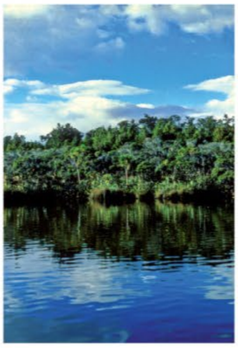

NZLRI/LUC Roadmap

Landcare Research
Manaaki Whenua

NZLRI/LUC Roadmap

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Contents

Executive Summary

This Roadmap outlines the current state of the NZLRI and identifies a number of key issues that need to be addressed. These are:

1. Lack of formal Governance.
2. Lack of formal database manager.
3. Inadequate formal archiving of earlier versions.
4. The NZLRI contains data that is becoming dated and lacks genuine national consistency.
5. The NZLRI is based round a "static" approach to data collection and interpretation that makes regular updating extremely costly.
6. Lack of error correction protocols and versioning.
7. The need for a national extended Land use capability legend.
8. The need for updated data (e.g., erosion) and links to other contemporary data (e.g. LCDB).
9. Consideration of contemporary scale requirements (e.g., farm-scale mapping).
10. Loss of expertise and institutional knowledge.
11. Need for new developments (e.g., new interpretation, automated mapping, on-line presence).

To address these issues a series of projects are proposed that will facilitate the progression of the current static and dated NZLRI to a more dynamic and flexible NZLRI that incorporates the best elements from the past but which is not at the same time constrained by that past. Projects are prioritized and initial estimates of resources required are indicated. The projects are:

1. **Priority 1**
    a. Establishment of a Governance group.
    b. Appointment of a Database Manager.
    c. Archiving, scanning and management of original field and published map sheets.
    d. Development of a National Extended LUC legend.
    e. A rethink of the way erosion is recorded within the NZLRI/LUC.

2. **Priority 2**
    a. Error Correction Protocols/Correct Previously Identified Errors
    b. A demonstration of the potential for employing automated mapping techniques
    c. An assessment of the feasibility for incorporating farm-scale mapping into the national NZLRI dataset.
    d. An evaluation of data structures for incorporating temporal information (error corrections and changes over time) into the NZLRI.
    e. User engagement, marketing and user feedback activity

3. **Priority 3**
    a. Develop data structure of NZLRI to incorporate knowledge of both spatial and aspatial data uncertainty.

1 Introduction

This roadmap has been prepared for several distinct interest groups including (but not exclusive to):

- Landcare Research 'Informatics' and 'Soils and Landscapes' Teams, and the 'Characterising Land Resources' and 'Realising Land's Potential' portfolio science leaders who have responsibility for the national dataset and are seeking to determine options for the future development of the dataset.
- The science and research community – mainly Crown Research Institutes (CRIs) but also including the academic and private sector research communities.
- National policy community – mainly central Government Departments who have used or continue to use land use capability (LUC) as a basis for policy development (e.g. MfE, MPI).
- Regional and local policy community – mainly Regional Councils, but also District and City Councils who have used or continue to use LUC for policy development, implementation and compliance.

1.1 Perspective and background to this roadmap

The land resource inventory and land use capability 'system' have been used in New Zealand as an approach to mapping physical attributes of land that affect land use, and suitability of land for productive use since the 1950s. It has been applied at scales ranging from farms and catchments to regions and nationally.

It is very important from the outset to appreciate how the NZLRI and LUC relate to each other:

> • The NZLRI used the generic standard LUC methodology developed between 1970s and early to mid-1990s at 1:63360 and 1:50 000 to map inventory and gave LUC classifications at the national and regional scale – hence producing the NZLRI and NZLRI GIS database. The NZLRI has aged.
>
> • The LUC mapping methods and LUC classification (Handbook) are independent of scale and can be used, applied, interpreted at any scale (e.g. 1:1000 -1:1000 000).

The NZLRI (NWASCO 1975-79, 1979; NWASCA 1986a, b) is single-layer, multi-attribute geospatial database. The LRI is a map depiction of five physical attributes of land that are deemed to strongly determine the suitability of land for use in a sustainable manner, and the land use capability is a structured assessment of the suitability of each parcel of land for productive use. The five physical attributes of the land comprise: rock type, soil, slope, vegetation cover and erosion. These are traditionally mapped to single set of geographic boundaries (polygons), and within each mapped polygon a value is assigned for each attribute.

The NZLRI and LUC are often referred to as the only “nationally consistent” view of the land resources of New Zealand and have been widely used in land use planning for at least 35 years. LUC is frequently quoted in central, territorial and local government policies, and, as a result in resource consent hearings, under the Town and Country Planning Act 1977 and more recently the Resource Management Act 1991. The land use capability system is also widely known and understood (or in some cases misunderstood) in the rural and environmental consulting communities where it has been used since 1952.

1.2 Land Use Capability

The Land Use Capability system and methodology is a simple and robust land classification system, initially used for farm-scale, catchment and regional planning studies and forms the bases of the nationwide NZLRI.

