Where to from here? - a review of the Land Use Capability Classification System

Key Points

- The Parliamentary Commissioner for the Environment highlighted that significant gaps exist in the core datasets and knowledge that underpin our stewardship of New Zealand's environment.
- The national Land Use Capability Classification System (LUCCS) has provided a standard method and the information for evaluating New Zealand's land resources (natural capital) for more than 40 years.
- The LUCCS is well entrenched in catchment and land management decision making, and more recently underpins national policy and regulation.
- A major challenge is that LUCCS has remained in a static state, with no major funding for the last 20 years, and some of the core data are now obsolete.
- A multi-agency LUCCS Governance Group was formed with the vision to 'Provide the preeminent information system (LUCCS) and knowledge base for planning and managing the land resource of New Zealand'. This review identifies key recommendations to help implement that vision.

<u>Background to the LUCCS</u>

- The national Land Use Capability System (LUCCS) consists of the New Zealand Land Resource Inventory (NZLRI) and the Land Use Capability (LUC) classification.
- The NZLRI is a multi-factor (soil, slope, and erosion) national land resource database mapped at a scale of 1:50,000. It comprises over 100,000 mapping units each classified using LUC classification of eight main classes.
- The LUC is a simple robust land classification system originally designed for soil conservation, erosion planning and farm management. LUC mapping is based on the national Land Use Capability Survey Handbook and can be applied at any scale.
- The NZLRI has been widely used over the last 40 years by central and local government, research institutes, farmers, consultants, and primary sector organisations. The NZLRI and LUC were designed originally as a national resource inventory and applied to a wide range of land management and environmental issues. More detailed LUC mapping has been used as a farm management tool in a number of regions' farming sectors.
- Between 1971 and 1979, New Zealand was mapped (1st edition) using LUC at a scale of 1:63 360 (1 inch to 1 mile). In the 1980s the maps were adapted to the metric 1:50,000 scale. Several regions[1] were later remapped (2nd edition). The information is stored on the Manaaki Whenua's Land Resource Information System (LRIS)as a geospatial database.
- Since 1993, the database forms part of the country's Nationally Significant Collections and Databases (NSCD), but funding has been limited to maintaining the provision of the existing dataset, with improving the data currently out of funding scope. A review of the NSCD is currently underway by Ministry of Business, Innovation and Employment. Ideally, this paper will inform MBIE's review.

<u>Significant issues facing the LUCCS:</u>

- Funding for the regional-scale (1:50,000 scale) mapping has ceased. Long-term funding of land resource datasets is becoming increasingly tenuous. The LUCCS has remained in a static state for over 20 years.
- Several of the underlying resource inventories are obsolete, and the LUCCS needs to incorporate and use modern datasets (e.g. S-map, LiDAR) and invest in new datasets (e.g. erosion susceptibility)
- The LUCCS is increasingly being used to support resource management plans, regulations and farm planning. The general scale of mapping, obsolete data and lack of formal training for LUCCS surveyors are likely to increase the risk of litigation.
- Farm environment plans will be required to include a mandatory freshwater module, which is likely to increase the demand for better quality land resource information to identify potential risks to freshwater bodies.
- New digital methods of evaluating and collecting land resource information and analysing geospatial datasets are evolving rapidly.
- The pool of experienced LUC surveyors is declining, and their accumulated body of work needs to be archived.
- LUC mapping is being used for farm planning purposes and regulation, increasing the risk of litigation due to the current inadequacies of the LUCCS.

<u>Recommendations for the future direction of LUCCS</u>

- Repeating the original NZRLI multi-factor mapping programme using conventional methods should not be attempted as this would not be cost effective nor provide LUCCS with the flexibility that is now required.

- The LUCCS remains an essential tool for evaluating land resources in New Zealand. The LUCCS continues to be relevant both now and into the future provided there is investment in the maintenance and improvement of the underlying databases to support its use at regional and national scales and farm planning at local scales. The overall aim should be to modernise the LUCCS to support the expanding range of uses, while ensuring that the system is flexible enough to support new or evolving applications, such as digital land resource mapping.
- Increased public investment is needed to:
  - Update the detail and extent of the natural resource inventories to address the shortcomings in the country's environmental databases.
  - Train new practitioners and revise the LUC Handbook to increase knowledge and ensure the correct use of LUCCS, especially for national policy implementation and farm environment planning.
- New technologies for developing more accurate, databases provide an opportunity to update LUCCS to make it fit for purpose for the future requirements of natural capital management in New Zealand.

Priority areas for work and investment

National and regional mapping and databases

- Prepare a business case to support the public investment to update the core erosion components of the NZLRI, for example, development of an erosion susceptibility layer.
- The LRIS needs to continue to be recognised as one of the country's Nationally Significant Databases, and funding to maintain the database needs to be increased in "real terms".
- Develop an overarching investment strategy is required to ensure the LUCCS remains current, consistent, and nationally available.
- Develop a communication strategy to inform users of ongoing developments in LUCCS.
- Prepare guidelines on the appropriate use of LUCCS for regulation and policy.
- Advocate for continued national investment to extend and complete national coverage of the supporting land resource inventories - S-map and LiDAR. High quality open source geospatial datasets would support a wider range of new and evolving end uses and applications.
- Support further development and testing of methodology for digital LUC mapping from the base NZLRI data layers.
- Manaaki Whenua – Landcare Research & AgResearch Ltd to investigate updating the regional stock carrying capacity extended legend for the LUC units.
- Manaaki Whenua – Landcare Research & GNS Science to investigate developing a national parent material geospatial layer to complement QMAP and S-map.

Farm environment plans/property scale mapping

- Prepare a paper detailing and discussing the role of the LUCCS for Farm Environment Plans.
- Undertake a survey of LUCCS users to understand their needs, use of the LUCCS and its strengths and weaknesses.
- Develop a post graduate qualification and a nationally recognised certification scheme for LUC surveyors.
- Apply for funding to revise the 3rd edition of the Land Use Capability Survey Handbook.
- Manaaki Whenua – Landcare Research to complete and publish the national LUC classification legend.
- Apply for funding to develop a digital archive of NZLRI publications, extended legends, and regionally produced soil conservation reports, and maps.

Summary

In a recent review, the Parliamentary Commissioner for the Environment found the national environmental datasets were deficient and suffered from a lack of public investment.

The New Zealand Land Resource Inventory is a typical example. The government invested heavily in the programme during 1970s and 1980s, but apart from some regional updates, the database has languished since the late 1990s.

This briefing paper has been written for people who are familiar with the Land Use Capability Classification System (LUCCS) and those with little knowledge of the system. It examines how LUCCS

is managed and used, the challenges facing the system, and identifies new opportunities for developments to refresh and update the system to meet the increasing demands on New Zealand's natural capital.

Background

High quality basic data about New Zealand's land resources is indispensable if we are to make good well founded decisions about managing the environment[1]. Land resource information is widely used by businesses, rural industry, research organisations and council and government agencies.

Since 1980, various reviews have pointed out the deficiencies in the quality, coverage, currency, and availability of the country's land resource information[2].

The Land Use Capability System (LUCCS) incorporating the New Zealand Land Resource Inventory (NZLRI) and the Land Use Capability classification (LUC) was originally developed to set national standards for soil conservation and erosion control planning and management[3]. Over the last few decades, the LUCCS has been used widely as a policy/planning tool and as the principal source of land resource information, reflecting the lack of comprehensive detailed natural resource databases in New Zealand. It has resulted in the LUCCS being used for purposes it was never designed for or envisaged when it was originally produced, such as allocating nitrogen loads from farms, or implementing regulations.

Many parts of the LUCCS database are out of date and some are becoming obsolete. Since the late 1990s, there have been only four regional updates to 2nd edition LUCCS mapping standards (Northland, Gisborne-East Coast Wellington and Marlborough) and no significant updates to the NZLRI inventories or national classification The LUCCS mostly consists of data collected in the 1970s, incorporating the regional 2nd edition updates in the 1980s and 1990s, based on concepts and methods developed in the 1950s. In the last 20 years, newer, higher quality geospatial datasets[1] and quantitative methods of analysis have become available[4].

Many of the people with expertise in the LUCCS and land use capability mapping are retiring, and there is urgent need to ensure that their skills and knowledge are used to update existing inventories and to be passed onto the next generation of researchers and practitioners.

These emerging issues led to a multisector workshop in 2012 and subsequent reports[5] on the future of the NZLRI. Since then, only a limited amount of work has been done to update individual inventory factors[6].

Regional council's Special Interest Groups (SIGs) for land[2] acknowledge the inadequacies of New Zealand Land Resources Inventory (NZLRI) and Land Use Capability (LUC) for contemporary use and consider the modernisation of the LUCCS as a high priority[7].

At their May 2019 meeting, the LUCCS Governance Group[3] decided to commission a briefing paper to examine the current state and use of the LUCCS, and to recommend ways to modernise the LUCCS.

A brief history of the LUCCS

The land use capability system was developed as a tool for regional catchment, and farm soil conservation planning. The concept originated in the United States as a way of assessing the country's land resources for agricultural production[8]. Data on the land resources (soils, lithology, slope, vegetation, erosion) was collected and used to delineate areas into homogenous mapping units with similar physical characteristics and limitations or hazards according to its long-term primary production potential. Each land unit was assessed using an eight class scale (Box 1). Similar management and conservation practices would apply to land with the same grading[9].

During the 1950s, a series of land capability surveys were carried out in New Zealand, resulting in the adoption of the United States eight class system[10]. The land mapping system, adapted for New Zealand conditions, comprises two key sets of information, a multifactor inventory of the land resources and a LUC classification (Box 1).

Between 1973-1979, the Ministry of Works and Development, on behalf of the National Water and Soil Conservation Authority, carried out a nationwide survey producing the 1st edition 1:63,360 (one inch to one mile) land use capability (LUC) worksheets with extended legends[11].

The country was divided into 12 regions (Figure 1). Each region had a separate LUC classification outlined in an extended legend and bulletins, with more supporting information, were published for eight regions. The worksheets were digitised and stored in an early geospatial database system[12].

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[1] For example. GNS Science's geological geospatial database QMAP, Manaaki Whenua's soil geospatial database S-map., LiDAR
[2] Land Monitoring Forum (LMF) and Land Managers Group (LMG).
[3] The Land Use Capability Classification System Governance Group, comprising central, regional government, industry and MWLR representatives, was established in 2012 to ensure that the system is maintained and developed to meet future needs

A land capability classification for urban areas was also developed[13], and used by a few councils[4] for urban planning and hazard mapping.

Four regions[5] were remapped at a scale of 1:50,000, and limited revisions were made to the lithology, erosion and vegetation definitions and symbols[14].

