertaken at the district/regional level, implementation is undertaken at the farm level. A farm map of targeted land is used as a template for developing farm-specific works plans (Figure 18).

5.2 LUC mapping for planning at the catchment level

Catchments are natural units of resource management. However, most resource management decisions are made within the farm unit. Catchment control schemes seek to integrate and coordinate resource management across many neighbouring farms within a given catchment of interest. This is considered to have far greater cumulative benefit in terms of flood and erosion control (and more recently water quality management), relative to treating individual farms in isolation.

Catchment control schemes were established under the Soil Conservation and Rivers Control Act (1941). The first schemes started in the late 1950s, gradually increasing to 121 Schemes covering two million hectares in 1985. Many have since ceased, and only a small number continue to operate under regional council administration.

Greater Wellington Regional Council maintains six catchment control schemes in Wairarapa. Each aims to protect community assets from soil erosion and flooding. Catchment rating classifications provide contribution from the community, which is matched 'in kind' by the Council. Decisions regarding fund allocation and works priority are made by a community Scheme Advisory Committee.

One example is the Maungaraki Catchment Control Scheme located east of Gladstone. This is a relatively small scheme, involving 12 farms covering 6,500 ha. The catchment is predominantly steepland-mudstone country prone to moderate and severe gully, earthflow and soil slip erosion, and road access is particularly vulnerable to storm damage.

LUC mapping has been undertaken for most of the catchment on a cumulative farm-by-farm basis (Figure 19), and property conservation plans have been prepared for each farm. Aggregated works indicate the scale of land use change that can be achieved using a catchment approach (Figure 20 and Table 25).

Table 25: Integrated protection of erosion-prone land under the Maungaraki Catchment Control Scheme, 2008.

Erosion-prone land protected by:	Extent
Farm plan woodlots	295 ha
Retired native bush	62 ha
Scheme woodlots	140 ha
Gullies planted with soil conservation trees	41 km

Figure 19: LUC classes for the Maungaraki Catchment Control Scheme.

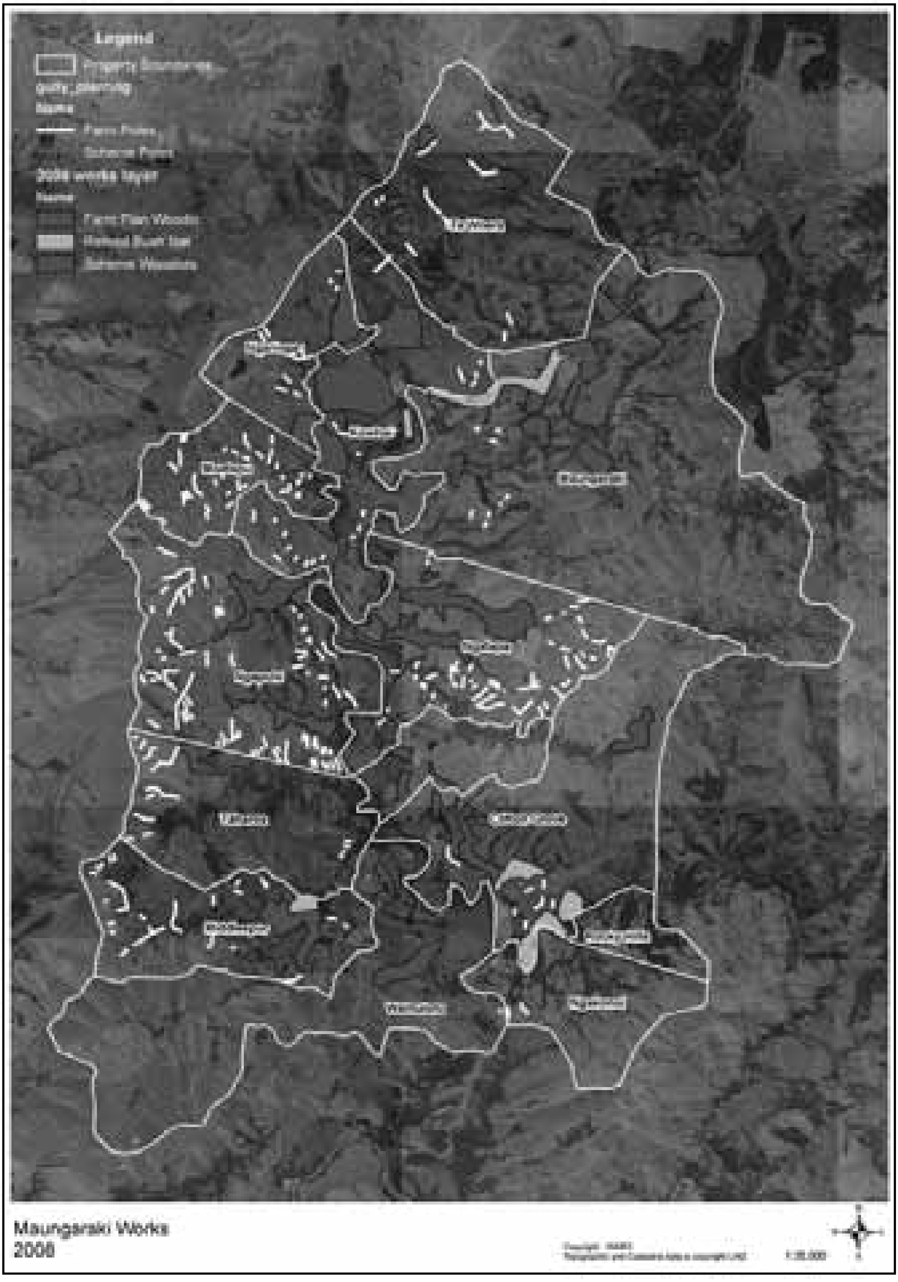


Figure 20: Maungaraki Catchment integrated works programme for 2008.

5.3 Farm planning

At its simplest, a resource management ‘farm plan’ refers to a plan of recommended works that aims to improve the resource management status of an individual farm. Traditionally such plans are based on an initial assessment of farm LRI and LUC, with most sharing the following components:

1. ***Farm description***: Includes location, tenure, legal description, climate, objectives and an overview of the farm production system.
2. ***Resource description***: LRI is reported as a map or table, and each physical factor is discussed.
3. ***LUC classification***: LUC is classified or correlated to the relevant regional LUC classification, presented as a map, and summarised as an extended legend. Resource management issues or opportunities are also discussed.
4. ***Works programme***: Includes recommendations and a 5–10 year works plan that covers **what** activities will be undertaken, **when** and **where** they will be implemented (schedule and works map), **how** technical works should be undertaken (specifications), and an estimate of **how much** it will cost (budget).
5. ***Monitoring and follow-up programme***.

Two farm plan examples are provided. The first represents the application of LRI/LUC mapping and farm planning in a higher capability landscape, while the second represents a more traditional soft-rock hill country application.

5.3.1 Farm plan example for flat to undulating terrain

Many terrain types can be mapped at the farm level. On this Taranaki property with significant amounts of high capability flat to undulating land, LUC units 2c3, 2e1 and 3e2 are mapped with LUC units 7e9 and 8e3 on the gully slopes (Figure 21). The LUC units are from Fletcher (1987).

Land Use Capability is used as a basis for planning a programme of recommended works (Figure 22). Emphasis is to look at all aspects of the farming operation, with an aim to identify ‘wise use’ management practices that protect soil and water resources while maximising the productive capability of the farm. This includes an analysis of existing stocking rate to potential carrying capacity (see Section 4.6), whereby suggestions are given to help realise the potentials without compromising land resource integrity.

The works programme map shows proposed subdivision, recommended activities, pole planting, planting for shade, scrub clearance and land retirement of the LUC class 7e9 hill country (Figure 22).

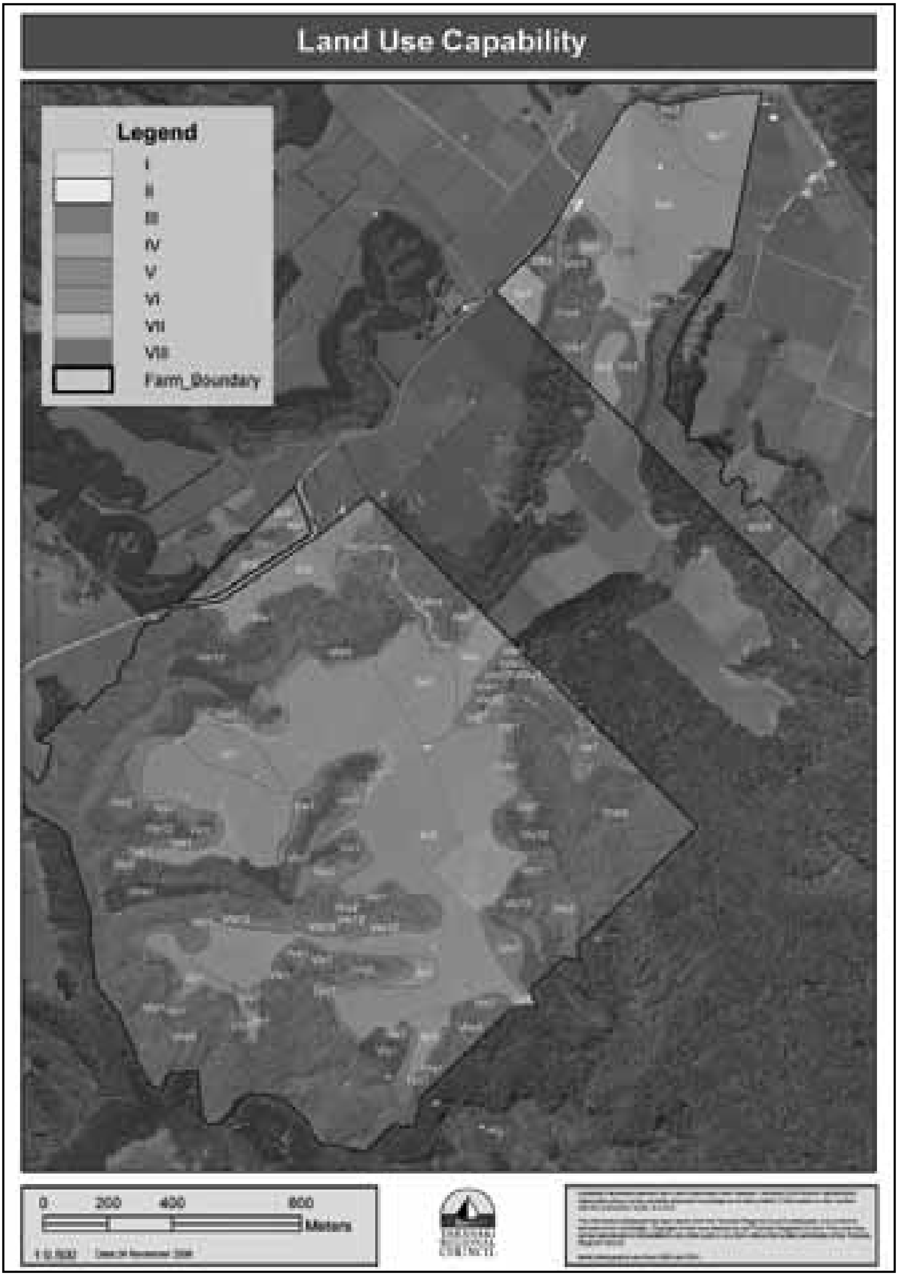


Figure 21: LUC mapping at the farm scale on flat to undulating terrain.

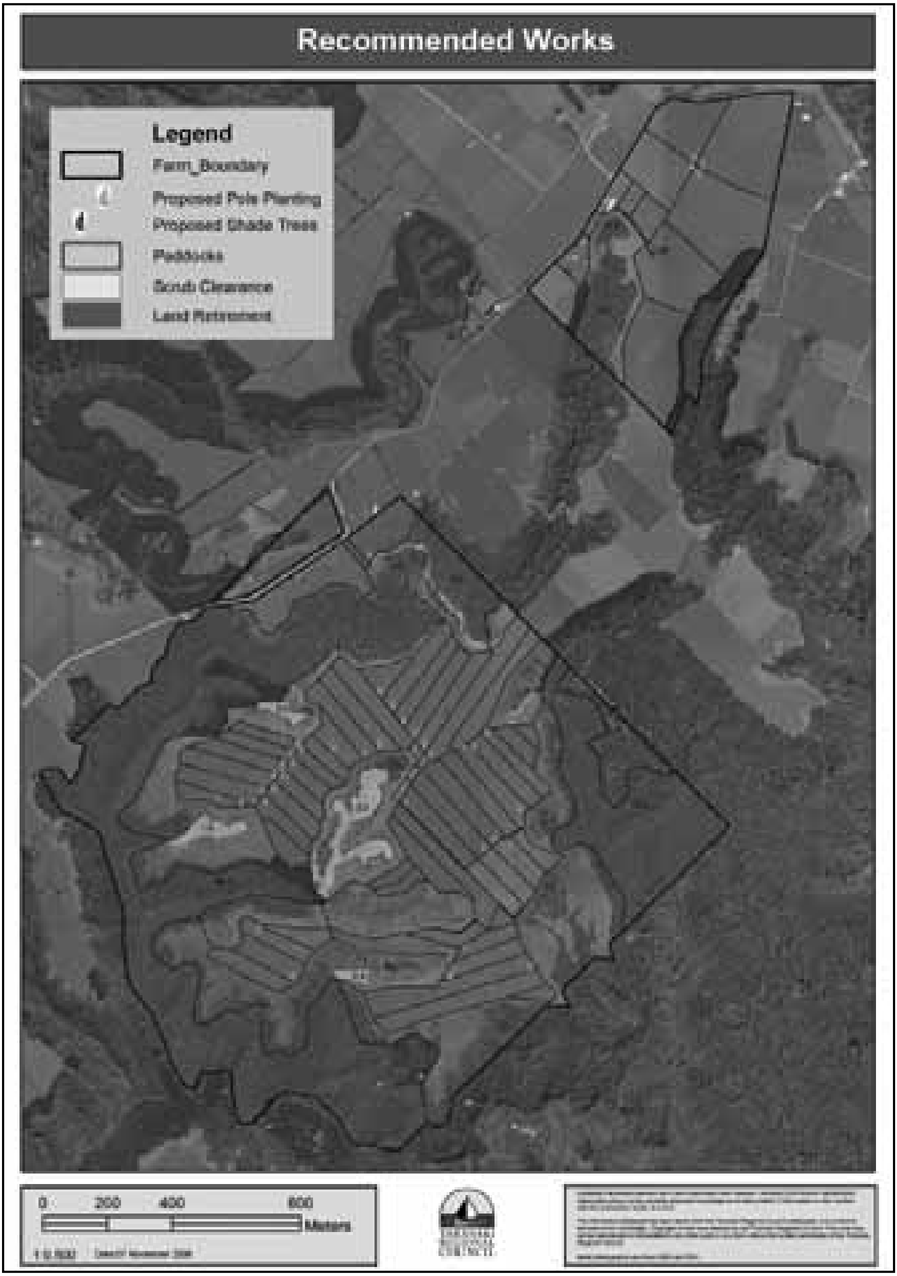


Figure 22: Proposed subdivision and recommended works.

5.3.2 *Farm plan example for soft-rock hill country*

This example depicts the detailed physical inventory and Land Use Capability (Figure 23) for a typical Wanganui soft-rock hill country property with derivative current and potential pasture production (Figure 24) and recommended works programme (Figure 25). Below is an extract from the extended legend that accompanies the farm LUC classification (provided courtesy of LandVision Ltd and Horizons Regional Council).

LUC	Area (ha)	Rock type	Soil	Slope	Vege-tation	Erosion	
						Actual	Potential
IIc1 Flat to undulating high terrace with soils formed from loess and tephra	4.3	Tephric loess	Westmere silt loam	0-7	Pasture	Nil	Nil
IIIw2 Flat, narrow alluvial valley floors and areas of higher terraces mantled with colluvium	9.0	Alluvium and colluvium	Ki Iwi silt loam	0-7	Redwood forestry	Nil	Slight to moderate stream-bank erosion
IVe3 Rolling to strongly rolling downlands with soils from volcanic tephra.	142.5	Tephric loess	Westmere silt loam, Parakino sandy loam	8-20	Pasture	Nil	Moderate to severe sheet and rill when cultivated
VIe14 Moderately steep to steep hill country formed on unconsolidated to moderately consolidated sandst ma	141.2	Patches of loess over un- and mod. consolid-	Westmere hill soil, & Manga-weka hill soil	20-35	Pasture	Slight sheet, soil slip and tunnel gully erosion	Moderate soil slip, slight sheet and tunnel gully erosion

Figure 23: Extended legend example (extract) for a farm LUC classification.

In regard to the following maps, note the detailed recording of the full physical land resource inventory and cameo descriptions of the LUC units (from Fletcher 1987). The current production estimates are derived from stocking rates and distributed according to LUC units adjusted to relative yield. Potential production estimates are derived from stock carrying capacities reported in the NZLRI regional legend (Fletcher 1987) with variable utilisation rates adjusted according to LUC and soil fertility levels.

	Strengths	Limitations	Landuse suitability	Conditions of use
	▪ Good physical fertility ▪ Contour ▪ Free draining ▪ Fencing access reasonable	▪ Exposure to climate ▪ Limited area ▪ No shelter & shade ▪ Slight wind erosion under cultivation	Intensive pastoral farming.	▪ Care with cultivation to prevent wind erosion ▪ Maintain soil fertility levels ▪ Shelter & shade for livestock
	▪ Currently planted in redwoods ▪ Reasonable natural fertility ▪ Generally summer safe ▪ Good shelter	▪ Wetness limitation even after drainage ▪ Easily pugged with heavy cattle ▪ Streambank erosion potential ▪ Flooding (once every five years) ▪ Access & location ▪ Slip debris from above	Intensive pastoral farming with drainage. Afforestation	▪ Care with heavy cattle during wet periods to prevent pugging damage ▪ Care with machinery at harvest time to reduce structural degradation.
	▪ Reasonable soil physical properties ▪ Responds well to fertiliser applications ▪ Good contour & position ▪ Reasonable access ▪ Some good natural shelter for livestock	▪ Prone to moderate sheet and rill erosion under cultivation ▪ Shelter	Intensive pastoral farming.	▪ Use zero or conservation tillage techniques for pasture renewal ▪ Maintain soil fertility levels ▪ Care with heavy cattle during wet periods to minimise pugging and treading damage ▪ Shelter & shade for livestock
	▪ Free draining ▪ Loess derived soils more naturally fertile	▪ Moderate potential for soil slip erosion under pasture and slight sheet and tunnel gully erosion ▪ Cool winter temperat[illegible]	Pastoral farming with conservation plantings.	▪ Space planted trees over erosion prone parts of the slope ▪ Maintain soil fertility to enhance sward

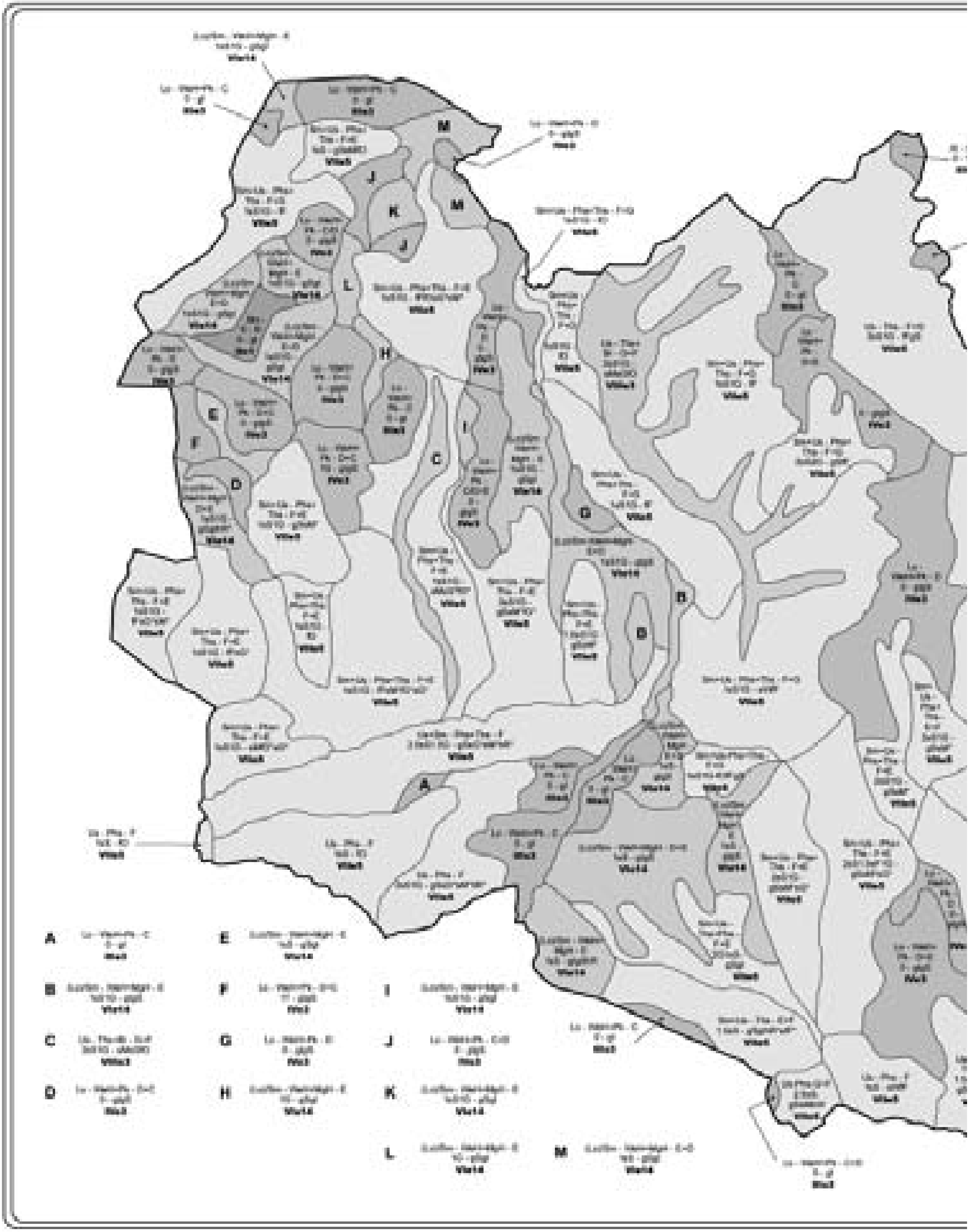
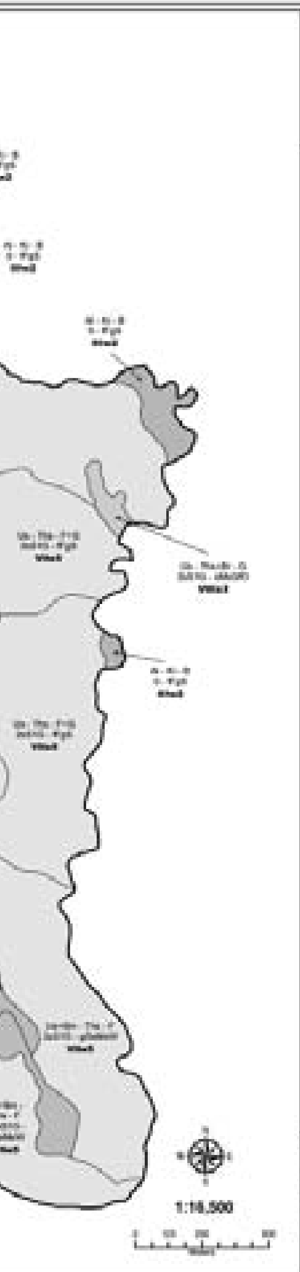


Figure 24: Detailed inventory and Land Use Capability map for a typical Wanganui soft-rock hill country property.



LAND USE CAPABILITY

LUC & description

IIc1

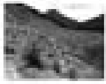
Flat to undulating high terrace with soils formed from weathered loess and tephra

IIIe3

Undulating to rolling downlands with soils developed from weathered loess and tephra

IIIw2

Flat, narrow alluvial valley floors and areas of higher terraces mantled with colluvium from nearby valley slopes



IVe3

Rolling to strongly rolling downlands with soils developed from weathered and volcanic tephra

VIe14

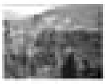
Moderately steep to steep hill country formed on unconsolidated to moderately consolidated sandstone +/-mantled with loess

VIIe5

Steep to very steep slopes formed on unconsolidated to moderately consolidated sandstone

VIIIe3

Very steep slopes formed from unconsolidated to moderately consolidated sandstone



Land Use Capability classifications according to Fletcher, 1987.

Fletcher, J.R. (1987). Land use capability classification of the Taranaki-Manawatu region : a bulletin to accompany the New Zealand land resource inventory worksheets. National Water and Soil Conservation Authority by the Water and Soil Directorate, Ministry of Works and Development, Wellington, N.Z.