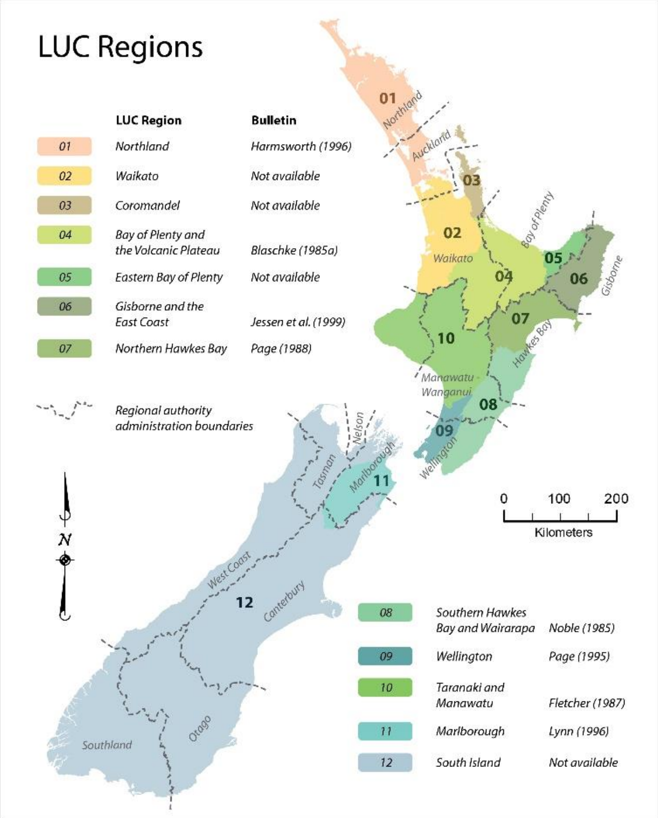

Figure 1 Land use capability regions &published bulletins (Lynn et al., 2009)

In the mid-1990s, the funding for the regional-scale mapping ceased. The LUCCS database has remained in a static state and some of the information is now outdated[15]. During this period, catchment authorities and later some regional councils, produced detailed land capability maps and soil conservation plans of some farm properties[16].

In 2011, the LUCCS datasets were moved with other land resource data onto Manaaki Whenua's Land Resource Information System (LRIS) database[17]. LRIS now contains archived hard[6] and digital[7] land resource information[8], derived data sets, and an associated suite of analytical models for generating derivative and integrative interpretations[18].

Since 1993, LRIS, including the LUCCS, has been one of the country's Nationally Significant Collections and Databases[19].

Box 1: The New Zealand Land Use Capability System

The New Zealand Land Use Capability system has two main components:

1. The **New Zealand Land Resource Inventory (NZLRI**) is a single layer, national, geospatial database containing an inventory of five key physical factors (rock, soil, slope, erosion, and vegetation) that define the suitability of land for sustainable use. Mapping units consist of land with similar physical characteristics. An inventory code records the physical factors for each mapping unit.

   Rock type – Soil unit – Slope
   Erosion degree and type – Vegetation

   e.g. Gw – 58 – F
   2Sh – P4

2. The **Land Use Capability (LUC) classification is an assessment of** the capacity of the land for long-term sustainable agricultural production.

The LUC system is a three level hierarchical classification system, comprising LUC class, LUC subclass, and LUC unit.

LUC Class is the highest level. It classifies the land into eight main classes, based on increasing physical limitations and decreasing versatility for long-term agricultural uses.

Other information e.g. flood risk, climate, is used to support the LUC classification of the land.

Four **LUC subclasses** – erosion (e), wetness (w), soil physical or chemical limitations (s), and climate (c) – are used to identify the dominant factor limiting sustainable agricultural production in each class.

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	Environmental land

LUC Unit is the 'management' level of the LUC classification. It is the most detailed mapping unit of the classification and comprises land with similar physical characteristics which would require the same kind of management and have similar production yields.

The revised **Land Use Capability Survey Handbook** sets out the methods and standards for undertaking LUC surveys at any scale (Lynn et al., 2009).

Who uses the LUCCS information?

The LUCCS is freely available to anyone. The data is commonly accessed via the LRIS[20]. The original hard copy LUCCS regional worksheets and extended legends and reports are less accessible[9]; some scanned reports are available via the LRIS[21], or as hard copies in some libraries.

[4] For example: Whangarei and Palmerston North city councils.
[5] Northland, Wellington, Marlborough, and Gisborne-East Cape
[6] Annotated aerial photos, oblique photos, card files and maps.
[7] Satellite imagery, photographs.
[8] Vector and raster based spatial layers.
[9] LRIS provides LUC extended legend information in attribute tables with the GIS layers.

Despite its age, LUCCS information is still widely used. A 2018 survey found LRI (including LUC) information was one of the top five sources of land use information for councils (Figure 2).

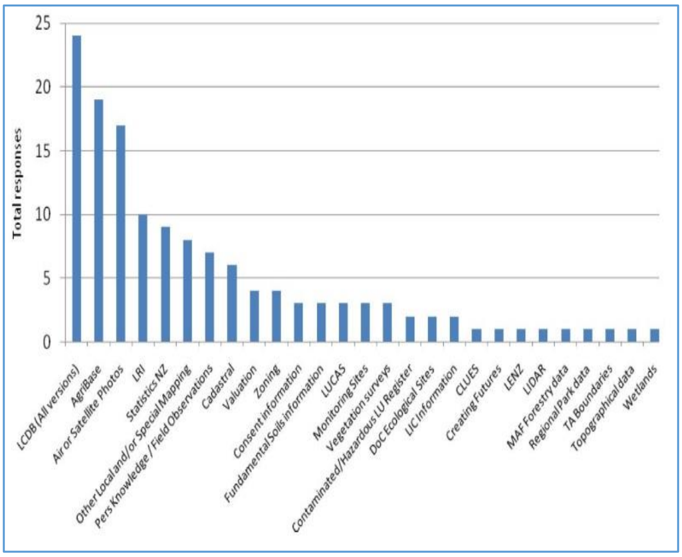

Figure 2. Local government use of land use related datasets (Source: Morgan et al., 2010[22])

Downloads of LUCCS data have increased over the past decade (Figure 3), with LUC comprising 30% of the 9,000 downloads[23].

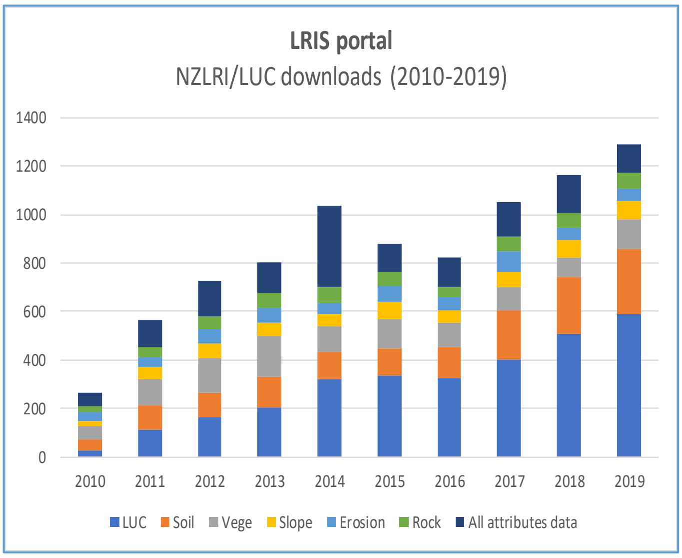

Figure 3. Summary of downloads of LUCCS data from the LRIS (Source: Manaaki Whenua-Landcare Research)

The LUCCS users include consultants, the education sector (12%), local and central government, researchers, and the agricultural industry (Figure 4). The high proportion of unknown users are likely to be individuals or consultants.

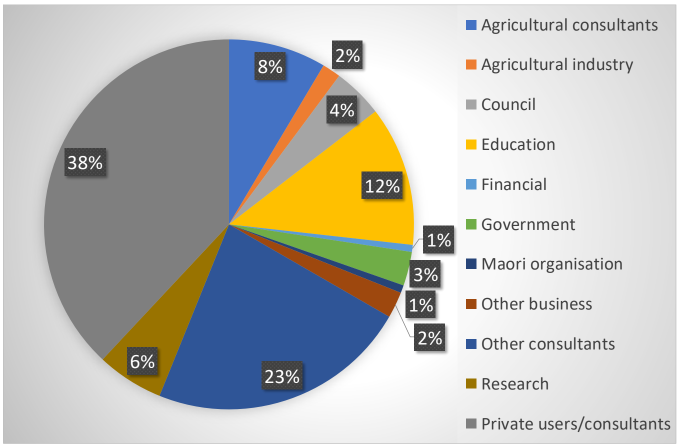

Figure 4. The proportion LRIS download users since 2011. (Source Manaaki Whenua-Landcare Research).

How has the LUCCS been applied to land use planning and management?

The LUCCS was originally designed to provide regional and local authorities with a comprehensive set of resource information for land use planning, with an emphasis on soil conservation and erosion management[24]. It has been subsequently used to support policy at national, regional, and territorial levels, and regulation through resource consents for water abstraction, earthworks, forestry activities, subdivisions, and farm management plans.

The LUCCS 1:50,000 scale data layers (incorporating FSL data and available on LRIS) remains one of the few national land resource data sets. Because LUCCS was compiled using a relatively consistent methodology and national coverage[10], it is often used as the default source of information for New Zealand's physical environment. In the absence of any new or updated national land resource (including improved S-map soil data), the LUCCS has been used well beyond its original intended purpose[11], such as allocating nitrogen loads.

Despite the widespread use of the LUCCS over many years, there appear to be very few targeted studies looking at what difference these works have made to environmental outcomes[25].

Misuse of the LUCCS has been exacerbated, in part, by, the increased use of GIS tools which simplify the manipulation of spatial data, and users not understanding the link between field observations, map scales and map information (Box 2).

[10] Note that the classification of erosion differed in North and South Islands, regional legends varied with multiple legends in the North Island and are two legends in the South Island, one South Island wide, and a revised 2nd edition for the Marlborough region.

[11] Examples include the use of the 1:50,000 LUC polygons in the NES-PF and the proposed NPS-HPL.

Some of the common problems include:

- Enlarging regional data and mapping to inappropriately detailed scales i.e. they do not capture the fine detail required for property scale regulation and management[26].
- The location of map unit boundaries, which are accurate at a regional scale, become increasingly inaccurate when enlarged to property scale[12].
- LUCCS data are used beyond their original intent to substitute for missing data, e.g. soil maps.
- Parts of the LUCCS inventory (e.g. erosion, vegetation) are dated and do not represent the current state of the environment.