Date:	1 October 2008	Surveyors:	LandVision Ltd
Property owner(s):		Survey scale:	1:10,000
Property:		Aerial photo:	Supplied by Horizons Regional Council (0.75m orthophoto from Terralink). Flown 2004/05

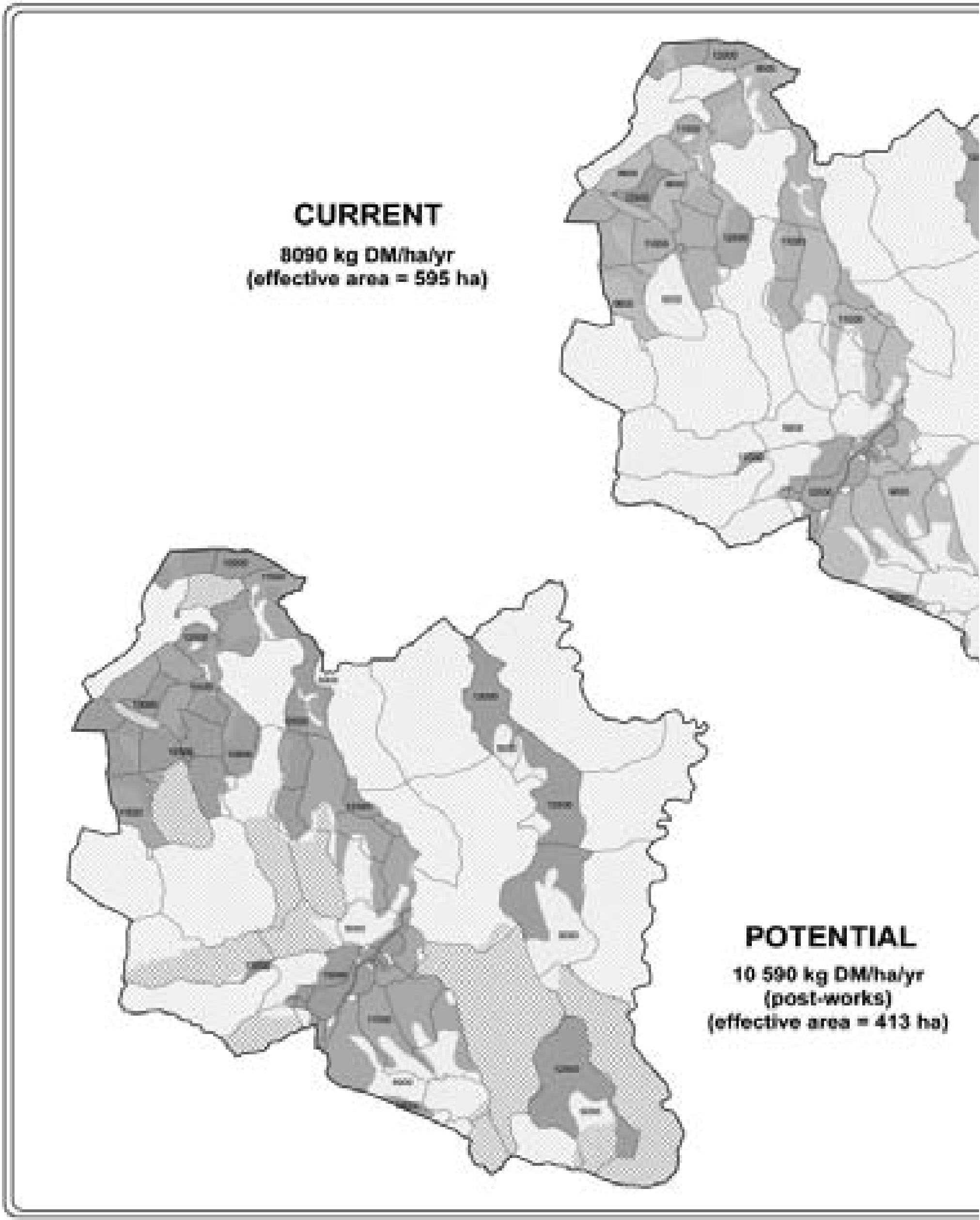
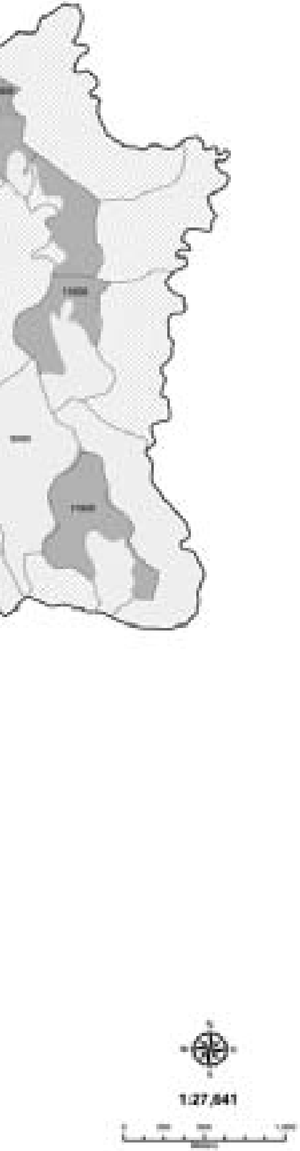


Figure 25: Current and potential pasture production estimates derived from LUC unit stocking capacities, and adjusted for relative yield, utilisation and soil fertility levels.



PASTURE PRODUCTION

Pasture production classes (kg DM/ha/yr)

- 4000 - 5000
- 5000 - 6000
- 6000 - 7000
- 7000 - 8000
- 8000 - 9000
- 9000 - 10000
- 10000 - 11000
- 11000 - 12000
- 12000 - 13000

- Ungrazed or non-pastoral
- Land retired from works programme

FOR COMPARATIVE PURPOSES ONLY. Current production estimated from stocking rate and distributed according to Land Use Capability (LUC) classes for the property adjusted to relative yield. Potential production estimated from carrying capacities reported in LRG (1981), using 1 su requiring 550 kg DM/ha/yr, variable utilisation rates according to land class, and soil fertility levels.

Land Resources Group. 1981. Stock carrying capacities and fertiliser data for the North Island. Internal report No 33. Aokautere Science Centre, Ministry of Works & Development, Palmerston North, New Zealand.

Date:	1 October 2008	Surveyors:	
Property owner(s):		Survey scale:	1:10,000
Property:		Aerial photo:	

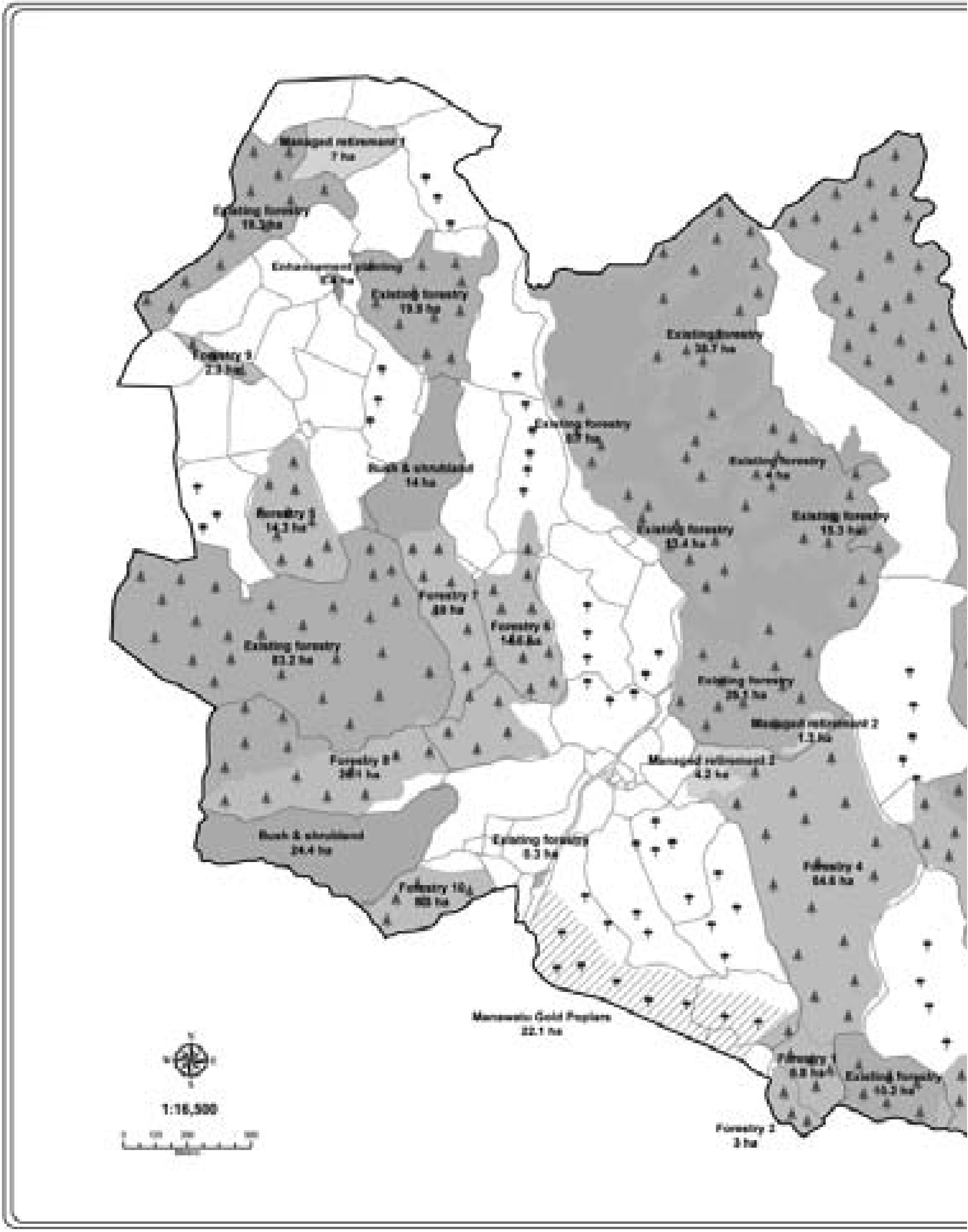
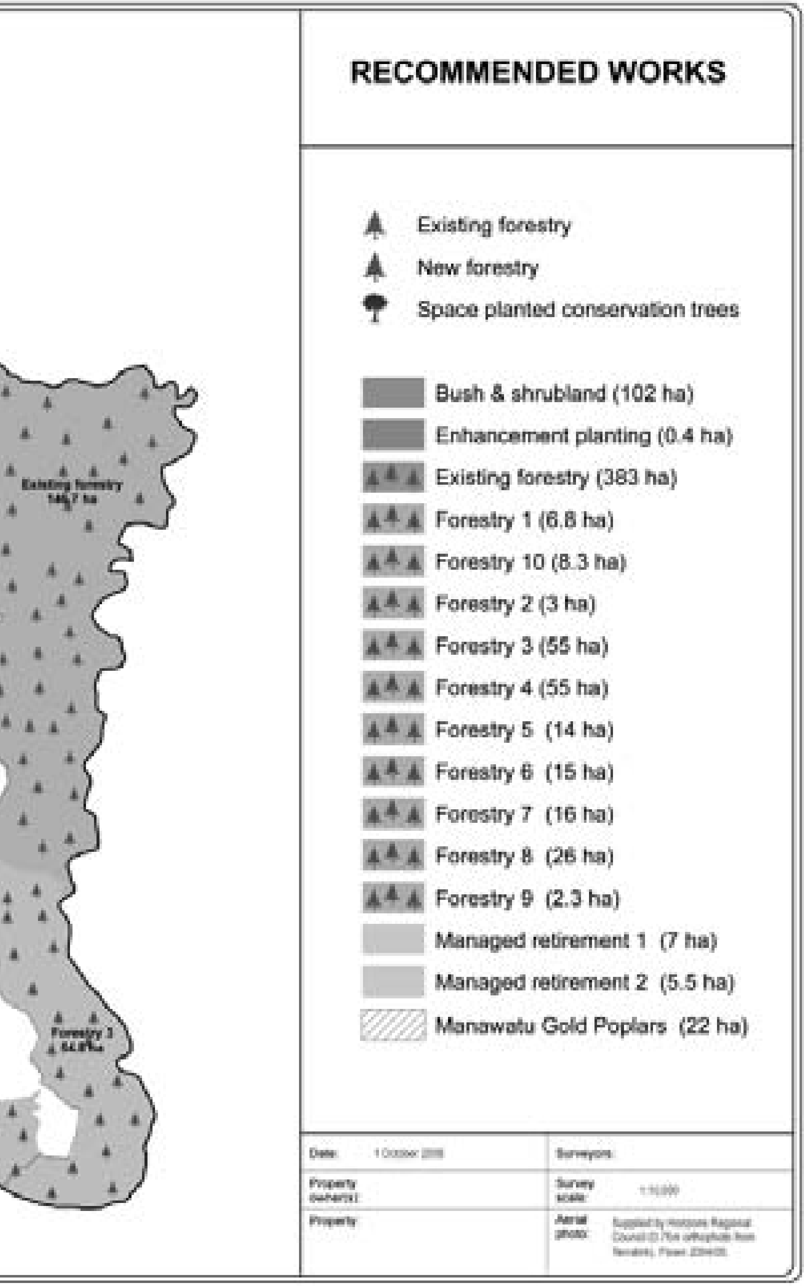


Figure 26: Recommended conservation works for a typical Wanganui soft-rock hill country property.


RECOMMENDED WORKS
Existing forestry
New forestry
Space planted conservation trees
Bush & shrubland (102 ha)
Enhancement planting (0.4 ha)
Existing forestry (383 ha)
Forestry 1 (6.8 ha)
Forestry 10 (8.3 ha)
Forestry 2 (3 ha)
Forestry 3 (55 ha)
Forestry 4 (55 ha)
Forestry 5 (14 ha)
Forestry 6 (15 ha)
Forestry 7 (16 ha)
Forestry 8 (26 ha)
Forestry 9 (2.3 ha)
Managed retirement 1 (7 ha)
Managed retirement 2 (5.5 ha)
Manawatu Gold Poplars (22 ha)
Date:
Surveyors:
Property owner(s):
Survey scale:
Property:
Aerial photo:

ACKNOWLEDGEMENTS

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A systematic review and updating of this Handbook has been undertaken prior to publication of this third edition. It was undertaken by a team of scientists, some of whom were involved with the preparation of the New Zealand Land Resource Inventory, and a panel of regional council representatives. Funding was provided by the Foundation for Research, Science and Technology under the Envirolink Tools programme. Printing was funded by Envirolink, the New Zealand Association of Resource Management (NZARM), and the New Zealand Society of Soil Science (NZSSS).

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M Jessen, a highly regarded member of the land resource mapping fraternity, was killed in a road cycle race in January 2006. His contributions to the many developments in the LUC mapping system incorporated into this edition of the Handbook are acknowledged.

PHOTO CREDITS

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APPENDIX 1: SLOPE CLASSIFICATIONS

Slope has a marked effect on farming and forestry operations, soil erosion and slope stability. Slopes of 0–7° present few obstacles, although between 3–7° difficulties may be experienced with ‘gapping’ of machines or mechanised weeders, precision seeders and some root crop harvesters. Between 7° and 15° the use of combine harvesters becomes restricted. Over 11° additional front weights may be necessary to compensate for drag and steering difficulties for standard two wheel drive tractors. Two-way ploughing also reaches a limit about 12°, although much depends on the configuration of the ground, e.g. a short slope of 15° within a field with turning space at head and foot might well be tackled safely whereas a field with uniform 15° slope would call for one-way ploughing only. On slopes towards the 15° limit loading difficulties with trailers may be met (loading on one side only) and loads can only be removed from the field directly down slope.

Slopes greater than 15° are not suitable for normal crop rotations, remain in grass for long periods, and cultivation costs can be high. Slopes greater than 20° are difficult to plough and topdress, and even if these dangers are accepted costs are high and normal crop rotations are limited. Slopes between 20° and 25° are occasionally cultivated for pasture improvement. Above 25° some soil movement and the formation of stock tracks across slope are common.

For forestry operations slopes between 18° and 20° are the accepted maximum limit for rubber-tyred skidders on favourable slopes subject to weather conditions, (MacDonald 1999; Occupational Safety and Health Service 1999). The accepted maximum limit for tracked machines vary between 22°, (Occupational Safety and Health Service 1999) and 26° (MacDonald 1999), while some specialised self-levelling tracked machines can work on favourable slopes up to 30°. All machines must be equipped with brakes capable of holding the machine and its load on any slope on which it is operated. Some commonly recognised critical slopes for specified activities are given in Table 26.

Table 26: Commonly recognised critical slopes for specified activities (modified from Bibby & Mackney 1969; McRae & Burnham 1981; MacDonald 1999; and Occupational Safety and Health Service 1999).

Slope group	**Slope group (degrees)**	**Activities**
A	0-3	Free ploughing and cultivation (1^0)
B	4-7	Soil erosion begins to be a problem (>3^0) Some heavy agricultural machinery restricted (6^0) Difficulties with weeders, precision seeders and some root crop harvesters (3^0–7^0)
C	8-15	Additional front weights to compensate for drag and steering difficulties for standard wheeled tractors (>11^0) Limit of two-way ploughing (depending on field configuration) (12^0) Limit of combine harvester operation (depending on field configuration) (15^0) Restricted loading and off loading of trailers (15^0)
D	16–20	Restricted crop rotations, higher cultivation costs, longer periods in pasture (>15^0) Typical maximum limit for rubber-tyred skidders (18^0 - 20^0)
E	21-25	Difficult to plough, lime and fertilise, higher cultivation costs, normal rotations impossible (>20^0) Occasional tillage for pasture improvement (20^0 - 25^0)
F	26-35	Soil movement and the formation of cross-slope stock tracks Typical maximum limit for tracked skidders (26^0) Specialised self-levelling tracked harvesting machines (26^0 up to 30^0)
G	>35	

APPENDIX 2: EROSION TYPE DEFINITIONS

Surface erosion

SHEET – **Sh** (aka sheetwash)

Sheet erosion is the removal of surface particles by non-channelised overland flow of water. Areas susceptible to sheet erosion include bare ground such as cultivated paddocks and tracks, areas of heavy stock concentration, landslide scars and debris tails. It also occurs in the form of diffuse movement of particles through an incomplete vegetated sward. Sheet erosion is caused by a combination of raindrop impact which dislodges fine soil particles, and overland flow which transports them. Rills develop where overland flow concentrates into channel flow with increased volume and velocity.

Factors that influence susceptibility to sheet erosion include: soil parent material, slope angle, slope aspect, altitude (especially where freeze and thaw cycles and wind dislodge particles), drought conditions, and overgrazing. Although sheet erosion may occur on a wide variety of terrains, it is most common on seasonally dry hill country, cultivated slopes and in upland areas.

WIND – **W**

Wind erosion is the detachment, and transportation by saltation (bouncing along the surface) and aerial suspension, of fine-grained particles by wind action. Wind erosion rates depend on wind turbulence and currents, particle-size and uniformity, moisture content of the material, surface roughness, and vegetation cover. Loose, exposed particles begin to move once a critical wind velocity, set by the surface properties, is exceeded. Further detachment is initiated by the impact of saltating particles on the surface.

Wind erosion may occur on flat or sloping land. Where steep bare surfaces are affected by wind erosion, sheet erosion also usually occurs. Wind erosion is the dominant erosion process on sand country, increasing in severity towards the coast where there is little soil development, on recent volcanic soils above ~600 m asl on the central plateau, and is widespread throughout low-rainfall areas especially where soils are exposed to desiccating north-westerly winds.

SCREE – **Sc** (aka scree creep)

Scree erosion is the transport and accumulation of coarse, fragmented rock debris on slopes as a result of physical weathering and gravititational movement. Scree erosion occurs where rock material is indurated or hard, on steep slopes with shallow soils, and is common at higher altitudes where physical weathering (freeze-thaw and frost heave) rates are high and add to fragmentation and downslope movement.

Scree material may be angular as in the case of greywacke, and hard volcanic rocks, or rounded in the case of gravels exposed in terrace scarps. Many screes are relatively stable (typically up to 35-36°), long-lived features, and in some cases have developed in situ from disintegration of underlying bedrock rather than from transport and accumulation of material from upslope. The presence of woody vegetation and lichens, surface rock weathering discolouration, and weathering rinds on rock fragments are indications of stability.

Mass movement erosion

In the broadest sense soil slip, debris avalanche, debris flow, rock fall, earthflow, and slump are all types of landslides. Landslide is a generic term in scientific and geotechnical literature for the movement of a mass of rock, earth or debris down a slope, under the influence of gravity. Landslides usually involve rapid failure along a slip plane at the contact between a more permeable material and an underlying less permeable material. Landslides occur when shear stress forces (shearing) exceed shear strength (resistance). The balance between these forces is influenced by vegetation (root strength, interception, and evapotranspiration of subsurface water), soil cohesion, internal angle of friction, slope angle, weight of regolith (depth, bulk density), and slope hydrology. When slope materials become saturated, pore water pressures rise, reducing frictional resistance between particles, ultimately leading to failure. Landslides vary in size and volume from <10 m^3 to >1,000,000 m^3.

Landslides occur on a wide variety of terrains and rock types. Mudstone and sandstone hill country are especially susceptible, but loess and tephra covered hills, greywacke hills and ranges, and volcanic mountains and other terrains are also susceptible. In the LUC Handbook erosion classification, all of the mass movement erosion types are forms of landslides.

SOIL SLIP – **Ss**

Soil slips are shallow, rapid slides and flows involving soil and regolith. Movement rates are typically 0.5–5 m/s, or fast walking to running pace. They comprise a scar (source area), and a debris tail. The failure surface is planar and parallel to the ground surface and <1 m deep. The slip plane or shear surface is often above relatively impermeable material. Movement is initially by sliding or a combination of sliding and flowing, but where the failed mass becomes saturated with water, it forms a chaotic mix of debris which can flow down slope for a considerable distance (10s to 100s of metres, or >10 times the scar length). The scar surface is slow to revegetate (often 10+ years), and the rate is influenced by such factors as hardness, weathering rate, fertility, water holding capacity and rainfall/drought conditions. The debris tails revegetate more quickly (usually several years). Typical shallow soil slips in pastoral hill country are <1 m deep and have a volume of between 150 and 500m³. They are triggered by a variety of natural agents, most commonly intense and/or prolonged rainfall, earthquakes, and undercutting of slopes by stream or wave action. Soil slips are also induced by human activities, especially slope modifications for roads, tracks and buildings.

Slope, aspect and vegetation are important determinants of soil slip occurrence. They rarely occur on slopes <8°, with the majority occurring on slopes >20°. Dependent upon rock type and rainfall intensity, mean slope angles are between 28–35°. Many storm damage assessments (Eyles 1971; James 1973; Crozier *et al*. 1980; Salter *et al*. 1983; Phillips 1988; Hancox & Wright 2005a, 2005b) show an aspect preference for soil slipping that may be influenced by storm direction, or by previous erosion events. Northerly aspects are often more severely affected and this may be because of a more extreme winter wetting/summer drying cycle. Land use change, especially removal of woody vegetation, increases susceptibility to soil slipping. Dependent on terrain type, densities under pasture are between 3 and 10 times that under either indigenous or exotic forest (Hicks 1991; Hicks *et al*. 1993; DeRose 1996; Page & Trustrum 1997; Hancox & Wright 2005b).

The term earth slip was used in previous editions of the LUC Handbook to map slips with a failure surface that is concave and >1 m deep. As they are not common (and difficult to recognise from aerial photography) they have been included with soil slips in this classification. However, where necessary they may be recorded using the prefix ‘d’. Such deeper failures are more likely to occur in unconsolidated or deeply weathered materials.

DEBRIS AVALANCHE – **Da**

Debris avalanches are rapid slides or flows on long, usually very steep slopes exposing an extended, narrow scar with a long run-out. The initial failure surface is small, the debris scouring a deep but narrow scar down a significant length of the slope.

Debris avalanches occur on steep (>25°) forested slopes in both the North and South Islands, and on steep, greywacke colluvial slopes, under a grassland cover in the South Island.

DEBRIS FLOW – **Df**

Debris flows are generally the consequence of landslides triggered by exceptionally heavy rainfall, and consist of dense fluid mixtures of debris (rock, soil, vegetation) and water that enter a watercourse, forming a channelised flow. They have high sediment concentrations, with a consistency like wet concrete. They move rapidly down a stream channel (faster than the flow of water in the same channel), adding further sediment scoured from along the channel, and are capable of transporting very large boulders.

ROCK FALL – **Rf**

Rock fall is the more or less abrupt free fall, bouncing and rolling of masses of rock of any size from very steep slopes or cliffs. The slopes are so steep that no significant protective mantle of rock waste can accumulate, and mass movement can proceed as fast as weathering and disintegration of the rock mass permits.

Rock falls are most common in steep mountainous terrain, along cliffed coastlines and deeply incised gorges. Bedrock competence, joint, fracture, and bedding plane patterning, regional deformation trends and the location of fault and crush zones largely determine the site and extent of rock falls. Rock falls are often triggered by strong earthquake shaking, and less commonly by intense rainfall.

EARTHFLOW – **Ef**

Earthflow erosion is the slow movement of soil and associated regolith, usually along basal and marginal shear planes, with internal deformation of the moving mass. Movement rates vary from <0.5 m/yr to > 25 m/yr. The original vegetated surface, although often still present, is hummocky and may contain numerous tension cracks. The disrupted nature and high water content of the material impede both surface and subsurface drainage and often result in the development of ponds. Earthflows may be shallow (< 1–2 m) to deep-seated (>1–2 m to tens of metres, and typically 3–5 m). Deep-seated earthflows typically occur on slopes between 10 and 20° and can cover large areas of a hill slope (hundreds of square metres), while shallow earthflows are more common on slopes >20°, and are smaller in area.

Rates and depth of movement are influenced by rock type (usually mudstones and argillites), degree of shearing and crushing, and proportion of associated plastic clays, slope, vegetation cover, and rainfall, which in turn strongly influence pore water pressures. Movement rates within earthflows usually vary, and are often most active where the toes are undercut by streams or roads, or where gullies have developed. Earthflows may show seasonal variation in activity and may reactivate following years of stability. They often commence or increase activity late in winter in response to periods of saturated soil-water conditions.

Mudflow was an erosion type listed in the erosion classification in previous editions of the LUC Survey Handbook. In Eyles (1985) mudflows are defined as 'very rapid flows of predominantly fine-grained materials which have high water content. Mudflows often recur in the same channels'. This definition is similar to that of a debris flow, except for the fine-grained nature of the sediment. Because mudflows have not been mapped during NZLRI or farm plan mapping, the term has not been included in this classification.

SLUMP – **Su**

Slumps are deep-seated failures, usually of large blocks of rock and regolith. They involve rotational slide movements along curved failure planes, resulting in a raised lower (toe) slope relative to the upper part of the slope. This often results in the formation of ponds or lakelets at the head of a slump.

There may be strong structural controls on the occurrence of slumps, and most occur in bedded mudstones and sandstones. They often occur in earthflow-prone terrain and earthflow/slump complexes are common.

Fluvial erosion

RILL – **R**

Rills are closely spaced channels resulting from the uneven removal of surface soil by running water. Rills are <60 cm deep and <30 cm wide. They are features that can be removed by cultivation using normal farm equipment (Brice 1966). In certain circumstances rills may develop into gullies.

Rills occur most commonly on cultivated slopes where they usually incise to the base of the cultivated layer. In general the potential for rilling increases with slope angle. Rills are only occasionally observed on slopes with established pasture cover.

GULLY – **G**

Gullies are formed by the removal of soil, regolith or rock by fluvial incision. They are large, permanent features, >60 cm deep and >30 cm wide. Initially they form through the channelised flow of water and involve headward and sideward migration of the channel. Gullies may be linear or amphitheatre in shape, depending on rock type, and usually only carry water during rainstorms. In some instances gullies are formed by a complex process of mass movements, sheet erosion and debris flows in response to oversteepening of gully side walls by channel incision. They may also form through the deepening and coalescing of rills, small usually numerous features <60 cm deep and <30 cm wide, that usually form on bare surfaces during rainstorms.