Implementing national policy and planning regulations

Both the proposed National Policy Statement (NPS) for Highly Productive Land and the National Environmental Standards (NES) for Plantation Forestry 2017 contemplated the use of LUC classes to define planning zones to manage land use activities.

As a general principle, where maps are used for statutory purposes, they must be at sufficiently large scale to accurately show property or planning zone boundaries and any other relevant information. At the mapping scale of 1:63,360 and 1:50,000, the LUCCS was only intended for catchment and regional planning. Significant problems have arisen, (e.g. coarse mapping scale, dated information) when LUC mapping polygons are used to implement planning rules or national regulations[27].

The NES for Plantation Forestry 2017

The NES for Plantation Forestry 2017 uses a national classification of erosion susceptibility (the Erosion Susceptibility Classification ESC) to regulate the environmental effects of plantation forestry [28]. The original version of the classification system was based on the potential erosion values in the LUCCS. It required several revisions before the final version was gazetted[29].

Specific problems with the ESC include[30]:

- the mapping units are based on the LUCCS polygons which is generally suitable for establishing regional or national erosion risk but not suitable for site management of forestry activities.
- misclassification of erosion potential caused by not recording multiple erosion types in the South Island.

The final version of the ESC is based on the 1:50,000 LUC polygons, and only applies to mass movement, gully erosion and wind erosion for specific coastal LUC units.

> **Box 2: Understanding map scales**
>
> Map scale is the relationship between the distance or area depicted on a map and the corresponding location or area on the ground. It is important to understand the limitations imposed by map scale. Maps are usually drawn at specific scale depending on the smallest area of interest for a particular use and the density of field observations. For example, a 1:5,000 scale map requires on average four observation/ha while a 1:50,000 scale map requires 0.04 observation/ha (four observations per 100 ha)[31].
> With GIS tools and geospatial databases, it has become easy to manipulate maps, creating the temptation to rescale or manipulate all or part of a map beyond its original scale of collection (Lynn et al., 2009).
>
> Enlarging maps from their original scale will not provide the same accuracy or contain more detail then a coarse scale map. Inaccuracies, such as the location of boundary lines, will be magnified. The increase in scale will not capture the effect of different parameters or factors that control the distribution of soil types [32]
>
> The information expressed in the map needs to match the level of detail of information needed for its application. Enlarging maps may mean that information shown on the map is too coarse or unreliable to show features on the ground[33]
>
> The LUC classification can be applied at any scale. Farms are typically mapped between 1:5,000 and 1:15,000, while catchment and regional maps are mapped at 1:15,000 to 1:50,000. The Land Use Capability Handbook sets out recommended mapping scales for inventory surveys and LUC mapping (See Tables 1 and 18).

The ESC, at a 1:50,000 scale, is a screening tool to assess the risk of erosion in particular forest holdings requiring forestry companies to carry detailed mapping on land where the ESC shows there is a higher erosion risk[34]. Any remapping of ESC area must be undertaken by a LUC surveyor, who is registered as a Suitably Competent Mapper [13]. As there is no public register of LUC surveyors, an approved list of suitably competent mappers is overseen by the LUCCS Governance Group and New Zealand Association of Resource Management (NZARM)[14].

Future development of a national erosion layer needs to include (at a finer scale) mapping of different erosion types (e.g. landslide, earthflow, gully erosion, and soil erosion), causal factors and their connectivity to waterways[35].

[12] An example of this is illustrated in Figure 1 (page 7) of Barringer et al. (2018).

[13] An SQP approach has also been adopted for the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health.

[14] Appendix 1 in Te Uru Rākau. 2019.

The NES for Freshwater Management

The new NES will require all pastoral and arable farms of 20 ha or more and horticultural farms of 5ha or more to have a freshwater module as part of their farm environment plans[36]. Although the detailed requirements for the module are still to be developed it is likely to require an assessment of a farm's land resources and to identify potential risks to freshwater bodies.

The proposed NPS for Highly Productive Land

The proposed NPS for Highly Productive Land uses the LUC classes 1-3 as a proxy measure for highly versatile soils[37].

The default definition will apply for a transitional period until councils identify and map highly productive land in their respective areas, using specified criteria - land capability, climate, water availability and the size of the land area. In the absence of an alternative national classification that brings together soil and land characteristics, councils will most likely retain LUC for at least part of their highly productive land definition[15].

Soil information compiled in the LUCCS is from multiple surveys available at the time of mapping[38]. Minimal changes were made to accommodate the soil information within the LUCCS (mostly adjusting map unit boundaries, generalising detailed soil maps or interpreting smaller scale soil maps at more detailed scales)[39].The soil information provided was of varying scale[16] and quality, the soil attributes are not well defined.

The LUC classes have a bias towards arable cropping, pastoral farming, and plantation forestry. These attributes do not reflect the wider range of services provided by these soils[40]. The lack of soil moisture and local climate parameters limits the use of LUC for mapping intensive non-arable horticulture land, where subtle changes in climate and soil properties can determine the suitability of the land for a range of horticulture crops[41].

The current LUC maps are too generalised for property scale planning purposes, and the boundaries and definition of classes are likely to be a source of litigation[42]

The proposed NPS_HPL will require a significant investment in more detailed soil and LUC mapping, to accurately delineate areas of highly productive land[43]. For example, estimates of the amount of highly productive land in Canterbury vary by up to 600,000 ha, depending on the data source (Table 1).

Table 1: Variation in estimates of highly productive land: in the Canterbury Region

Data source	Area (ha)	
	LUC 1& 2 classes	**LUC 1, 2 & 3 classes**
Land Use Capability (LUC) maps	293,497	838,437
Fundamental Soil layer	513, 270	1, 437,166
S-map data	200,722	737, 672

(Source Manaaki Whenua- Landcare Research)

State of Environment reporting

A striking feature of New Zealand's environment reporting system is the ad hoc collection of, often dated and/or inadequate, information to describe current changes in the state of the environment[44]. A key weakness with the national monitoring is the lack of time series data to track changes in the environment over time.

Nonetheless, the LUCCS is one the few comprehensive natural resource datasets covering nearly all the country. One of the earliest applications of the national mapping was the vegetation map of New Zealand[45]. Later, LUCCS mapping was used to report on the extent of erosion in New Zealand[46], assess the potential effects of mass movement erosion on soil carbon stocks[47], and the loss of highly versatile land to urban and rural residential developments[48].

Monitoring sustainable land use

NZLRI has been used as a proxy indicator for assessing the sustainable management of rural land. Some examples are:

- The 2007 Environment report[49] used the LUC classes to map erosion-prone pastoral hill country and satellite imagery to compare changes in the vegetation cover between 1997 and 2002 to identify areas at risk of erosion.
- To guide their non-regulatory land management programmes, the Hawkes Bay Regional Council created a map of sustainable land uses, based on regional LUC classes and a map of current land cover from satellite imagery. By comparing the two maps, the council can identify land which is being used beyond its level of sustainability[50].
- Environment Southland mapped the distribution of major rural land uses in Southland and quantified their distribution across different LUC classes[51].The pattern of

[15] The PCE's Submission on the proposed National Policy Statements on Urban Development and Highly Productive Land noted that the LUC offers a good starting point for classification of versatile soils, fundamental to the concept of highly productive land.

[16] Soil map scales ranged from 1:15,840 (Gisborne Plains) to 1:253,440 (General Soil Surveys).

land uses correlated well with the capability of different LUC classes.

Monitoring the loss of primary production land

Highly versatile land has few limitations to agricultural and horticultural production. New Zealand has a limited supply of high class land. Just over 14% of the land area, comprises LUC class 1-3 land, while the best land – LUC classes 1-2 - only covers about 5% of the country[52].

Highly versatile land is coming under pressure from competing uses, especially the growth of urban and rural–residential areas. Between 1990 and 2008, 29% of new urban development encroached onto LUC class 1 and 2 land. By 2013, lifestyle blocks in rural residential areas occupied about 10% of LUC class 1 and 2 land [53].

Many district plans and regional policy statements contain rules and policies to control subdivision of land. Until recently, the lack of consistent monitoring by councils made it difficult to obtain a regional or national picture of the piecemeal development of highly versatile land[54]. The national guidelines for monitoring land fragmentation use the LUC classes to provide a standard method of reporting of changes to different types of production land[55].

Used as a data set for policy analysis

Land use modelling is frequently used to explore policy options, such as effects on rural land use, freshwater management, mitigating climate emissions and to inform decision making. These models utilise several core data sets, including the NZLRI[56]. For example, the information was used to:

- estimate the production potential of rural land for agriculture and exotic forestry, land use scenario modelling, e.g. the Land Use in Rural New Zealand Model, NZ FARM Model and to estimate annual dry matter yield[57] or delineate areas of non-productive land[58] .
- delineate land units in catchments or within regions for modelling catchment nutrient yields and land use change effects, usually based on LUC class, slope and soil[59].

The inventory dataset was compiled in the 1970s and updated in some regions with the 2nd edition mapping. The dynamic inventory factors, present erosion type and severity, and vegetation cover, are now out of date. Some of the 'permanent' factors (e.g. soil, slope, and lithology) are still relevant but could be improved using modern data (e.g. LiDAR).

Each regional LUC extended legend or bulletin contains estimates of regional productivity indices for each LUC unit. Two indices were developed – three levels of stock carrying capacity for a sheep and beef farming system and a *Pinus radiata* site index for forestry[60]. As there was very little research data at that time, the indices were estimated using the expertise of land resource scientists, Ministry of Agriculture and Fisheries farm advisory officers, New Zealand Forest Service advisors and the forest industry and represented the contemporary view of land capability and production[61].

The *P radiata* site index has been superseded by the Scion's Forecaster Calculator, which estimates the growth and yield of radiata pine and Douglas fir through a rotation[62].

The estimates of stock carrying capacity have not been updated to include subsequent improvements in farming techniques and practices. Since the first estimates were put together, the expansion of dairy and the improvements in farm productivity over the subsequent three decades (including animal genetics) are likely to have resulted significant changes to stock carrying capacity[63].

With the advances in geospatial modelling of land uses and better datasets (Appendix 1), the stock carrying capacity estimates should be reviewed and updated.

Allocating nitrogen discharge allowances using land capability classes

Horizons and Hawkes Bay regional councils apply a natural capital approach, using soil and its properties, to allocate nitrogen discharge allowances to rural land in their regional plans[17].

The LUC classification is used as a proxy measure of the land's natural capital[64]. Nitrogen allowances are assigned according to the land's inherent pastoral productivity. More versatile land, (i.e. Class 1 & 2) is allocated higher discharge allowances compared to less productive land.