TUNNEL GULLY – **T** (aka pipe/shaft erosion, under-runners, tomos)

Tunnel gully erosion is initiated by the subsurface concentration and flow of water, resulting in eluviation and scouring, and the formation of narrow conduits, tunnels or pipes. Soluble, dispersive or low strength material is removed, ultimately resulting in collapses, visible either as holes in the land surface or as gullies when sufficient collapses coalesce to form continuous linear features (after Lynn & Eyles 1984). Tunnel gullies form in a range of regoliths where subsurface water concentrates above a relatively impervious layer.

Land susceptible to tunnel gully erosion includes loess-mantled (typically >50 cm thick) moderately steep sandstone, mudstone, and weakly consolidated conglomerate hill country with Pallic Soils, on colluvial footslopes, and where coarse thick tephra deposits overlie consolidated rock types.

STREAMBANK – **Sb** (aka bank erosion, channel erosion)

Streambank erosion refers to the removal of material from the bank of a stream or watercourse usually during or following elevated stream flow. Headward extension of the stream channel and downcutting of the streambed are often associated with lateral bank erosion but are not always recognised separately. Mechanisms of failure include bed and bank scour, which removes support and leads to the toppling of the bank. This generally occurs on the falling stage of a flood event, when the strength of the material forming the bank is decreased, and the weight of the bank has been increased by uptake of water from the river, and the support of the river has been removed. Water flowing along the bank may also shear off blocks of material by hydraulic action. Lateral bank erosion typically removes 2–50 m of material.

DEPOSITION – **D** (aka siltation, sedimentation)

Deposition refers to sediment, (including vegetation) that has been eroded, transported, and subsequently deposited by running water. The material may be deposited within channels, on flat floodplains and terrace surfaces by overbanking of streams or rivers, or on fans, colluvial slopes or floodplains and terraces during overland/ephemeral flow. Sediment particle size ranges from clay to boulder. Although not an erosion process per se, deposition is a related process and the end product of erosion. Debris tails of soil slips and other mass movements deposited on hillslopes are not mapped separately from the scar (source area).

APPENDIX 3: NZLRI VEGETATION DESCRIPTIONS

GRASS

gI Improved pasture. Sown legume-based pastures maintaining high levels of pasture production (>10,000 kgDM/ha). Pastures are typically perennial and short rotation ryegrass (*Lolium perenne*) /white clover (*Trifolium repens*) dominated, but also include prairie grass, tall fescue, cocksfoot, phalaris, red clover and paspalum and kikuyu in northern districts. Soil fertility would be in the optimum range (Olsen P 20–35). Includes irrigated pastures and lucerne.

gS Semi-improved pasture. Pasture dominated by low fertility grasses, generally capable of maintaining only low levels of pasture production (3,000–8,000 kgDM/ha). Common grasses are brown top, sweet vernal and danthonia. Also included are Yorkshire fog, fescue and *Poa annua*. Also white clover, annual clovers (*T. subterranaen* and *T. dubiums*), *Lotus pedunculatus* and *L corniculatus*, plantain and other herbs and mosses. Soil fertility would be below optimum with Olsen P <15.

gT Short tussock grassland. Indigenous grassland dominated or characterised by ‘short tussocks’. These are commonly fescue (hard), silver and blue tussock (*Festuca* and *Poa* spp.), but also include the less common alpine fescue tussock and bristle tussock. Frequently occurs in combination with gI or gS where short tussock is scattered through pasture.

gW Snow tussock grassland. Indigenous grassland dominated or characterised by snow tussocks (*Chionochloa* spp.). These are mainly the tall snow tussock species, but also include the low snow tussock species. Specifically excluded from this class is red tussock.

gR Red tussock grassland. Indigenous grassland dominated or characterised by red tussock. This class is characterised by a single tall tussock, *Chionochloa rubra*.

gD Sand dune vegetation. Herbaceous vegetation, dominated by sand-binding grasses or other herbaceous plants. Principal species are marram grass (exotic), and spinifex and pingao (indigenous). Minor species include iceplant, shore convolvulus, sheep sorrel, catsear, haresfoot trefoil, harestail and kikuyu.

CROPS

cC Cereal crops. Principally wheat, oats and barley, but also including ryecorn and millet. These crops are commonly grown in districts with cooler, drier climates. This class includes crops grown for grain production and green feed (except maize).

cM Maize. Maize, whether grown for grain production, sweet corn or green feed. Maize is grown in areas with a warm moist climate and/or soil conditions.

cP Pip and stone fruit. Temperate tree fruit, principally apples, pears, plums, peaches, apricots. Nut trees can also be mapped in this class.

cG Grapes and berryfruit. Grapes largely grown for wine production but also including table grapes. Berryfruit includes all canefruit, currants, gooseberries, blueberries etc., but excludes strawberries.

cK Kiwifruit. Although a subtropical fruit, kiwifruit is grown far more extensively and over a wider climatic range than other subtropical fruit.

cS Subtropical fruit. Subtropical fruit, apart from kiwifruit, and including citrus fruit. Includes fruit grown on trees, bushes and vines, such as avocados, babacos, feijoas, tamarillos and passionfruit.

cR Short-rotation forage and fodder crops. Includes short-rotation forage crops which include annual (Diploid and Tetraploid) and Italian ryegrass (*Lolium multiflorum*), birdsfoot trefoil (*Lotus corniculatus*) and forage herbs (chicory and plantain). Fodder crops include swedes, leaf and bulb turnips, rape, choumoellier, kale, fodder beet and winter cereals grown for whole crop cereal silage. Soil fertility would be in the optimum range (Olsen P 20–35) with annual production exceeding >15,000 kgDM/ha in some cases.

cV Vegetables, nurseries. All fresh vegetables and those grown for processing, except sweet corn. Includes crops such as peas and potatoes grown for seed. Also includes strawberries, tree, shrub and flower nurseries.

SCRUB

sM Manuka, kanuka. Scrub and shrubland dominated by manuka (*Leptospermum scoparium*) or kanuka (*Kunzea ericoides*). This class is used to record stages of manuka and kanuka growth from juvenile open shrubland to closed mature stands. Kanuka stands >6m in height however are mapped as broadleaved forest (fB).

sC Cassinia. Scrub and shrubland dominated by *Cassinia* spp. The class includes 4 or 5 species which are collectively known as tauhinu, the two most common being *C. fulvida* and *C. leptophylla*. Often, but not exclusively growing in areas with a coastal influence. Specifically excluded from this class is *C. vauvilliersii* where it is a component of sub-alpine scrub.

sD Dracophyllum. Scrub and shrubland dominated by *Dracophyllum* spp. Typically 'frost flat' vegetation, *Dracophyllum* is a low growing shrub and includes a number of species, especially inaka and monoao. A variety of other shrubs and herbs may be part of the class including *gleichenia* fern, red tussock and manuka. *Dracophyllum* spp. may occur as part of sub-alpine scrub and are therefore included in that class.

sF Fern. Vegetation dominated by ferns, excluding tree ferns. A large number of fern species are mapped in this class, principally bracken, ring fern, prickly shield fern, water fern and kiokio.

sS Subalpine scrub. Indigenous scrub communities occurring above the montane zone. These communities range from monospecific to highly diverse, but typically form dense assemblages less than 2.5m high. Characterised by species of the genera *Olearia*, *Senecio*, *Coprosma*, *Hebe*, *Phormium*, *Hoheria* and *Dracophyllum*. In areas of indigenous forest it is confined to above the treeline but in deforested areas, e.g. eastern South Island, it may descend below the treeline into the upper montane zone.

sX Mixed indigenous scrub. Scrub and shrubland comprising mixtures of indigenous species occurring in the lowland and montane zones, and where manuka and kanuka are not prominent components. Includes stable communities maintained in specialised habitats, e.g. steep, rocky terrain, and dynamic successional assemblages, e.g. succession from induced grassland to forest. Normally consists of a large number of species, but may also include vegetation consisting of one or several species, e.g. mountain flax, bog pine.

sT Mixed indigenous scrub with tree ferns. Scrub and shrubland comprising mixtures of indigenous species in which tree ferns are a significant component. Occurring in the lowland and montane zones, especially in moist locations. Tree ferns are species of *Cyathea* and *Dicksonia*.

sB Broom. Scrub and shrubland dominated by exotic broom (*Cytisus* spp.). Common broom (*C. scoparius*) is the most abundant species, but white broom and Montpellier broom which occupy similar habitats are included within the class. Typically forms dense, monospecific stands.

sG Gorse. Scrub and shrubland dominated by gorse (*Ulex europaeus*). Typically forms dense, monospecific stands and acts as a 'nurse species' through which other, usually indigenous, species emerge.

sK Blackberry. Scrub dominated by blackberry (*Rubus fruticosus*). Blackberry normally forms localised thickets in lowland, farmland and scrubland.

sW Sweet brier. Scrub and shrubland dominated by sweet brier (*Rosa rubiginosa*). Usually occurs in short tussock grasslands in low to moderate rainfall montane basins of the South Island.

sA Matagouri. Scrub and shrubland dominated by matagouri (*Discaria toumatou*) and associated small-leaved shrubs. Matagouri forms monospecific stands or occurs as shrubland with grass and tussock. It is sometimes associated with other species including *Corokia cotoneaster*, *Coprosma propinqua*, pohuehue, prostrate and small-leaved kowhai and native broom.

sV Mangroves. Coastal wetland vegetation characterised by mangroves (*Avicennia resinifera*). Mangroves form a canopy of low trees which are reduced to shrubs toward the margin of their habitat.

sL Lupins. Scrub and shrubland dominated by lupins, especially *Lupinus arboreus* which usually occur on sand dunes, but may also occur in riverbeds or on adjacent stony terraces, and on recent tephra. Often occurs in monospecific stands.

sH Heath. Scrub and shrubland dominated by exotic heath (*Calluna* spp. and *Erica* spp.). This class is used to record heather in a grassland situation and in combination with *Dracophyllum* in montane scrub.

sO Coastal scrub. Scrub and shrubland dominated by salt-tolerant plants. Typically low-growing, divaricating shrubs, particularly *Coprosma* and *Muehlenbeckia* spp. Also includes flax. May include lupins where these are not a dominant component. Occurs on both sand dune and hard rock coastlines.

sE Exotic scrub. Scrub and shrubland characterised by exotic species other than those already specified. Includes both monospecific and mixed communities. Species have a limited range although they may be of regional importance, e.g. hakea, barberry, hawthorn.

FOREST

fC Coastal forest. Forest confined to coastal habitats and characterised by broadleaved species. Species are largely confined to coastal habitats, but also include many trees and shrubs with a wider distribution. Species include pohutukawa, ngaio, karaka, puriri, kohekohe, and nikau. Shrubs and small trees include species of *Coprosma*, *Myrsine, Pittosporum*, and kawakawa.

fK Kauri forest. Forest characterised by kauri (*Agathis australis*). Most forests containing kauri have been heavily logged and kauri is rarely a dominant canopy-forming tree. The class occurs in three main situations.

1. *Limited areas of forest where only kauri is dominant in the canopy, either old, unlogged stands, e.g. Waipoua, or as ricker stands. In both cases broadleaved species such as towai, and rewarewa are confined to the understorey, as are regenerating podocarps.*
2. *Commonly in areas previously logged where remnant larger trees are now scattered to locally frequent, often together with some regenerating kauri, within podocarp–broadleaved forest. In this situation the forest should be identified as logged by the use of the symbol 'c' for cutover.*
3. *In areas where the forest has been heavily logged or burnt, kauri occurs as pole or ricker stands in association with regenerating broadleaved shrubs and podocarps. The kauri is emergent and of tree height. Kauri saplings below tree height are not recorded.*

fP Podocarp forest. Forest with a canopy dominated by podocarp trees. Rimu, miro, totara, matai and kahikatea are the common dominant podocarps. Broadleaved species are generally confined to the understorey. Includes pole stands and mature forest. Normally mapped on flood plains and terraces.

fB Broadleaved forest. Forest with a canopy dominated by broadleaved trees, excluding beech. Often dominated by tawa, kamahi or rata but including many other species. Includes forest where podocarps are naturally absent and where advanced regrowth has occurred after fire, gales, landslides, volcanism etc. and can be regarded as forest, but where podocarps have not yet become a significant element. Also includes podocarp–broadleaved forest from which podocarps have been logged to such an extent that they are no longer a significant element in the forest canopy.

fO Lowland podocarp–broadleaved forest. Forest with emergent podocarps above a prominent canopy of broadleaved species, and occurring below the altitudinal limit of rimu (*Dacrydium cupressinum*) which is a common emergent. Podocarps in this class, in addition to rimu, include matai, miro, totara, Hall's totara, kahikatea and tanekaha. Common broadleaved species include kamahi, rata, tawa, taraire, pukatea, titoki, towai, tawari, hinau, rewarewa and maire. Much lowland podocarp broadleaved forest has been logged (cut over).

fI Highland podocarp–broadleaved forest. Forest with prominent podocarps and a canopy of broadleaved species, occurring above the altitudinal limit of rimu. Podocarps in this class include Hall's totara, miro, pink pine, bog pine, mountain toatoa, kaikawaka. Common broadleaved species include kamahi, mountain ribbonwood, broadleaf, southern rata, maire and *Quintinia*.

fD Podocarp-broadleaved beech forest. Forest with emergent podocarps above a prominent canopy of broadleaved species and with irregular admixtures of lowland beech species. In some localities the beech is restricted to ridges. Occurs below the altitudinal limit of rimu.

fW Lowland beech forest. Forest with a canopy dominated by beech (*Nothofagus*) species, principally black, hard or red beech, and occurring below approximately 1,050 m a.s.l. in the North Island. Silver beech may be present in some areas. The upper altitudinal range varies from 1,200 m a.s.l. in the Raukumara Range to 700 m a.s.l. in the Tararua Range.

fG Highland beech forest. Forest with a canopy dominated by beech (*Nothofagus*) species, principally silver and mountain beech, and occurring between approximately 1,050 m a.s.l. and the tree line in the North Island. Minor species include red beech, broadleaf, bog pine, pink pine and subalpine shrub species.

fU Beech forest, undifferentiated. Beech forest often comprising mixtures of lowland and highland elements, at mid-altitudes, on long slopes in the montane and subalpine zones and on harsh lowland sites.

fF Exotic conifer forest. Principally plantations of exotic softwoods, established and managed for wood production. Normally close planted, but in the agro forestry situation may be open planted in pasture. This class is also used to record soil conservation plantings (which are identified by the prefix 'e', e.g. efF) and naturalised exotic trees (which are identified by the prefix 'n' e.g. nfF). *Pinus radiata* is the major species, but others include Corsican pine, *Pinus contorta*, Douglas fir, larch and cypress.

fR Exotic broadleaved forest. Includes plantations of exotic hardwoods, established and managed for wood production. This class is also used to record soil conservation plantings (principally poplars and willows), which are identified by the prefix 'e', e.g. efR. Also included are naturalised exotic trees (which are identified by the prefix 'n', e.g. nfR). Species include eucalypts, poplars, willows, flame trees, wattles, Tasmanian blackwood, silver birch and black walnut. Normally close planted, often in association with exotic conifers.

HERBACEOUS

hW Wetland vegetation. Herbaceous vegetation occurring in non-saline wetland habitats (swamps and bogs) in which the water table is at or near the surface for most of the year. Swamps are typically dominated by raupo, flax, niggerhead and kahikatea. Cabbage trees, manuka, and other shrubs may also occur, especially on swamp fringes. Bogs are typically dominated by rushes, sedges (*Baumea* spp., *Juncus* spp., wirerush) and sphagnum moss. Bogs may also include manuka and *Dracophyllum*.

hR Rushes, sedges. Vegetation characterised by rushes and/or sedges. This class is normally mapped in combination with pasture where drainage is impeded or on the margins of wetlands. Main genera are *Juncus*, *Carex*, *Scirpus* and *Baumea*.

hA Alpine and subalpine herbfield/fellfield vegetation. Herbaceous vegetation, excluding grassland, occurring in the subalpine and alpine zones. Includes species of *Celmisia*, *Ranunculus*, *Astelia*, *Aciphylla*, *Raoulia*, *Senecio*, and sub-shrubs such as *Dracophyllum pronum*, lichens, and cushion and bog vegetation.

hS Saline vegetation. Herbaceous vegetation occurring on saline, coastal wetlands. Salt tolerant communities are dominated by low-growing, often turf-forming, creeping plants. The species present are controlled by the degree of salinity and range from salt barley grass, *Polypogon* and *Puccinellia* spp., plantain, *Cotula coronopifolia*, *Selliera radicans* and *Chenopodium* in areas of low to moderate salinity, to *Mimulus repens*, *Atriplex* spp., and *Sarcocornia quinqueflora* in areas of moderate to high salinity.

hP Pakihi vegetation. Herbaceous sedge/restiad/fern/moss vegetation, sometimes also including scrub, occurring on pakihi. Typically dominated by wirerush, sedges (*Baumea* spp.), pakihi fern and sphagnum moss. Manuka and to a lesser extent gorse are common emergent shrubs.

hM Semi-arid herbaceous vegetation. Herbaceous vegetation confined to freely draining sites in semi-arid districts (<600 mm p.a.). The class includes sparse communities of exotic and indigenous herbs and grasses, on severely modified and depleted short tussock grasslands. Includes scabweed, sheep sorrel, catsear, hawkweed and grasses, including *Poa maniototo*, *Aira caryophyllea* and vulpia hairgrass. The shrubs thyme, sweet brier and matagouri are locally conspicuous.

uV Unvegetated land. This symbol is used in place of the vegetation code where vegetation is absent or where vegetation is insignificant (<10% of the map unit). This means uV will only be used where no vegetation class is recorded. The class will therefore be mainly restricted to the alpine zone above the altitude limit of vegetation or on bare sand dunes near the coast.

PREFIXES

Cutover forest is recorded as follows:

fO Unlogged podocarp–broadleaved forest.

cfO Logged podocarp–broadleaved forest, but where forest still contains podocarps (i.e. still has the characteristics of a podocarp–broadleaved forest).

cfB Logged podocarp–broadleaved forest where podocarps have been removed to such an extent that they no longer constitute a significant component of the forest (i.e. appears as a broadleaved forest).

fB A naturally occurring broadleaved forest. Includes areas of regeneration where podocarps have not yet become a significant element.

s Stunted. Indicates vegetation with a stunted canopy. This symbol is used on coastlines and exposed headlands where forest is subject to severe wind and salt spray shear. It is also used in the upper montane to subalpine zones where forest is subject to severe temperature stress.

e Erosion control trees. All trees planted and managed dominantly for erosion control. Typically open planted poplars on farmland, or willows in gullies or along streambanks, but also including a wide range of other species, e.g. *Pinus radiata*, *Pinus contorta*, eucalypts, acacia, flame trees. Erosion control trees may also be block planted in plantations, where the primary purpose of the planting is erosion control, although they may ultimately be milled. Some large-scale plantings such as the Mangatu Forest (near Gisborne) have both erosion control and production functions. Trees on eroding or potentially unstable sites have the primary function of erosion control. Where the two components cannot be separated, the area is mapped as fF efF, or efF fF depending on assessed extent of the two types.

n Naturalised exotic trees. Self-sown or untended exotic trees, not managed for production (any erosion control function is incidental and fortuitous). Such trees are randomly scattered or clumped. In some cases they may be aggressive colonisers and can be regarded as a weed.

Also included are trees that have been planted but have not been managed for production or erosion control (e.g. trees planted around abandoned homesteads). Species include *Pinus contorta* near the Desert Road, willows in swamps in the Waikato, macrocarpas or pines that have seeded on farmland, wattles, silver birch, acacia and eucalypts.

APPENDIX 4: AREAS OF LUC IN NEW ZEALAND

The total area of each LUC Class in hectares for both the North and South Islands, and their national percentage as mapped in the New Zealand Land Resource Inventory using the latest edition data, are given in Table 27.

Table 27: Area in hectares of LUC Classes 1–8, estuaries, lakes, quarries, rivers and towns as mapped in the North and South Islands during the national NZLRI survey, 1975–1999.

	North Island[2] (x100 ha)	South Island[2] (x100 ha)	NZ Total[2] (x100 ha)	NZ[2] (%)	Total arable and non arable land[2], (ha) & national %
LUC class 1	1525	345	1870	0.7	
LUC class 2	6958	5062	12020	4.5	
					Arable land LUC Classes
LUC class 3	10645	13778	24423	9.2	1–4
LUC class 4	13004	14769	27773	10.5	6 608 700, 25%
LUC class 5[1]	935	1167	2109	0.8	
LUC class 6	40787	33943	74730	28.1	Non-arable land LUC
LUC class 7	27746	29148	56894	21.4	Classes 5–8
LUC class 8	10154	47853	58007	21.8	19 173 300, 72%
Estuaries	220	117	337	0.1	
Lakes	1132	2204	3336	1.3	
Quarries	10	.2	11	0.0	
Rivers	281	2458	2739	1.0	
Towns	1149	316	1465	0.6	
Grand Total	114548	151158	265706		

[1] *Class 5 as mapped under the former SCRCC (1974) definition.*

[2] *Excludes land not mapped as part of the national NZLRI survey such as outlying islands and Stewart Island.*

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GLOSSARY OF TERMS

Aeration: Presence of air-filled space in the soil profile. Aeration limitation is defined as the proportion of the year in which anaerobic conditions may prevail in the soil.

Aerial oversowing and topdressing: The application of fertiliser and seed from aircraft.

Allophane: A non-crystalline soil mineral; an oxide of silicon and aluminium with high water content, variable-charge surfaces, and a very high surface area.

Allophanic Soils [NZ Soil Classification]: Soils dominated by allophane (and also imogolite or ferrihydrite) minerals; have a porous, low-density structure, greasy moistened feel, stable resistant topsoil, low natural fertility and high phosphorus retention.

Alluvium: Sediments such as sand, silt or gravel that have been deposited by streams, rivers and other running waters.

Alluvial soils: Recent soils derived from alluvium, and showing incipient marks of soil forming processes, but with a distinct topsoil.

Anaerobic: Absence of air. The condition that pertains when the soil is waterlogged and supply of oxygen is limited to plant roots.

Andesite: A dark-coloured volcanic rock intermediate in composition between rhyolite and basalt.

Andesitic ash: Unconsolidated volcanic ash of intermediate silica content, of Recent and Upper Pleistocene age. Occurs as a primary deposit, or as rewashed material in river and coastal terraces.

Anthropic Soils [NZ Soil Classification]: Soils substantially disturbed/created by man, e.g. as a result of mining activity.

Arable: Capable of being ploughed; fit for tillage.

Arable use: Suitable for cultivation for cropping, and capable of growing at least one of the common annual field crops, or more per season, with average yields under good management and without permanently degrading soil conditions.

Argillaceous: Rocks or substances composed of clay, or having a notable proportion of clay in their composition.

Argillite: A mudstone or siltstone that has undergone hardening by pressure, heat or cementation.

Basalt: A type of volcanic rock which has a high iron and magnesium content but low silica. Molten basalt flows easily.

Bedrock: The solid rock that underlies soil or other loose material.

Beech forest: Evergreen trees of the beech family comprising hard beech, black beech, mountain beech, silver beech, and red beech.

Bentonite: Soft, plastic, porous, light-coloured (often green or red) rock composed essentially of montmorillonite clays, feels greasy or soapy, has the ability to absorb water and increase in volume up to eight times, leading to the development of deep-seated earthflows.

Berry fields: Growing of shrubby plants, mainly cane plants, for soft fruit production. The term excludes growing of strawberries, which is defined as a horticultural activity.

Border dyke irrigation: A flood irrigation system restricted to land <4° where parallel borders 10–20m wide are separated by low levees or ‘dykes’. Between the dykes water is flooded from a headrace.

Breccia: Angular rock fragments in fine-grained material.

Broadleaf–podocarp forest (aka. Podocarp-broadleaved forest): Forests characterised by podocarps, e.g., rimu, miro, matai, kahikatea, silver pine, totara, and broadleaved or hardwood subcanopy species such as taraire, tawa, puriri, mahoe, hinau, maire and karaka, ngaio and pohutukawa in coastal locations.

Brown Soils [NZ Soil Classification]: Have yellowish brown subsoils, stable and well structured topsoils, are well to imperfectly drained, with low to moderate fertility, and are generally drought free.

Capability: Suitability for productive use, after taking into account the various physical limitations the land may have.

Catchment control scheme: A scheme combining river and erosion control works and an improved pattern of land use in a catchment where erosion and flooding have created community problems which have required a co-ordinated effort to resolve.

Catchment Protection (Land): Class 8 land which has such unfavourable characteristics that it is unsuited for agricultural, pastoral, or forestry use, although it is often well suited for recreational and wildlife use, and for water yield.

Clay: Soil material which consists of particles less than 0.002 mm in diameter.

Cleavage: Tendency to split along closely spaced planar structures or textures.

Climatic limitations: Limitations for the growth of pasture, crop and tree species, such as rainfall, temperature, wind and frost.

Colluvium: A general term for weathered soil and rock material mantling slopes which has been transported primarily by gravity and sheet wash.

Community of interest: Problems shared by a group, largely as cause and effect, and which require collective effort to resolve.

Compound slopes: Used in inventory code when slope patterns cannot be separated at the scale of mapping, and are recorded as a complex using double or multiple symbols, e.g. D+E.

Conglomerate: A coarse sedimentary rock consisting of pebbles or boulders set in a sand and silt matrix.

Conservation fencing: Fencing designed to enable grazing management to control and prevent soil erosion, e.g. the separation of eroded from non-eroded land, summer from winter grazing country, sunny from shady slopes.

Conservation planning: Based on land inventory and land use capability assessment, a series of one or more five-year programmes are compiled which incorporate two concepts:

(a) The extent of the physical measures required to meet the magnitude of the conservation problems, and the degree of financial assistance applicable to combat existing or potential erosion.

(b) The ‘tailoring’ of these measures to the ability of individual farmers to meet the local share, from money budgeted for the purpose.

Conservation tillage: Seed drilled directly into an undisturbed soil (direct drilling), where the stubble of the previous crop is retained on the surface.

Conservation trees: Tree species used specifically for erosion control, e.g. willows and flame trees.