The use of the LUC classes to allocate catchment nitrogen discharge allowances poses several difficulties[65]. The LUC classes were primarily designed for soil conservation. The most versatile land (Class 1-4) is classified according to its suitability for arable cropping rather than pastoral production. Within each LUC class, pastoral productivity can be highly variable depending on the versatility and the inherent physical limitations of the land. Similarly, there is also considerable variability in the potential nitrogen leaching rates within each LUC class.

[17] Horizons Regional Council -One Plan, and the Hawkes Bay Regional Resource Management Plan - Tukituki catchment.

The legal position on the use of LUC to allocate nitrogen allowances is not yet settled. Although the approach was accepted for the Horizons One Plan[66] and Plan Change 6 Tukituki catchment[67], it was not adopted for Plan Change 10 Lake Rotorua because of the degree of uncertainty associated with the method[68].

Managing erosion prone land

Soil erosion is a serious problem for New Zealand. Erosion rates are naturally high, because of the climate, steep terrain, geology, and soil, but modelling indicates that a significant amount of soil is also being lost from pasture[69]. The economic cost of soil erosion in 2015 was estimated at $250-$300 million a year.

Erosion is a major limiting factor to sustainable land use, and it has been the target of soil conservation efforts for the last 80 years[70]. The erosion dataset in the LUCCS describes the type and severity of erosion at the time of mapping[71]. Because of its importance, erosion limitations are applicable at most levels in the land use capability classes[18].

Ten regional councils have soil conservation programmes targeting erosion prone land, mostly hill and steep-land farms[72]. The work is directed at priority farms, catchments, and certain high risk LUC classes or units.

In the Waikato region, catchment modelling used LUC classes to identify erosion prone land and direct soil conservation work. Modelled sediment reduction and cost estimates[73] provided a basis for prioritising sub-catchments for soil conservation. This may provide an opportunity for future assessment of the benefits, provided soil conservation works are recorded.

The Erosion Control Funding Programme (ECFP)[19] was established in 1992 to manage the severely eroding soft rock hill country in the Gisborne District[74].The project receives government funding, provided the Gisborne District Council implements planning rules[20] requiring all landowners on the most severely eroded land[21] to have effective tree cover by 2021.

Both the ECFP and Gisborne District Council's Tairāwhiti Resource Management Plan use LUC[22] classes to classify highly erodible land in the district into one of three categories, according to their erosion severity. The categories (or overlays) are shown on planning maps.

The ECFP is based on the regional LUCCS, mapped at 1:50,000 while the district planning maps (Land Cover 3A) are at a property scale. The discrepancy in scale resulted in the target area of severely eroded land in the Waiapu catchment being about half the size compared to the ECFP mapping[75].

Farm environment plans and catchment conservation works

Farm planning falls broadly into three periods:

- By 1989 an estimated 4,730 farm plans covering 50% of New Zealand's farmland had been prepared. The focus of these plans was primarily on managing erosion and vegetation degradation[76].
- During the 1990s, government subsidies for soil conservation and catchment works declined significantly. Between 1200-1450 new plans have been prepared[77]. Several councils developed alternative approaches to farm environmental planning[78].
- From 2000 to present, the role of farm plans has shifted away from soil conservation plans to become an environmental management tool. Regional councils and industry organisations either require, or actively promote the use of farm plans to manage a wider range of farm environmental issues[79], e.g. water quality, nutrient management[23]. In the next 5 years[80], all farms may be required to have a farm environment plan[24].

Although the scope of farm planning may have expanded to include other aspects of farm management (e.g. nutrients), the basic structure of farm plans has essentially remained unchanged over the last 60 years[81]. Each plan contains a description of the property and its resources, often accompanied by a detailed LUC map of the property, management objectives and a work plan. The plans identify better quality land where farm production could be maintained or increased and erosion prone land which should be retired, or targeted conservation measures applied. The information has also been re-interpreted and applied to other environmental problems, such as managing non-point source discharges and biodiversity loss[82].

Property-scale land use capability maps provide a simple way of communicating a large amount of land resource information to landowners about a property, its capacity to sustain production, and provides the basis for deciding future management options[83].

18 LUC class 1 is the only LUC class that does not have an erosion limitation.

19 Formerly called the East Coast Forestry Project.

20 Gisborne District Council Tairāwhiti Resource Management Plan.

21 Mapped as Land Overlay 3A.

22 NZLRI Gisborne East Coast Region, Second Edition

23 There appears to be no up-to-date estimate of the number of farm plans.

24 The farm plan would include soil maps and identify the source of potential contaminant losses, such as erosion prone land.

Fresh water quality and soil erosion are currently the top priorities for FEPs[84]. Many FEPs use land capability mapping as one of the core data sets[85].

Industry groups are also promoting FEPs. Examples of industry initiatives include:

- Beef and Lamb and Deer Industry NZ Land and Environment Plans (LEPs) include the provision of farm scale LUC maps for delineating Land management units for Level 3 LEPs[86].
- Other farm environment planning approaches such as Fonterra's sustainable milk plans[87] and Horticulture New Zealand's NZGAP accreditation[88] do not include LUC but require soil map information. Where S-map does not provide for this, soil information is most likely sourced from the Fundamental Soils Layer which is based in part on the NZLRI mapping.

Over the long term, if implemented, this information should contribute to better farming decisions, e.g. increased productivity, reduced mass movement in hill country and surface erosion, and generally improve the outcomes for properties[89].

Several decades of LUC related work programmes have probably contributed to a widespread understanding and acceptance that varying land types have different productive capacities and limitations[90]. Land, which is unsuited for primary production should be retired from production, e.g. Land Improvement Agreements, Review South Island Pastoral leases -'Tenure Review', or used for targeted soil conservation or catchment control works.

Potential source of land resource information

Many of the historic farm plans and their associated inventories compiled by regional authorities have been archived or discarded. This data, if it can be recovered, potentially represents an important source of detailed or historic information about a farm's land resources that would be a starting point for new surveys.

Initial trials have shown that copies of this data can be captured from hard copy maps or aerial photos and stored on a geospatial database[91].

Useful tool for specific purpose surveys

Land capability surveys of individual properties may be undertaken for other purposes, e.g. resource consent applications or to identify areas of high class soils prior to subdivision. Some councils also require field confirmation of high class soils (based on LUC map units) at sub-property scale[25].

Emerging trends and opportunities

The LUCCS mapping is one method of representing complex information about land resources. Alternative ways of collecting and presenting land resource information are being developed, often using new techniques to process and analyse geospatial data. These drivers are likely to influence the future use of the LUCCS.

Use of other land classification systems

Despite the long history of use with LUCCS in New Zealand, several alternative approaches to classifying land, have been developed, including:

- *Land versatility index*: A 'land versatility index', originally proposed by DSIR scientists in 1980[92], classifies the potential productivity of arable land according to physical properties of the soil, the number of growing degree days and the likelihood of seasonal moisture deficits. The approach was adapted and used to evaluate: the potential for the versatility of horticultural land and suitability for urban use in Christchurch City[93]; classify the soils of lowland Southland[94]; horticulture in the Maniapoto rohe[95] and the northern part of the Kapiti District[96].
- *Tasman District's Productive Land Classification*: An alternative system for identifying productive land was developed in the Tasman District because of limitations[26] with the LUC[97]. Land was classified, using similar criteria as the Land Versatility system, into eight classes, based on the land's capacity to support a range of primary productive activities, with an emphasis on cropping and horticulture. The land classes are used in the Council's resource management plan (TRMP) to protect highly productive rural land in the district[98].
- *Soil Vulnerability*: This classification is based on soil's physical properties. Interpretive maps are created from S-map showing the relative vulnerability of soils to nitrogen, phosphorus, and microbial contaminants by leaching or runoff, and which areas are best suited for particular land uses[99]. The approach was applied to the Culverden Basin and the central Canterbury Plains and used to show relative susceptibility of rural land to different contaminant losses.
- *Physiographic Environments*: Regions or catchments are classified into zones where similar biochemical and hydrological processes determine the quality of freshwater in the landscape[100]. The classification was developed and applied in the Southland Region, which was divided into 9 classes and 8 subclasses, to manage the loss of nitrogen, phosphorus, sediment, and microbial pathogens to water.
- *Land Environments New Zealand (LENZ)*: Areas of land with similar environmental conditions are grouped into units or

[25] In the Waikato region, Waipa and Waikato District Councils commonly request property scale soil and LUC field assessments.

[26] E.g. LUC's focus on soil conservation and extensive land use, the mapping scale was not suitable for planning purposes, and it was not appropriate for intensive horticulture.

'environments' which, regardless of where they occur in New Zealand[101]. It uses a hierarchical system to classify soil, climate, and land geospatial data sets into four levels which depict the land with increasing level of detail. The system is primarily designed for ecosystem management, and been applied to conservation management of indigenous ecosystems, environmental monitoring predicting the spread of new harmful organisms, and identifying the best areas for growing particular crops.

Unlike LUCCS, most of these approaches are designed for specific uses or applications such as managing contaminant losses to fresh water or assessing the potential for intensive horticulture. Regardless of the land classification, all the approaches rely on the same inventories of basic resource information which typically include LUCCS data (Appendix 1).

Increasing use and reliance on 'geospatial data'

Data is an essential part of New Zealand's infrastructure; it plays a significant part in the country's wellbeing and economy[102]. The Government's goal is to ensure all non-personal non-confidential data and information held by government agencies is available and easily accessible[103]. Open access to geospatial data will have significant economic benefits, enable environmental monitoring, and aid policy implementation and support innovation and development[104].

Over the last 10 years there have been significant advances in collecting and processing digital data, including[105]:

- the reduction in the cost of data collection and proliferation of numbers and types sensors.
- rapidly evolving technology, e.g. mobile phones, expansion of 5G networks, increasing use of artificial intelligence (AI) to collect and process data.
- increasing use of cloud computing, allowing large volumes of data to be stored and processed more cheaply.
- advances in statistical and analytical techniques that apply 'rules' to process data and extract information from multiple data sets.

Detailed geospatial data sets are now available for many of the environmental attributes used to classify land (Appendix 1).

Recently, two projects used modern geospatial datasets and semi-automated digital processing to remap LUC classes over 100km^2 of Northland[106] at 'farm scale' (1:10,000) and the Canterbury Plains[27] at 1:50,000[107].

Both projects demonstrated that digital mapping of LUC units is feasible. The extent to which the process can be automated, and the amount of resources needed, depends on the quality of the underlying spatial datasets. For the Northland study, a high resolution Digital Elevation Model (DEM) was available, additional work was required to produce a digital soil map and map erosion features. Field work was needed to verify the rock and soil types. The Canterbury study relied on the S-map and with expert knowledge, was able to derive a map of LUC classes for the Central Plains in about two weeks[108].

The Northland study also compared traditional and digital LUC mapping methods. Both approaches produced similar farm- scale LUC maps. Table 4 summarises the strengths and weaknesses of their respective approaches.