Conservation works: Consist of the following practices: conservation fencing (including cattle-proofing), tree planting (open, close, windbreaks, pair planting), gully control structures such as debris dams, drop structures and flumes, terraces, water diversion (graded banks, spring tapping, pasture furrows), regulating dams, stock ponds, strategic firebreaks, revegetation including over-sowing and topdressing, sod seeding, bulldozing of tunnel gullies, and retirement from productive use.

Contour furrows: Contoured across-slope plough furrows designed to intercept and slow surface runoff and sheet wash.

Debris flood: A rapid, hyper-concentrated, channelled flow of water charged with sand and silt sized sediment. They have lower sediment concentrations than debris flows and are less damaging, often extending downstream beyond debris flows. Debris floods can occur in the absence of debris flows, and are not classified as landslides.

Debris flow: A type of landslide triggered by exceptionally heavy rainfall events. They consist of dense fluid mixtures of debris (rock, soil, vegetation) and water. Sediment concentrations are high, with a consistency like wet concrete. They move rapidly down a channel faster than the flow of water.

Debris mantle regolith: Comprises slope debris derived from the underlying and upslope bedrock and bedrock regolith, and may contain layers of regionally derived loess, and/or interlaid tephric loess, and/or tephra depending on location.

Degree of erosion: Extent of sheet, wind, and scree erosion is recorded on an areal basis as the percent of bare ground or area eroding. However soil slip, slump, debris avalanche, earth flow, rill, gully, tunnel gully, and streambank erosion are recorded in terms of seriousness, which is decided with reference to standard selected sites, parent material, physical loss of land, and cost of repair.

Degree of limitation: Applies to the Land Use Capability Classes, and expresses the relative limitations to sustained use, from Class 1 to Class 8.

Diversion channel: A channel constructed around the slope or a designed gradient, to intercept and divert water away from highly erodible sites (particularly effective for gully control).

Downland: Undulating land; usually an extensive area of gently to strongly rolling land around the margin of a plain.

Drop structures: Structures constructed in gullies to dissipate the energy and erosive power of falling water.

Erosion control forestry: (a) Planting exotic forest species principally for soil conservation and water management purposes but with a variable component of production permitted. (b) Management of indigeneous forests principally for soil conservation and water management purposes but with some selective milling permitted (also see production forestry).

Erosion definitions and types (See Appendix 2).

Erosion severity: (See Degree of erosion**).**

Fan: Fans are gently sloping, fan-shaped masses of material formed along the margins of hills and mountain ranges by the streams that drain their slopes. A fan commonly occurs where there is a marked decrease in gradient, for example where a stream meets the gentler floodplain or river terrace.

Ferrihydrite: A non-crystalline iron oxide mineral; has a very large surface area per unit weight.

Ferromagnesian minerals: Minerals containing iron and magnesium.

Field survey: As referred to in land inventory mapping, is the field observation, measurement and recording of the physical factors of the landscape in symbol form on a suitable base map.

Fine earth fraction: Those particles in a mass of soil less than 2 mm in diameter, i.e., *sand* (particles between 0.06 and 2.0 mm), *silt* (particles between 0.002 and 0.06 mm), and *clay* (particles less than 0.002 mm) in diameter.

Flood plain: The surface of relatively flat land adjacent to a river channel; built of alluvium deposited by that river or stream, which in the absence of flood protection works may still be flooded.

Fluviatile: Belonging to a river, produced by river action; growing or living in freshwater rivers.

Foliation: A planar arrangement of textural or structural features, especially that which results from the flattening of the constituent grains of metamorphic rocks.

Forage crops: Supplementary feed crops for livestock. Winter forage crops include hay, silage, turnips, swedes, choumoellier, and kale; summer forage crops include soft turnips, rape, lupins, barley, cereal greenfeeds; autumn forage crops include rape, kale, turnips, lupins, green maize.

Forestry potential: The potential for establishment of productive exotic forest, based on assessment of the physical factors of the site, *but not* on a full-scale study of economics, transport, markets, etc.

Fractured rock: Rock in which breaks, cracks or joints occur due to mechanical failure by stress, with or without displacement.

Fragipan: A subsoil horizon which has a high bulk density and which is relatively hard when dry but softens when wet. Fragipans usually impede the downward movement of water. The presence of a fragipan frequently gives rise to impeded drainage and *perched water tables*.

Friable: A soil consistence term relating to the ease of crumbling of soils.

Gley Soils [NZ Soil Classification]: Are saturated by water for prolonged periods and have pale greyish subsoils. Many were originally wetlands before being drained.

Gleying: Absence of oxygen in soil leading to strong reducing conditions that create grey coloured profiles. Usually associated with drainage limitations, perched water tables and severe compaction.

Gneiss: Hard coarse-grained metamorphic rock often similar in appearance and composition to granite; usually has some banding.

Graded diversion (See Diversion).

Granite: Coarse-grained hard igneous rock that has crystallised deep below the earth's surface. It is rich in crystals of quartz, feldspars and shiny black and white micas.

Granular Soils [NZ Soil Classification]: Clayey soils derived from strongly weathered volcanic rocks or ash, well developed resistant structure, slowly permeable and limited rooting depth.

Gravel: Rock fragments greater than 2 mm in diameter.

Grazing control: Control of stock numbers and movements to specific areas, most commonly by fences.

Greenfeed crops: Special-purpose crops grown to provide succulent nutritious forage, e.g. for flushing ewes, for lambing ewes in August, and for milking cows in August and early spring.

Greywacke: A dark grey sandstone, flecked with angular fragments of finer rock; formed by the hardening of deposits in ocean basins; the major rock type of central New Zealand.

Groundwater: Water which occurs in the soil or rocks below the ground surface, and which is free to flow.

Gully planting: Gully control and stabilisation involving the establishment of vegetation with extensive rooting systems to reduce the velocity of flow and hence transporting power; to increase the resistance to flow; and to trap debris. This is usually done in conjunction with small structures, diversions, fencing for stock exclusion, and perhaps minor bulldozing.

Hard rock: Rocks that have hardness and strength through induration. They ring when struck with a hammer, require a strong blow to fracture and are impractical to dig with a spade.

Hazard: The danger/risk of erosion and/or flooding.

Homogenous mapping units: At the scale of mapping the inventory factors (rock type, soil, slope erosion severity and type and vegetation cover) are considered homogeneous within the mapping unit.

Horticultural use: The growing of crops, excluding berry fruit, vines and orchard crops, for the fresh fruit and vegetable market, and intended to be consumed fresh.

Hydromorphic features: Mottling or gleying caused by chemical oxidation/reduction reactions associated with changes in oxygen availability.

Igneous: Rocks that were once molten. If they crystallise deep below the earth's surface they are plutonic (e.g. granite); if they are erupted they are volcanic (e.g. rhyolite).

Imperfectly drained soils: Soils that have 50% or more grey mottles between 30–60 cm of the soil surface (but not within 15 cm of the base of the A horizon), or soils that 2% or more rust-coloured mottles or less than 50% grey mottles within 15 cm of the base of the A horizon, or within 30 cm of the soil surface.

Intermontane: Situated between, or surrounded by mountains or mountain ranges.

Intrusive rock: Rock that consolidated from magma beneath the surface of the earth.

Joint: Fracture or parting in a rock, without displacement.

Kind of limitation: The single most limiting factor to the use of land for common agricultural purposes. Four kinds of limitation are recognised: erosion (e), excess water (w), root zone limitations (s), and climate (c).

Lahar: A flow of volcanic material, both ash and coarser products, mixed with water; often caused by the spilling-over of a crater lake.

Land Resource Inventory (LRI): An inventory of the five physical factors considered to be critical for long-term sustainable land use; rock type, soil, slope angle, erosion type and severity, vegetation.

Land Resource Inventory (LRI) map unit: The land contained by a mapping boundary within which each of the physical characteristics recorded in the inventory is uniform at the scale of mapping.

Land Use Capability map unit: The land contained by a mapping boundary within which each of the physical characteristics recorded in the inventory is within the range of those defined for a specific Land Use Capability Unit.

Landslide: Landslide is a generic term covering a wide variety of mass movement types involving the movement of a mass of rock, earth or debris down a slope, under the influence of gravity. Landslides usually involve rapid failure along a slip plane at the contact between a more permeable material and an underlying less permeable material occurring when shear stress forces exceed shear strength. Landslides vary in size and volume from <10 m^3 to $>1,000,000$ m^3.

Lapilli: Pebble-sized fragments of tephra.

Lava: The molten rock that exudes from a volcano. Also the solid rock formed from cooling the molten material.

Levee: Any naturally produced low ridge, but usually built of sand and silt by a stream on its floodplain.

Light summer grazing: Restricted, controlled grazing during summer to encourage flowering and seeding of native and/or introduced pasture. A management technique used in the rehabilitation of depleted and eroded high country areas particularly in the semi-arid and mountainous regions of the South Island.

Limestone: A rock composed predominantly of calcium carbonate.

Lithic contact: The contact of soil with underlying rock where the rock is hard or very hard, maybe cracked and shattered, is impracticable to dig with a spade, and is impenetrable to plant roots.

Lithology: The nature and composition of rocks.

Loess: A blanket deposit of silt-sized materials; usually carried by wind from dry river beds or outwash plains during glacial and post-glacial periods.

Magma: Molten rock generated within the earth; on cooling, forms igneous rocks.

Map unit: The area enclosed by a boundary indicating that within the limitations imposed by the scale of mapping the information mapped is homogeneous within that area i.e. rock type, soil, land use capability etc.

Marble: A hard metamorphic rock consisting predominantly of the calcium carbonate mineral calcite.

Massive: Occurring in thick beds, free from minor joints and lamination.

Melanic Soils [NZ Soil Classification]: Have high fertility, dark well structured topsoils, and are associated with lime-rich rocks or dark (basaltic) volcanic rocks.

Metamorphic rocks: Rocks that have been altered by heat and pressure deep below the earth's surface.

Minimum tillage: An alternative to conventional cultivation aimed at minimising disturbance of the soil after spraying with herbicide. The soil is lightly worked with a cultivator before drilling.

Modal classes: When formulating Land Use Capability standards each soil grouping is usually assigned a capability class. Variables such as slope, elevation, or erosion, may then be of significance and warrant placing variants in a higher or lower capability class.

Moderately well drained soils: Soils that have 50% or more grey mottles between 60–90 cm of the soil surface or greater than 2% rust-coloured mottles between 30–90 cm of the soil surface.

Moraine: Mound or ridge of debris deposited by a glacier. Lateral moraine is deposited at the sides of a glacier; medial between two tongues of ice, and terminal at the front end of the glacier.

Mottles: Spots or blotches of (often bright) colour different from the predominant soil colour. Very often the mottles are rusty in colour and are due to concentrations of iron oxides. Mottles indicate that there are periods of restricted *profile drainage*. The severity of the restriction to profile drainage is indicated by the abundance and depth at which mottles and *gleying* occur.

Mudstone: Soft sedimentary rock formed from material which contains a large proportion of clay. Form may be massive, bedded, frittered or bentonitic. Mudstone comprises much of the Tertiary 'soft rock' hill country. Soils formed from mudstones tend to be naturally fertile, but often carry a severe erosion potential.

Multiple symbols: Are used to denote that at the scale of mapping, there are two or more inventory factors or land use capability classes present within the mapping unit. The first recorded component is dominant, e.g. rock types Af+Pt; soils 99+90d; slope C+D … land use capability classes 3e4+6e12 etc.

Multiple use concept: Flexible land use and management that meets society's objectives and achieves sustainable yields whilst maintaining the resource.

Native pasture: Grasslands dominated by poa tussock, fescue tussock, snowgrass, and red tussock, and native grasses such as danthonia and fescue, and various small herbaceous plants which extended over considerable areas of New Zealand at the time of European settlement.

New Zealand Land Resource Inventory (NZLRI): A national land resource inventory survey that used the land use capability method of land evaluation at a nominal scale of 1:50,000 (1:63,360), which was initially completed in the late 1970s (1st Edition), with limited 2nd Edition regional remapping in Northland, part Waikato, Gisborne East Coast, and Marlborough in the 1990s.

New Zealand Land Resource Inventory (NZLRI) Worksheets: The map presentation of NZLRI inventory codes (rock type, soil, slope angle, erosion type and severity, vegetation cover) and land use capability codes.

No-till: An alternative to conventional cultivation aimed at minimising disturbance of the soil. After spraying with herbicide to kill weeds the seed is drilled directly into the undisturbed soil (also known as direct drilling).

Optimum crop production: Maximising sustainable crop production within the environmental limits of a particular soil and site.

Organic Soils [NZ Soil Classification]: Formed from partly decomposed plant materials, e.g. peat, are strongly acidic and have high water-tables.

Outfalls: Safe disposal areas for water directed from soil conservation structures such as flumes, diversion banks etc. Outfalls include natural depressions, sod flumes, road ditches, waste land, concrete channels and tile drains.

Oxidic Soils [NZ Soil Classification]: Clayey soils formed from weathered ash or dark volcanic rock, friable with low plasticity and fine stable structure, limited rooting depth, slow permeability, and moderate or rapid infiltration rates.

Pallic Soils [NZ Soil Classification]: Have pale coloured high bulk density subsoils, weak structure, are slowly permeable and have limited rooting depths. They are dry in summer and wet in winter.

Paralithic contact: The upper surface of rock or regolith that can be cut with difficulty with a spade or easily broken by a hammer, but is impenetrable to plant roots.

Parent material: The unconsolidated material in which the soil develops.

Parent rock: The rock from which the parent material is derived by weathering.

Pastoral use: Growing of pasture to be harvested by grazing animals, but in some cases, e.g. lucerne, to be harvested by machine and fed to grazing animals. The term may also embrace the growing of fodder crops for on-farm supplementary feeding of animals.

Perched water table: A zone in the soil where, due to a slowly permeable layer such as a fragipan, downwards percolation of water is impeded and the water table is said to be 'perched' above the slowly permeable layer of soil.

Perennial vegetation: Vegetation living for more than 2 years, e.g. pasture, forestry, tree crops (walnuts, apples and olives) and vineyards.

Permanent works: Major works such as large scale community based irrigation, flood control or drainage schemes that significantly reduce or permanently remove a limitation to use.

Permeability: A measure of the rate at which water can flow through the soil.

Phosphate retention: Capacity of a soil to 'lock up' phosphorus and make it plant-unavailable. High P-retention values indicate that plants will give a lower response to the same amount of phosphate fertiliser than on a soil with low P-retention.

Physical limitations: Permanent unalterable features of the environment that determine the potential use of an area, under a given climate, i.e. rock type, soil, slope, climate, erosion, and vegetation.

Plant-available nutrients: The proportion of soil nutrients available for plant uptake.

Plant-available water capacity: The amount of water a soil can hold that is available for plant uptake.

Podzols [NZ Soil Classification]: Occur in high rainfall areas, are strongly acidic and strongly leached, with very low fertility. Drainage is variable from well to poorly drained.

Polygon: A series of points that are combined together topologically to create a two-dimensional enclosed space, equivalent to a map unit.

Poorly drained soils: Soils that have 50% or more grey mottles within 15 cm of the base of the A horizon or within 30 cm of the soil surface, OR soils that lack a topsoil and have 50% or more grey mottles between 10–30 cm depth from the soil surface.

Porosity (soil porosity): The amount and nature of the voids in a soil. A soil with high porosity allows water and gases to pass relatively easily.

Potential evapotranspiration: Actual evapotranspiration is the total volume of water removed from land through evaporation and plant transpiration. Potential evapotranspiration represents the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate soil water supply.

Production forestry: Forests managed principally for commercial wood production.

Profile available water (PAW): The amount of water that can be extracted between field capacity (−10kPa) and −1500kPa to 1.0 m depth.

Profile drainage: Profile drainage provides an indication of how long a soil, or part of a soil, is saturated with water, and how quickly it can rid itself of excess water.

Profile readily available water (PRAW): The amount of water held in a soil that can be easily extracted by plant roots within the potential rooting depth. Profile readily available water (PRAW) is measured as the water that can be extracted between field capacity (−10kPa) and permanent wilting point (−1500kPa) for topsoils, and between −10kPa and −100kPa for subsoils to 1.0 m depth.

Protection forestry: Forests managed principally for soil conservation and regulation of water (also see erosion control forestry)

Protective blocks: Spaced or close planted blocks of trees, creating strong points to control gully head enlargement and the gradient of the longitudinal gully profile.

Pumice: A soft, light-coloured, frothy, glassy rock with the appearance of a sponge; usually formed by the trapping of bubbles of volcanic gases in molten rhyolite.

Pumice Soils [NZ Soil Classification]: Sandy or gravelly soils dominated by pumice, or pumice sand with a high content of natural glass, rapid drainage but high water storage capacity, low clay contents, low soil strength, high macroporosity, deep rooting depths, and low macronutrient reserves.

Raw Soils [NZ Soil Classification]: Very young soils lacking distinct topsoil, and developed on sites of active deposition or erosion.

Reach: The length of a channel, uniform with respect to discharge, depth, area, and slope.

Recent Soils [NZ Soil Classification]: Soils formed in young sediments. They have distinct topsoil, but weakly developed subsoil, with moderate to high fertility and well to imperfect drainage. They have widely variable rooting depths and water storage capacities.

Recommended land use: A legacy component of early Land Use Capability surveys, whereby a map of *recommended land use* was prepared to accompany the Land Resource Inventory and the LUC classification. Simply recognises that some land uses are more suited (or less suited) to particular land types and classifications. Similar to *potential land use* used in NZLRI extended legends.

Reconnaissance surveys: Quick investigative surveys to gain preliminary information for planning more comprehensive surveys.

Redox segregations: Redox segregations are mottles or concretions formed as a result of the reduction and solubilisation of iron and/or manganese, their translocation, concentration, oxidation and precipitation as oxides. They are indicated by the association of low and high chroma colours.

Regolith: A general term for the layer or mantle of fragmental and unconsolidated rock, whether residual or transported and of highly varied character, that nearly everywhere forms the surface of the land and overlies and covers the bedrock.

Resilient soil: Soils with the ability to recover or maintain essential soil physical qualities such as infiltration, aggregation and aeration from modification such as intensive cultivation.

Rhyolite: Volcanic rock rich in silica, but poor in iron and magnesium. Molten rhyolite is very stiff and usually gives rise to explosive volcanic eruptions with emissions of large quantities of ash.

Rooting barrier: The type of barrier that limits root extension, e.g. very dense soil horizons, pans, densely packed gravels, rock, anoxic conditions and high water tables.

Rooting zone limitations: Limitations to plant growth within the rooting zone such as profile shallowness, stoniness, pans, rock outcrops, low soil water holding capacity, low fertility (where this is difficult to correct), poor soil texture and structural conditions, salinity or toxicity.

Saline soil: Soil that contains enough soluble salts to interfere with the growth of most crop plants.

Sand: Material which consists of particles between 0.05 and 2.0 mm in diameter.

Sandstone: Sedimentary rock consisting of compressed or cemented sand-sized particles.

Schist: A metamorphic rock that has developed distinct layering (foliation); can be split into slabs or flakes. Mica appears as characteristic shiny flecks in the rock.

Seasonal wetness: Seasonal fluctuation of water table depths influencing plant performance through determining soil aeration, e.g. high water table in winter, lower in summer.

Sedimentary rock: Rocks resulting from the consolidation of loose material that has accumulated in layers, usually on the bed of the sea, in lakes or in rivers.

Seepage: Groundwater emerging at the surface. This commonly takes place at a change of slope, at the junction of permeable and impermeable strata, or where groundwater is perched.

Semiarid Soils [NZ Soil Classification]: Are dry for most of the growing season, have moderate to high natural fertility and are well to imperfectly drained. They are fragile with weak soil structure, and very low organic matter.

Silt: Material which consists of particles between 0.05 and 0.002 mm in diameter.

Soft rock: Weak rocks with minor or insignificant cementation that disaggregate with a mild hammer blow or can be crushed by hand. Soft rock can be cut by hand with a spade.

Soil and water conservation plans (farm plans): A conservation management plan designed to address soil erosion and water control issues through management, and the installation and maintenance of conservation works. Such a plan includes:

(a) An initial land inventory survey and land use capability assessment

(b) The design of a conservation programme based on land use capability, and effective, economic soil and water conservation techniques.

(c) An agreement between the regional authority and the farmer to carry out specified works or practices within a prescribed period.

Soil depth: Soils are assigned to one of five depth/stoniness phases according to their depth above gravel, bedrock or stone in the upper 20 cm: Deep (>90 cm), Moderately deep (45–90 cm), Shallow (20–45 cm), Very shallow (<20 cm), Stony (5–35% stones in upper 20 cm), and Very stony (>35% stones in upper 20 cm).

Soil erosion: Is the displacement of sediment, soil, rock and other particles usually by wind, water, or ice, by downward movement in response to gravity, or by living organisms.

Soil phase: Most commonly used as a subdivision of the soil type based on a characteristic or combination of characteristics potentially significant to land use, e.g. depth, physical composition, surface forms, drainage, salinity, erosion, sedimentation, or climatic regime. For example, Oxford silt loam, easy rolling phase; Mata clay, slightly eroded phase; Rukuhia peat, burned phase.

Soil profile: A vertical section of a soil showing all its horizons to 100 cm depth.

Soil salinity: Soils where the electrical conductivity of a saturated soil extract is greater than 0.8 mS cm^{-1}.

Soil series: As a profile class concept, a modal profile with defined range of values for certain properties, e.g. Templeton series. As a soil mapping unit – a soil-landscape mapping unit dominated by Templeton series profile classes, BUT which may contain other profile classes, for example, the Eyre or Wakanui series.

Soil set: A convenient mapping unit used on general surveys, and is a grouping of soils with like profiles or like assemblages of profiles. Its constituent soils need not be geographically related.

Soil structure: The way in which soil particles are aggregated into soil *peds*. Structure is described by ped size (fine, medium, or coarse), shape, and how strongly they are formed (weakly, moderately or strongly). The presence of peds is important because spaces are left between and within them. These spaces are necessary for root growth and the movement of water and air within the soil.

Soil texture/texture class: Soil texture is used to describe the particle distribution of those particles in a mass of soil that are less than 2 mm in diameter. Particles coarser than 2 mm are described as gravel and are not regarded as a textural component. Soil texture is described as a class determined from a standard texture triangle based on the relative proportions of sand, silt and clay.

Soil type: The basic unit of soil mapping, a unique combination of chemical, physical, biological, and mineralogical characteristics and site features. Often designated by a geographic name and/or a topsoil textural and depth qualifier.

Stony soils: Soils that have 5–35 % stones in the upper 20 cm depth.

Stopbanks: Embankments along streams or on floodplains designed to confine river flows to a definite width for the protection of surrounding land from flooding.

Supplementary feed crops (See Forage crops and Greenfeed crops).

Surface runoff: Is that portion of the precipitation that makes its way towards stream channels, lakes, or oceans as surface flow. The term runoff also includes subsurface and deep seated flows. Runoff will occur only when the rate of precipitation exceeds the rate at which water may infiltrate into the soil.

Tephra: A general term for all solid (rather than molten) materials ejected from a volcano during an eruption: boulders, lapilli and ash.

Terrace: A relatively flat or gently inclined surface (tread) less broad than a plain, bounded one edge by a steeper descending slope (riser) and along the other by a steeper ascending slope (riser), and sufficiently elevated to be beyond the reach of the waterway that formed it.

Texture: (see soil texture**).**

Topsoil: A general term for the upper part of a soil with evidence of organic matter accumulation; usually identified as an A horizon.

Tree crops: The growing of trees for fruit and/or nut production.

Tuff: A general term for consolidated volcanic tephra.

Ultic Soils [NZ Soil Classification]: Strongly weathered soils with a well-structured, clay-enriched subsoil horizon, clay depleted E horizon immediately beneath the topsoil. Ultic Soils are acid and strongly leached with low levels of Ca and other basic cations, are slowly permeable, and have low nutrient reserves.

Ultramafic: Relates to igneous rocks with very high contents of dark-coloured minerals containing iron and magnesium and less than 44% silica.

Very poorly drained soils: Soils that have an O horizon (an organic horizon), or lack a distinctive topsoil and have 50% or more grey mottles at less than 10 cm from the soil surface.

Vineyards: Growing of vines for their fruit, e.g. grapes, kiwifruit; or flowers, e.g. hops.

Volcanic ash: Fine ash-like rock particles ejected from volcanoes during eruptions; may be transported large distances by wind.

Water holding capacity: The storage capacity (or ability) of a soil to hold water.

Waterlogging: Periods of soil anaerobic conditions after rain or flooding. S*hort-term water logging* is where anaerobic conditions may occur after heavy rainfall for periods of up to one week; W*ater logging* is where there are sustained anaerobic conditions for periods of greater than one week due to a high groundwater table or perched water table.

Water table: At a depth below the surface, the ground is saturated with water. The upper surface of this zone of saturation is termed the water table.

Well drained soils: Soils that have no evidence of gleying or mottling within 90 cm of the soil surface.

Windbreaks: Any type of barrier for protection from winds. Although more commonly associated with vegetative barriers, they also include non-vegetative barriers.

The New Zealand Association of Resource Management (NZARM) and the New Zealand Society of Soil Science (NZSSS) proudly support and endorse the LUC Handbook and its use for consistent and professional application of the LUC Classification system in New Zealand.

Simon Stokes

Simon Stokes, NZARM President 2009.

Brent Clothier

Brent Clothier, NZSSS President 2009.

Our land resource

New Zealand's productive landscape is built upon the diversity and capability of land. Each landscape combination of soil, climate, and landform is uniquely different, with each having its own production potentials, alternative uses, and individual management requirements for sustainable production.

Land Use Capability

Realising land potentials requires a knowledgeable understanding of the land resource to begin with. Land Use Capability (LUC) is a complete system for not only identifying and describing individual units of land, but also for assessing the capability of those units against a national classification reference. This is a robust and established system that has been used in NZ agriculture and resource management since 1952.

The LUC Survey Handbook

This Handbook introduces the reader to the contemporary methods and standards of the LUC system, including:

1. *How to prepare a physical inventory of the land resource.*
2. *How to rank land according to its general capability for sustained production.*
3. *How to identify the dominant limitation to sustainable use.*
4. *How to classify similar areas of land for selective use and management.*

The intended audience is beginner and experienced surveyors, but the Handbook is suitable reading material for any person with a need or interest in finding out about LUC and its practical application.

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