The advantages of digital LUC mapping are:

- Spatial information for each LUC attribute is stored as a database layer. Each attribute or a selection of attributes can be easily depicted or manipulated to produce maps tailored for end uses.
- Inventory layers can be rapidly updated, so the LUC maps remain current. Revised maps can be quickly produced and disseminated to users, e.g. LINZ Topo250 and Topo50 series. The revised GNS Science QMAP includes new information, such as new features caused by the 2016 Kaikoura earthquake[109].

Table 4. Comparison of traditional and digital LUC mapping methods (Adapted Barringer et al., 2018)

	• Strengths	Weaknesses
Traditional LUC 'manual'	• Nationally, a well-tested method. • LUC field manual sets national standard. • Only one mapper required for field work, check inventory factors, and have consistent overview of LUC mapping. • Uses landowner knowledge and can target specific farm management issues.	• Mapping subjective, relies on a person interpreting boundaries and older inventory maps. • Accuracy difficult to quantify. • Farm scale mapping may require additional LUC units. • Remapping not costly to repeat. • Difficult to scale up to regional level, costly and issues with quality control.

[27] The mapping was limited to slopes < 20° and to LUC classes.

Digital LUC mapping	• Based on separate inventory layers, uses objective criteria to create a consistent and repeatable set of maps. • Utilises knowledge of specialists and the most current data sets. • Lower costs to remap areas as individual components can be upgraded separately and a revised LUC map produced.	• Requires multiple experts with skills in data collection and management. • Potential issues with correlating information if data sets are at different scales. • Incorrect perception that digital mapping is 'less accurate' because it involves limited field work. • Costly to undertake over small to moderate areas.

- The collection and processing of data is undertaken consistently over large areas, including difficult to reach locations. The 'rules' for processing the data are clearly defined and open to critical review.
- The marginal cost of producing digital LUC maps will diminish as larger areas are mapped and if underlying datasets (e.g. LiDAR) are available.
- Once completed national LiDAR coverage will provide very detailed maps of the terrain and highlight subtle changes in topography.
- By combining with S-map, the variability of soil properties within each LUC Class can be quantified, and there is more detailed information on factors, e.g. Profile Available Water, root depth, that affect the suitability of the land for production.
- The datasets can be used on digital platforms and other emerging technologies, e.g. precision agriculture[110] .

Nonetheless, digital LUC mapping still faces considerable challenges, including:

- There is a high up front cost to collect and create the base data sets, e.g. obtaining LiDAR-based digital elevation models.
- Clear protocols for data interoperability are also essential for the correct application of the data (i.e. the data is used within its limitations and is *fit for purpose*).
- Storing and processing the large volumes of inventory data needed for a national digital LUC dataset would require significant computing resources[111].
- Reconciling the differences in the scale of different inventory datasets. There may be considerable variability in the location of map boundaries when different data sets are combined.
- Remapping and undertaking field work to update obsolete datasets and create new inventory layers. There is considerable variability in the extent and quality of the geospatial information. Some datasets, e.g. QMAP cover the country, others, such as S-map only cover 35%of the country, primarily the lowland areas. The datasets may only have basic information. For example, QMAP describes possible rock types within time-stratigraphic map units, but it has little or no data on the physical properties of the strata e.g. degree of weathering, density, induration, cementation, porosity, or permeability. The extent and severity of present erosion must be remapped as the last surveys were undertaken in the 1970s and 1980s.

New frameworks for evaluating land are being developed

There is increasing interest in the wide range of ecosystem services soils provide to society, including carbon storage, a physical foundation for buildings and infrastructure, a medium for plant growth, regulating the loss of contaminants and nutrients to water, and the provision of natural and modified landscapes[112].

Traditional methods of land evaluation, such as LUCCS, assess the physical characteristics of the land, and grouping land with similar features into map units, with an assessment of their capacity to support primary production.

Recently, alternative ways of evaluating and mapping land have begun to be explored that recognise the wider range of ecosystem services provided by land and the need to consider the wider consequences of land use decisions. A common feature of these new emerging frameworks is their reliance on the same key resource information, including for most, the LUCCS (Appendix 1).

The *Natural Capital-Ecosystem Services* approach differs from traditional land evaluation methods by quantifying and valuing the ecosystem services from property scale to communities. The approach has been applied to farm management planning used to show natural capital stocks can be sustained by defining ecological limits while maintaining a profitable farm system[113] .

The *Land Resource Circle* also applies the ecosystem concept, combing the functions and processes provided by the land with its capacity to resist external pressures that will degrade its natural capital[114]. An ordinal scale is used to score the various processes and land use pressures, the results are combined, and the outputs depicted spatially at national or regional scales, or as graphical plots.

The *Land Use Suitability tool*, being developed by Our Land & Water evaluates economic potential of land within the framework of the receiving freshwater environment and its capacity to assimilate contaminants, and catchment water quality objectives[115]. The outputs are scored numerically or mapped at catchment to national scales.

The *Soil Security* concept takes the land evaluation approach further considering and mapping the biophysical, social and economic, regulatory and public policy factors that impinge on sustainable management of the soil resource[116.] Each of these factors are scored separately and combined into a soil security index score for the land.

Spatial whole farm modelling tools are developed

Proprietary decision-making tools are being developed that model the loss of contaminants from farm land.

For example, two tools – MitAgator™[117] and LUCI[118] - have been developed for New Zealand conditions. These systems are integrated with the OVERSEER® nutrient budget model and utilise national geospatial data sets, e.g. S-map, and digital elevation models. They are designed to assess how effective a measure, or a combination of measures, are at reducing the loss of contaminants from a property while minimising the loss of productivity.

Both tools estimate the average annual loss of nutrients, sediment, and *E. coli* to surface water, and map the relative losses across a property, highlighting the critical source areas for contaminants.

At present, the tools assume the environment and management measures operate in a steady state and they do not consider episodic natural events, such as storm induced erosion.

Mapping of erosion susceptibility, based on the primary drivers – climate, topography, rock type, land cover and land use – if undertaken nationally, would provide a consistent national geospatial dataset[119]. This information would provide land managers with a tool to assess the variation in erosion risk across a property, and potentially it could be incorporated into farm decision making tools.

Strengths of the LUCCS

The LUCCS database was a major achievement when it was produced. To complete the national coverage with one mile to one inch (1:63,360) work sheets in six years, and to remain an important source of resource information for over 50 years is an impressive achievement.

Over this period, there has been major improvements in mapping and data management technologies. Intensive use of the LUCCS has shown up its strengths and weaknesses. This creates an opportunity to shape a much awaited revision of the LUCCS to make it suitable for 2020 and ensuing decades.

Still provides the only consistent national land classification

The LUCCS provides an integrated, consistent inventory and classification of the country's land resources. The existing inventory layers and 1:50,000 worksheets are familiar, well understood, and they have been widely used and cited by central and local government over several decades[120].

Past and future mapping of land use capability classes is underpinned by the 'Land Use Capability Survey Handbook[121]. Three editions of the handbook have provided consistency to the LUCCS by standardising the classification criteria and mapping methods at any scale. These methods apply at different scales and for multiple applications. Nevertheless, there remain criteria issues that require revision. For example, reducing the ambiguity around limitations criteria (e.g. depth to hydromorphic features in the wetness limitation[28]). This will become increasingly important when the LUC is being used in a regulatory context, such as with Environment Court cases.

New geospatial mapping tools, such as LiDAR are likely to be increasingly available for LUC mapping. Potentially, the use of these new tools to survey land could be a source of dispute when compared with traditional LUC mapping approaches. To ensure that the Handbook continues to be the principal guide for LUC surveys, the next edition should include guidance on new or evolving techniques, (e.g. using geospatial data sets) and use of new guidelines (e.g. New Zealand Soil Mapping Protocols and Guidelines).

Useful way of conveying complex land resource information to property owners and other users

The LUC system is a simple robust tool for supporting decision making. It has long been used by soil conservators and land management officers working with rural land owners to manage soil erosion and achieve sustainable land management.

Of particular value to farm LUC mapping are the New Zealand Land Resource Inventory (NZLRI) LUC extended legends and LUC suites[29] which provide the detailed LUC Unit information and link the LUC Units to the landscape[122].

Some users have noted that at the farm or property scale the general definition of the LUC sub classes does not describe the types of limitations in sufficient detail for land owners to make management decisions[123].

A modified version of the LUC classes and subclasses, which replaces the current four subclasses, with 20 specific subclasses has been developed for farm scale mapping and tested with landowners in the Auckland region. If similar problems with interpreting the subclasses occurs

[28] Personal Communication, Sharn Hainsworth, MWLR (April 2020).
[29] LUC Suites are defined as a grouping of LUC Units which, although differing in capability, share a definitive physical characteristic which unites them in the landscape – the specific definitive physical characteristics may vary and are documented in the NZLRI regional bulletins.

elsewhere, the modified classification could be trialled in other parts of the country, and eventually form part of national NZLRI legend.

Challenges for the LUCCS

Looking ahead, there are a number of areas where work is needed to bring the LUCCS database up to modern standards while ensuring the knowledge and information that was used to create the database is not lost.

Regional maps are dated – it's not just a scale issue

The regional mapping was completed using the best available cartographic techniques at the time. Data from the 1st edition and early 2nd edition field sheets and aerial photographs was transferred onto transparent overlays of topographic maps, manually digitised and stored on the Ministry of Works and Development computer system[124] Developments in technology since then facilitate the use of data such as LiDAR, and digital mapping techniques which greatly improve the spatial accuracy of map units[125].

Regional mapping scale is too coarse

There is increasing demand for farm and sub-property scale land resource mapping to comply with:

- national and regional planning requirements [30];
- voluntary programmes, such as the Horizons Regional Council's Sustainable Land Use Initiative; or
- the farm scale LUC mapping requirements for the proposed NPS for Highly Productive land [126].

The smallest mappable unit on the 1:50,000 scale LUC maps is 10 ha[127]. For farm and sub-property management decisions this is not *fit for purpose[128]*, but it remains the default dataset in the absence of any other more detailed information.

The recently published New Zealand Soil Mapping Protocols and Guidelines[129] does tackle this problem. It sets out clear practical requirements for soil mapping of properties. The guidelines would also apply to more general soil mapping and support detailed land use capability mapping.

Better access to supporting LUCCS information is needed

A large amount of background material has been written about the LUCCS[130]. Many of the regional bulletins have been scanned and can be downloaded. There is a considerable body of older unpublished and unpublished reports and papers, containing the knowledge and expertise of the original mapping teams. While this information may be available in some libraries and other institutions, it is not generally available, and potential users may be not be aware of this work.

The LRIS stores a large number of land geospatial databases, including the LUCCS, with supporting documentation[131]. Much of the earlier LUCCS background material could also be scanned and added to LRIS as part of the supporting documentation.

Re-mapping of the soil parent material layer (RMAP) is needed

The rock type inventory layer is one of the primary inventory layers in the LUCCS. Significant improvements were made to the original rock type layer during the revised (2nd Edition) mapping [132] of some regions and the descriptive codes were standardised in 1991[133].

Rock type and the overlying regolith or unconsolidated cover deposits (e.g. ash layers, loess deposits) comprise the parent material, which forms soil, and has a major influence on slope, erosion susceptibility, hydrology, and soil fertility[134].

Accurate mapping of the parent material layer is hindered by:

- The scale of the geological maps. The latest regional geological maps (QMAP [135]) are mapped at a generalised scale (1:250,000)[31], and the boundaries of units are accurate enough for detailed mapping.
- The grouping of different rock types in QMAP into broad composite mapping units, often delineated by time- stratigraphic units for sedimentary strata. Cover deposits less than 5m thick are not mapped[136].
- The practical difficulty of mapping areas with complex geology and landscapes with low relief (e.g. Northland)[137].

Geological maps generally depict the major rock types and other geological features, and do not include the superficial cover deposits overlying bedrock. Soil maps, such as S-map, only portray the top one or two metres of the land. Between these two datasets, there is a 'gap' in the mapping of the parent material. This 'near surface material' or regolith may play a significant role in areas, such as: erosion susceptibility, drainage, geohydrology foundation conditions.

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[30] For example, the National Environmental Standard for Plantation Forestry, the proposed National Environmental Standards for Freshwater, Canterbury Land and Water Plan, or to verify the location high class soils for potential subdivisions.

[31] The smallest area is 250 ha.

New methods, such as radiometric and aeromagnetic surveys and grid-based XRD/XRF coring[32], can improve the accuracy of geological and soil mapping[138]. Both GNS Science and Manaaki Whenua could look at the feasibility of producing a detailed national parent material map and supporting database to support future soil and land capability mapping and other applications.

Rethinking the LUCCS erosion layer will greatly benefit users

A recurring significant issue with the LUCCS is the weakness of the erosion layer.

The LUCCS erosion dataset suffers from several problems[139], including:

- The 'present erosion' mapping is out of date. The layer describes the type and severity of erosion at the time of mapping 1970s and mid-1990s, not the current state of erosion in New Zealand.
- A map of the current state of erosion only provides an ephemeral picture of erosion. Evidence of recent erosion is affected by factors, such as vegetation regrowth, storm frequency. Regular surveys of the current state of erosion after regional storm events, earthquakes, and volcanic eruptions should be undertaken.
- Inconsistent approaches to describing and mapping erosion severity between LUC regions and the North and South islands.
- The term 'potential erosion' is a subjective concept broadly meaning 'the inherent predisposition of land to erode'. The potential erosion layer is based on a post-mapping assessment of LUC units and reflects the understanding of erosion processes at the time of mapping.
- The Erosion Susceptibility Classification for the NES for Plantation Forestry does not incorporate the concept of erosion risk related to erosion triggering rainfall events or the consequences of erosion[140].

New developments

Since mapping for the NZLRI ceased in the 1990s, other methods of mapping erosion prone land have been developed[141]: These include:

- National protocols for assessing soil stability that is being used by many regional councils to monitor changes over time [142].
- Several studies have investigated geospatial methods for mapping landslide susceptibility (Waikato and West Coast), erosion risk (Eastern Bay of Plenty) and modelling erosion (Highly Erodible Land model).
- The Erosion Susceptibility Classification used a terrain classification based on the dominant erosion process, rock type and topography. The mapping units are based on the original LUCCS polygons[143].
- The New Zealand Empirical Erosion Model and Land Cover Database that were used to estimate long term erosion rates for New Zealand[144].
- The Smarter Targeting of Erosion Control programme[145], a new five year research programme that is applying high resolution data, modelling and spatial analysis to improve our understanding of the effects of natural events on erosion processes and the effects on freshwater quality, and ways of targeting erosion control measures.
- Recent erosion mapping for Nelson Forests Ltd that used quantitative techniques the map the landslide susceptibility of the company's exotic plantations and the susceptibility to catchments to debris flows[146].

Options for a revised erosion layer

The lack of a comprehensive, high quality national erosion dataset is hampering the implementation of national and regional policies and contributes to the lack of definitive reporting on the state of the environment. The collection of erosion data needs to fulfil two basic functions[147]:

- Provide a consistent picture of erosion across New Zealand over time, and
- Identify areas of land that are susceptible to erosion.

At present, there is no national erosion monitoring programme. Councils are working collectively[33] with the Ministry for the Environment towards a nationally consistent method for monitoring erosion independently of the LUCCS. The methods will be developed as part of the National Environmental Monitoring Standards (NEMS)[148]. A review by EMaR has evaluated potential methods for soil stability/erosion monitoring[149] and a NEMS for soil stability/erosion monitoring is listed for future development[150]

The erosion susceptibility approach offers a more objective quantitative method of assessing the long–term risk and consequences of different types of erosion processes[151]. It could include soil-landscape models in the S-map soil mapping[152] and erosion terrains[34] to locate erosion prone soils and erosion types in different parts of the landscape[153].

The probability that an erosion event will occur depends on the frequency of an erosion inducing rainfall event, and the influence of other factors, such as the extent of saturated ground, lithology, topography and soil types[154]. With the onset of climate change, an increase in the frequency of severe rainfall events is likely which will increase the frequency of erosion events.

[32] A field portable XRF analysis tool measures elemental concentration in the surface layers of soils.
[33] Local Government Special Interest Groups (Land Monitoring Forum and Land Managers Group).
[34] Erosion terrains are used in the SedNetNZ model to place erosion types.

Table 2 summarises the options for upgrading the LUCCS erosion data layer[155].

Table 2: Options for a Revised Erosion Layer

Options for updating the erosion field in the NZLRI	
Repeat mapping to **update the erosion field in the NZLRI**	• expensive to complete nationally • unrealistic using a manual method • remote sensing techniques still developing • requires continuous revision to maintain • limitation of being a snapshot-in-time • doesn't accurately reflect the risk • or long-term consequences of erosion
Fix mapping, inconsistencies and errors to **update the potential erosion layer**	• would maintain continuity with existing data • a permanent attribute of the land and not require updating. • used for continued ESC development • popular with regional councils. • definition and assessment require revision and clarity • still largely based on expert knowledge
Replace the potential erosion layer with an **erosion susceptibility layer**	• reflects the long-term risk of erosion • reflects effect on soil properties and capability for agricultural production • analogous with potential erosion but clearly defined • quantitatively derived from landscape attribute and climate, topography, rock type and land cover/use base data • a tool to map spatial variation • no requirement for updating
Incorporate **farm plan mapping data** completed by regional councils	• targets erosion-prone land rather than providing complete regional coverage • like original NZLRI mapping but more detailed • obtaining data difficult • scale, correlation, quality control and partial coverage issues • only provides a snapshot-in-time of erosion
Incorporate **land stability data** from councils	• provides time series data on trends in erosion • not compatible with NZLRI/LUC system • partial coverage issues • useful multi-regional time-series trends in erosion • requires regular re-survey

(Source Basher et al, 2014).

The cost and the resources required to carry out repeated surveys rule out most of these options.

The erosion susceptibility layer should form a standalone geospatial database that would support the LUCCS, and based on a well-defined, quantitative definition of erosion susceptibility that reflects long-term erosion risk. Pilot studies should be carried out to test the concept and its acceptability with LUCCS users.

Similarly, remote sensing techniques for capturing time series data on the national state of erosion combined with the soil stability monitoring by regional councils should also be investigated.

Underlying soil data sets can be updated to address current problem of mixed quality datasets

The LUCCS soil layer relied on the soil surveys available at the time of the LUCCS mapping. The scale of the soil surveys varies across the country (Figure 5). In flatter, more versatile agricultural areas, the soils were mapped at greater detail.

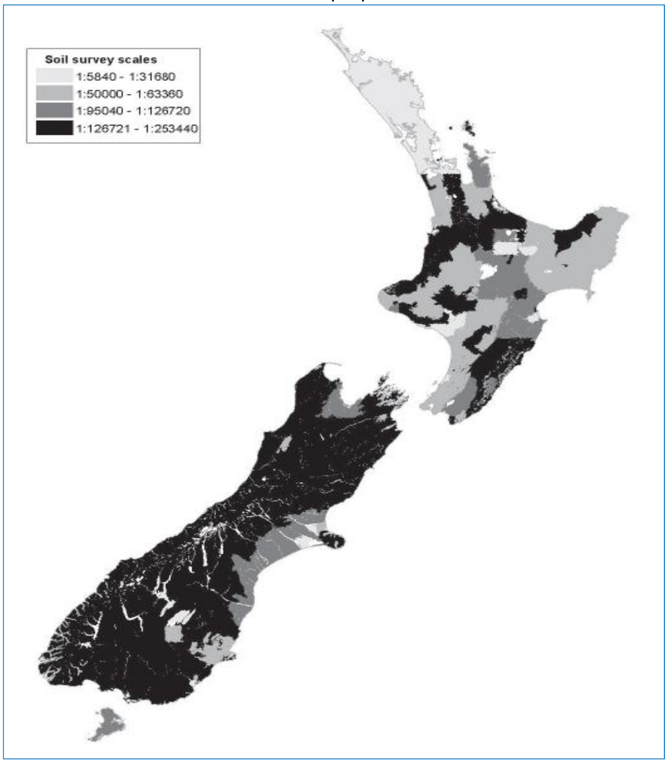

Figure 5 Mapping scales of the soil surveys used in the compiling the NZLRI (Source Leathwick et al 2002)

The North Island worksheets were compiled from approximately 40 surveys while about 20 surveys were used in the South Island worksheets[156]. Soil maps of similar scale were incorporated with little modification into worksheets, while more detailed soil maps were generalised. For a large part of New Zealand, comprising less productive land, the soil information was taken from the national 1:253,440 General Soil Survey[35] supplemented by field checks[157].

Since the LUCCS was finished, there have been significant advances in the knowledge of New Zealand's soils. A large number of new or updated soil surveys have been completed. The old soil classification system has been superseded by the New Zealand Soil Classification system[158].The Fundamental Soils Layer was created to provide a generalised national soil map[159].

The older soil surveys and the Fundamental Soils Layer are now being superseded by S-map, a new geospatial soil information system, created and operated by Manaaki Whenua[160]. S-map is underpinned by the National Soils Database Repository NSDR) and uses algorithms to predict soil properties that have not yet been analysed and to produce maps of consistent quality with more detailed quantitative information on soil properties[161].

As of May 2020, S-map covers 35% of New Zealand, mostly the lowland parts of the country. Approximately

[35] An estimated 37% of the North Island NZLRI and 83% of the South Island NZLRI was based on the General Soil Survey.

64% of LUC 1–4 land and 25% of LUC 5–8 have been remapped[162].

Integrating the newer soil data with the LUCCS is difficult, because of changes to the soil classification, mapping techniques, and storage of soil map data[163]. The S-map database can produce land use capability maps to class and subclass level[164], by combining with other spatial datasets, such as climate, slope, erosion susceptibility, and to use remote sensing imagery to map erosion state.

A consistent national LUC classification will add value to the LUCCS

The LUCCS survey was undertaken across region by region, and regional classifications were independently developed by the mapping teams. This created inconsistences with the mapping between regions and between the North and South Islands. The LUC mapping units may also differ between 1st and 2nd editions of regional LUC mapping, such as Marlborough [165] and Northland[166].

The LUCCS regions often do not coincide with regional council and unitary authority boundaries, several LUCCS regions may fall within a regional authority boundary [167].

Considerable efforts have been made to rationalise the regional LUC classifications. Several regional councils[36] have created a single, consistent LUC classification for their regions [168]. These classifications have not been incorporated into the national NZLRI[169].

A single North Island LUC classification was developed at a 1:50,000 scale[170], while the South Island was covered by one classification[171]. A single draft national LUC legend has been completed and is now being tested[172].

Long-term adequate and stable funding

Since the LUCCS was completed, fundamental changes to science funding in New Zealand have increased the challenge of securing ongoing funding[173]. Together with contestable funding and the corporatisation of research institutes, the delegation of natural resource management to regional authorities has led to ad hoc LUCCS revisions nationally[174].

The Ministry of Business, Innovation and Employment's (MBIE) Nationally Significant Collections and Database (NSCD)[175] funds about NZ$1.3 million p.a. for the last 11 years to maintain and manage the LRIS database[176].The funding, which is not inflation adjusted is shared between the National Soils Data Repository (NSDR)[177] the Soils Portal and Soil Map Viewer and some web support services. Since the mid-1990s, there has been no new investment to update the LUCCS database[178].

Updating and extending resource inventories that underpin the LUCCS and development new resource datasets are hampered by the lack of secure long-term dedicated funding[179]. Funding for datasets, such as S-map, and Land Cover database, largely rely on *ad hoc* contributions from regional councils and/or central government agencies.

Currently, MBIE is undertaking a review of the role and scope of the Nationally Significant Collections Database[180]. The review is expected to be completed by 2021[181]. While the outcome of the review is unknown, there is an opportunity to ensure that LRIS is continues to be recognised as part of the NSCD and funding is increased in real terms.

What resources are required to maintain and enhance the use the LUCCS?

Like other natural resource databases, the LUCCS requires ongoing support to:

- maintain and manage the database,
- retain the professional knowledge among scientists and land resource management practitioners, and
- ensure the LUCCS inventory layers are up to date.

Increase funding in real terms

The current national science funding model provides increased funding stability but remains focussed on new ideas rather than investing in the collection of core environmental data [182]. The funding challenge is like that identified for S-map [183] with most funding short-term, inadequate, and having to be sought on an ad hoc basis. Keeping the LUCCS current will require increased national advocacy and a more strategic approach to investment (both potentially driven through the LUCCS Governance Group).

Multiple funding sources could be used fund the components identified in this review. For example, national funding of NSCDB (if adequate funding were provided) could fund the ongoing maintenance and the updating of the of the database system, whereas Envirolink funding [37] through regional sector SIGs could fund archiving earlier LUCCS maps and publications and updating the LUC Survey Handbook[38].

[36] Hawkes Bay, Horizons, and Bay of Plenty regional councils
[37] https://www.envirolink.govt.nz/grants/.
[38] The current LUC Survey Handbook (3rd edition) was funded using Envirolink tools funding (https://www.envirolink.govt.nz/envirolink-tools/land-and-soil-tools/).

Other novel funding opportunities, such as the Provincial Growth Fund [184] might provide additional funding opportunities.

LUC knowledge and experience is being lost

In the 1980s, following the changes to the public service, the number of land management practitioners fell. Many of these people now work for agricultural companies, regional councils, and industry sector groups or as consultants[185].

The pool of experienced NZLRI professionals is declining. Many scientists and land use professionals, who developed and implemented the NZLRI are retiring. For example, only a small number of staff at MWLR are familiar with developing a LUC extended legend and field mapping. In the next few years half of those staff will have retired.

There is a critical need for "more accredited rural professionals/providers to transfer new techniques and knowledge" [186]. Demand for these skills continues to increase, as experienced practitioners retire, and central government regional council and industry requirements for FEPs grows[187].

Several consultants, who provided training courses have recently retired [188]. Currently, there are less than ten consultancies in New Zealand that can offer such skills[189].

Some organisations offer certification and training courses in soil conservation management:

- The New Zealand Association of Resource Management (NZARM) has the Resource Management Certification system for its members[190]. The system aims to maintain the professional competence of NZARM members rather than providing professional accreditation with specific training modules[191]. 35 members have achieved certification, and numbers are increasing[192].
- The New Zealand Institute of Primary Industry Management (NZIPIM) offer a 'Dairy Farm Systems Certification' Scheme and a 'People Management Certification Scheme' [193]. Certification requires membership of the NZIPIM, completion of training modules and continued professional development. The scheme does not focus on the LUCCS, but it provides a template for developing a land resource focussed certification scheme.
- Several universities (Massey, Waikato, and Lincoln) teach LUC as part of their graduate and post graduate courses. The Massey University courses also include field work[194]. The Farmed Landscapes Research Centre, at Massey University, offers a short professional development course in Advanced Soil Conservation, targeting rural professionals[195].

Formal qualifications and certification are required for LUCCS surveyors

Qualifications and certification are needed to ensure the proper use of the LUCCS. With the increasing use of LUCCS for planning and regulatory purposes, there is a greater likelihood of litigation, especially as the procedures can involve a degree of professional judgement on the part of the surveyors[196].

However, neither alone will fulfil the uptake of knowledge required to meet future demands. Establishment of LUCCS focussed qualifications are likely to be required at post-graduate level to ensure, in the absence of field experience, practising consultants can demonstrate they understand theoretical and practical land use capability concepts. Massey University's post graduate courses in Sustainable Nutrient Management provide a model for a formal professional qualification for a particular area of expertise[197].

At present, no certification scheme in New Zealand covers the range of skills required of a practitioner using the LUCCS. For example, use of the LUCCS is not limited to doing FEPs, it may include high class soil assessments, catchment modelling, specific research, and policy development.

As such, the focus of any certification needs to be on land resources and specifically the LUCCS, with the ancillary skills required for its now varied applications covered by other schemes. The Suitably Competent Mapper register used for the NES for Plantation could be adapted or used as the basis for a public register of qualified surveyors. The development and management of a certification scheme should be a high priority for the LUCCS Governance Group. National acceptance and uptake would require multisector involvement; LUCCS in collaboration with regional authorities, industry, research providers and constituent organisations[39] would be required.

The value proposition of repeating NZLRI mapping

The NZLRI is based on data collected in the 1970s, with four regional updates in the 1980s and 1990s. Much of this information (e.g. vegetation, climate, erosion severity and potential production indices) is out of date[198]. The NZLRI database is based on a 'static' or fixed design requiring a large amount of information to be synthesised into mapping units by a multidisciplinary team of professionals.

To compare conventional LUC mapping and automated digital mapping techniques and costs, over 100km^2 of

[39] Including but not limited to the New Zealand Association of Resource Management, and the New Zealand Society of Soil Science.

Northland were mapped at 'farm scale' (1:10,000) [199]. Generally, the difference in costs was minimal for small areas. However, if digital mapping techniques and semi-automated mapping methods using geospatial datasets, such as LiDAR, S-map and parent material, were applied over multiple catchments then potentially significant economies of scale, up to 50 times[40] might be achieved (Table 3).

To repeat the national NZLRI mapping programme at 1:50,000 scale[41] is likely to cost a similar amount to a national S-mapping programme which has an estimated cost of NZ$35 million[200]. If the mapping scale was carried at 1:10,000 scale, an indicative cost of the programme is likely to be between NZ$400–800 million, depending on the intensity of mapping required on land currently not in production. Surveys of erosion state and vegetation cover would need to be repeated regularly.

Table 3. LUC mapping costs per hectare

Coverage	Approximate scale	Conventional survey - cost/ha	Digital LUC survey cost/ha	Applications
National	1:250,000	$0.5 -$3	$0.5 -$2	National inventory
Regional	1:100,000 – 1:25,000	$5 -$15[42]	$3 -$5[43]	Regional planning & catchment management
Farm	1:15,000 - 1:5,000	$30 - $40[44]	$1[45] $40[46]	Land management
Issue specific	1:5,000 – 1:1000	$50 -$300[201]	$40 - $300[202] Depends on data available; requires some field survey	Specific uses. e.g. identifying highly productive land for subdivision

Where to from here for the LUCCS?

The LUCCS is a national database of the country's physical land resource. It is freely available as a geospatial data layer and remains ingrained in policy, catchment and soil conservation planning and farm management for over 40 years.

Because LUCCS was compiled using a consistent methodology and national coverage, it is often used as the default source of information for New Zealand's physical environment.

Several key themes have emerged from this review which will have an influence on the future use of the LUCCS. These include:

- There is increasing use of the LUCCS to support resource management plans and regulations, despite the LUCCS in its current state largely being ill suited for regulation. While LUCSS continues to be an essential tool for evaluating land resources in NZ, the lack of attention to funding its on-going maintenance and development serves to undermine its current and longer term usefulness both at local farm scales as well as at regional and national levels. New national investment will be required to make it robust and *fit for purpose* for resource management plans, farm environment planning, and regulations.
- All commercial farms will have a mandatory requirement to include a fresh water module as part of their farm environment plans. This is likely to increase the demand for higher quality land resource information and professional expertise to prepare these modules. The plans may use the LUC mapping or choose to use just some of the parts of the LUCCS inventory to delineate parts of a property.
- The decline in the number of experienced LUC surveyors and the loss of LUC information gathered by previous workers.
- New techniques for collecting and processing high quality geospatial data are advancing quickly, and could be applied to digital LUC mapping
- Open source data coupled with technological changes and enhanced computing capabilities will increase data use for research and commercial purposes.
- Good quality basic soil, geological topographic and climate information is becoming available in national geospatial datasets, but the LUCCS continues to suffer from a lack of long-term strategic investment to maintain the database,

[40] Only if all underlying data layers are available.
[41] Soil survey mapping costs provide an estimate of the approximate cost of LUC field survey mapping. Generally, halving the scale i.e. doubling the resolution (e.g. 1:50,000 to 1:25,000) increases the cost by 3-4 times. The complexity of the topography and the soil units also influences mapping cost.
[42] Estimated from Northland LUC report.
[43] Estimated from Northland LUC report.
[44] Varies with cost of labour and land complexity.
[45] Assumes input layers such as LiDAR, soil and parent material are already available.
[46] If input layers such as LiDAR, soil and parent material must be improved.

update and extend the land resource inventories.

Although alternative land evaluation systems that embody a much wider range of services are being explored, LUCCS has been used for many years. It is well understood and familiar to many people and should continue to be available to users. To understand how the LUCCS is currently being used and to identify where the system could be improved, a survey of LUCCS users to find out how they apply information, and from their perspective the strengths and weaknesses of the LUCCS.

Past improvements suggest that the LUCCS can be further developed to meet new needs, or at least provide the underpinning data and standards required at a national scale. Revisions to the LUCCS should utilise the knowledge and skills that have been acquired in the last 30 years.

The LUC Survey Handbook was revised over ten years ago. With the emergence of new technologies and open source datasets, a new updated edition should be considered to ensure the Handbook remains the primary reference for undertaking LUC surveys.

With the increasing use of the LUC mapping for planning purposes, there is a greater risk of litigation over LUC mapping. A formal qualification and certification of LUC surveyors would provide a way of ensuring that surveys meet minimum standards of quality and consistency

New developments to the NZLRI should maintain separate high quality geospatial datasets. The individual inventories should be regularly updated. With the onset of climate change, revision of the potential erosion layer should be a priority. The updated databases should be sufficiently flexible to create new information for specific areas or update existing LUC maps, used for other modelling or new, as yet undeveloped, applications.

Updating information about the country's physical land resources is a long-term public good investment, and the data and knowledge will be used for many years into the future and not depreciate in value. The use of regional scale LUC mapping to support plan provisions and regulations highlights the need for better quality datasets. Repeating the 1970's national mapping programme would be a costly exercise, and only serve to meet the requirements of the LUC classification system. A 'business case' for new funding will be required to support a case for new investment to update the LUCCS inventory layers.

There is a wealth of unpublished and published information on the LUCCS (e.g. extended legends) and in the resource information collected for catchment and farm soil conservation plans which should be captured in a digital archive. This information would form a valuable resource for LUC surveyors undertaking new surveys and provide a historic resource on the evolution of LUC concepts. Further work will be needed to resolve any issues over the ownership and quality of the information. Funding sources, such as Envirolink offer a way of acquiring and making this information to a wide range of potential users.

The future role of the LUCCS

Our general recommendation is that the LUCCS is still fit for purpose, but significantly more value could be obtained from the information if the existing issues with the LUCCS are rectified.

The future LUCCS would continue to support land resource planning and management in New Zealand. The system needs to evolve so that it is sufficiently flexible to meet the needs for national and regional policy and regulation while supporting new and evolving end uses and applications. The modernised LUCCS would support the traditional LUC surveys with higher quality land resource information, while being flexible enough to allow parts of the resource inventory to be used for specific purposes.

New public investment should address the shortcomings in the quality of the information about the country's natural capital[203] and ensure that the LUCCS remains relevant for many years. The focus should be on developing high quality single factor inventory layers from which LUC interpretations and other multifactor interpretations can be easily derived or updated with new information.

There are also a number of specific projects that we have identified from this review, including the training of LUC surveyors, and making available the large amount of unpublished LUCCS work.

Our recommendations fit within the LUCCS Governance Group's Strategic Plan to modernise and update the LUCCS (Table 4).

Table 4. Aligning the proposed work with the LUCCS Governance Group Strategic Plan

LUCCS Governance Group Objectives	Summary of recommended work streams
Lead overall maintenance and modernisation of the LUCCS so it remains fit for purpose	• Support investment to update the LUCCS to improve quality and coverage of the inventory databases. • LRIS including LUCCS, are recognised as a Nationally Significant Database.
Modernise the LUCCS to enable the use of new data & to be relevant to new needs and technologies	Support new investment to update the LUCCS to improve quality and coverage of the inventory databases.
Engage key agencies to support the maintenance, modernisation, and funding of the LUCCS.	• LRIS including LUCCS, are recognised as a Nationally Significant Database. • Review the regional stock carrying capacity production indices.

	• Support investment to update the LUCCS to improve quality and coverage of the inventory databases.
Ensure LUCCS is based on a nationally consistent framework, capable of being used at many scales, and used appropriately in a regulatory setting	• Support investment to update the LUCCS to improve quality and coverage of the inventory databases. • Complete and publish the national LUC legend • Undertake a revision of the LUC Survey Handbook
Ensure interpretation of the old/new LUCCS is supported through user capability development	• Support the establishment of postgraduate courses in LUC survey methods. • Develop a national register of qualified LUC surveyors. • Create a digital archive of LUCCS publications and soil conservation farm plans. • Undertake a survey of LUCCS users
Promote use of LUCCS and benefits for land risk mapping	• Support the establishment of postgraduate courses in LUC survey methods. • Update the national erosion layer.
Ensure there is a common interpretation of the LUCCS	• Publish the national LUC legend • Undertake a revision of the LUC Survey Handbook
Support and implement research initiatives	Support new investment to update the LUCCS to improve quality and coverage of the inventory databases.

Parts of the LUCCS are dated, there are significant issues with the erosion and soil layers. The inconsistencies with the LUC classes and legends are likely to be addressed with the upcoming release of the national LUC legend.

Recommendations

Our specific recommendations for the LUCCS Governance Group are grouped either as a national/ regional or farm scale projects. We envisage the Governance Group would take the initiative and 'drive' the implementation of these projects. The recommendations are the starting point. Further work will be needed to deal with the issues raised by the recommendations, (e.g. certification of LUC surveyors, ownership of soil conservation maps). Some of the recommendations will also require significant investment and expertise, while others are easier to implement but may require the co-ordination across different agencies and organisations.

National/ Regional mapping and databases

1. Prepare a business case to for funding a new erosion susceptibility layer based on a national model of erosion susceptibility that utilises geomorphic and soil- landscape concepts.
2. Develop an overarching investment strategy to provide timely delivery of (but not limited to) all of the recommendations for the LUCCS identified in this review to ensure it remains current, consistent, and nationally available.
3. Develop a communication strategy to inform users of ongoing developments in LUCCS.
4. Prepare a set of guidelines on the appropriate use of LUCCS for regulation and policy.
5. Advocate for continued national investment to extend and complete national coverage of the supporting land resource inventories - S-map and LiDAR.
6. Advocate for the LRIS, including the LUCCS, to continue to be recognised as one of the country's Nationally Significant Databases and to secure an increase in real funding to support the ongoing maintenance of the LRIS database.
7. The LUCCS Governance Group support a regional council funding application to further develop and test the methodology for digital LUC mapping.
8. Manaaki Whenua – Landcare Research and AgResearch Ltd investigate the feasibility of updating the regional stock carrying capacity extended legend for the LUC units.
9. Manaaki Whenua – Landcare Research and GNS Science jointly investigate the feasibility of producing a national parent material geospatial database (RMAP) to complement QMAP and S-map. It would map the distribution the parent material, and contain information about its physical, hydrological, and engineering properties at a larger scale than at present.

Farm Environment Plans and property scale mapping

10. Undertake a survey of a range of LUCCS users to understand their needs, how they use the LUCCS and the strengths and weaknesses of the LUCCS from their perspective.
11. Prepare a paper detailing the role of LUCCS in Farm Environment Plans.
12. The LUCCS Governance Group working with professional primary sector organisations and universities to develop a post graduate qualification in LUC surveys.
13. The LUCCS Governance Group in collaboration with regional authorities, industry, research providers and constituent organisations develop a formally and nationally recognised certification scheme of qualified LUC surveyors and practitioners.
14. Manaaki Whenua – Landcare Research complete and publish the national LUC classification legend.
15. LUCCS support a regional council application for funding to scan and archive the published and unpublished reports, containing supporting

information on the NZLRI (including extended legends), to be made available on the LRIS.

16. The LUCCS Governance Group support a regional council application for funding to undertake a stocktake of the old catchment board soil conservation and maps to assess their quality with the aim of scanning and archiving the maps.
17. The LUCCS Governance Group support a regional council application for funding to undertake a revision of the Land Use Capability Survey Handbook to incorporate new mapping techniques, and changes to the definition of LUC classes.

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Appendix 1: Summary of land attributes used by different classification systems

Land characteristics (modified from Webb & Wilson 1995)		Attributes	LUCCS	Soil Vulnerability	Land Versatility	Physiographic Environments	Land Environments NZ	Tasman District Productive Land
	Topography	Slope	•			•	•	•
		Elevation (m)	•			•		•
		Aspect (north/south)						•
	Soil physical properties	Effective rooting depth	•		•			•
		Penetrability					•	
		Profile Available Water		•				•
		Soil wetness				•	•	
		Porosity		•				
		Topsoil stoniness	•					
		Permeability/ drainage	•	•		•	•	•
		Texture	•		•	•	•	•
		Workability	•					
		Macropores (0 - 45cm)		•		•		
	Soil chemical properties	Nutrients					•	•
		pH						
		Salinity	•				•	
		Cation exchange capacity						
		Organic matter				•		
		Phosphorus retention				•	•	
	Environmental characteristics	Erosion risk & severity	•					•
		Rock type	•	•	•	•	•	
		Parent material (regolith)	•					
		Land cover	•					
		Flood hazard						
		Surface water networks				•		
		Water quality/ composition				•		
	Climatic characteristics	Soil water balance		•	•		•	
		Air temperature	•		•		•	•
		Sunshine hours / solar radiation			•		•	
		Soil temperature						
		Wind			•			•
		Frost free period			•			
		Growing degree days			•			•
		Chill period						•
		Precipitation (mm)		•		•	•	•

• denotes where the attribute is used in the land classification system.

National geospatial datasets (mapping scale)	Landcover database 1:50,000)	Manaaki-Whenua Landcare Research S-Map (1:50,000)	GNS Science QMAP (1: 250,000)	LINZ LIDAR (> 1m elevation)	Manaaki-Whenua Landcare Research LRIS Digital Elevation Model (25m DEM model)	NIWA Virtual climate network (5km grid)	LINZ – Topographic maps (1:250,000 & 1:50,000)
Current status	National coverage. Remapped at approx. 6 year intervals.	Approx. 33% of the country mapped.	National coverage. Revised 2nd edition published 2018.	Approx. % of the country is mapped. Another 100,000km^2 will mapped by 2025.	National coverage.	National coverage.	National coverage. Updated approx. 4 to 5 times a year.

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