Land Use Capability (LUC) Classification is defined as *a systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production* (Lynn et al 2009). Capability is used in the sense of *suitability for productive use or uses* after taking into account the physical limitations of the land.

Assessment of land for long-term sustained production is based on an interpretation of the physical information in a Land Resource Inventory (LRI). The Land Resource Inventory is supplemented with information on climate, flood risk, erosion history and the effects of past practices, which may or may not be mapped as part of the LRI/LUC system.

1.2.1 Categories of the LUC Classification

The LUC Classification has three components – **LUC Class**, **LUC Subclass**, and **LUC Unit** – each of which is represented by a number or symbol. Figure 1 illustrates the relationship between the three components of the LUC classification (for specific details see Section 3 of Lynn et al. 2009).

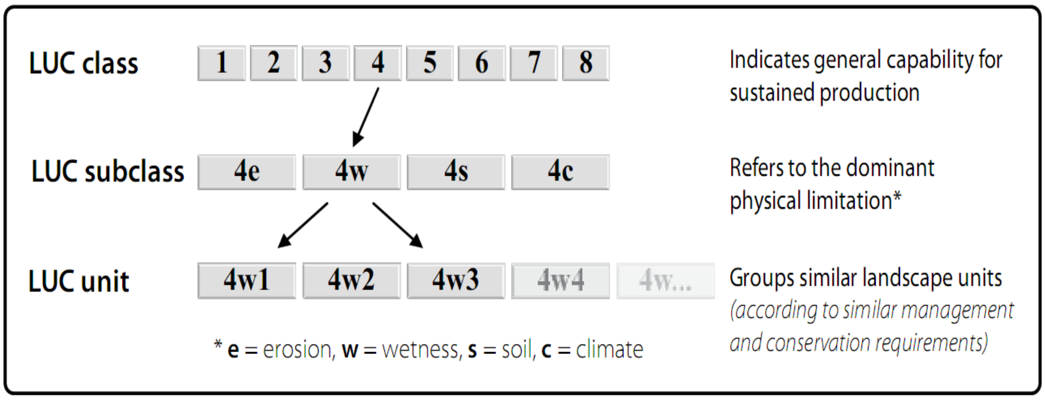


Figure 1: Components of the Land Use Capability Classification.

1.2.2 Land Use Capability Class

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

There are eight classes, denoted by Arabic numerals, with limitations to use increasing, and versatility of use decreasing, from LUC Class 1 to LUC Class 8 (Figure 2).

Increasing limitations to use ↓

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

Decreasing versatility of use ↓

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

LUC Classes 1 to 4 are suitable for arable cropping (including vegetable cropping), horticultural (including vineyards and berry fields), pastoral grazing, tree crop or production forestry use. Classes 5 to 7 are unsuitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry use, and in some cases vineyards and berry fields. The limitations to use reach a maximum with LUC Class 8. Class 8 land is unsuitable for sustainable grazing or production forestry, and is best managed for catchment protection and/or conservation or biodiversity.

1.2.3 Land Use Capability Subclass

The *LUC Subclass* is a subcategory of the LUC Class through which the main kind of physical limitation or hazard to use is identified. LUC subclass can be expressed as a question, *what is the single most important factor that is currently limiting <u>sustainable</u> production on this land?* Four limitations are recognised:

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

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

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

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

1.2.4 Land Use Capability Unit

The LUC Unit is the most detailed component of the LUC classification. LUC Subclasses can be subdivided into a number of LUC Units. LUC Units group together areas where similar land inventories have been mapped, which require the same kind of management, the same kind and intensity of conservation treatment, and are suitable for the same kind of crops, pasture or forestry species, with similar potential yields. LUC Units are identified by Arabic numerals at the end of the LUC code.

The advantages and disadvantages of the land capability use classification can be summarised in Table 1.

The lack of detailed soil information, agronomic records and knowledge of land response to intensive management is widely acknowledged as the greatest factors inhibiting land use capability evaluation.

Table 1. Advantages and disadvantages of land use capability classification (adapted from McRae and Burnham 1981 – pp. 83-86)

	Advantages	*Disadvantages*
1	*Small number of ranked categories, easily understood*	*Subjective*
2	*Qualitative rather than quantitative, allows rapid assessment*	*Limiting factor interactions are difficult to take into account*
3	*Versatile, easily modified to meet local conditions*	*Few categories, often too coarse*
4	*Easily to apply*	*Implied rank order of potential land use may disguise true value for a specific use*
5	*General purpose classification, separates arable/non-arable*	*Lacks suitability for a specific crop*
6	*Encourages soil conservation*	*Lands relative monetary value not indicated*
7	*Reflects current suitability at existing management levels*	*Negative, emphasizes limitations*
8	*Hierarchical structure allows display at a range of levels*	*Original USDA class 5 is anomalous and difficult to apply*
9	*Widely used internationally*	*Assessment difficult when lacking soil information*

10	*Gives reasonable and acceptable results that match local opinion*

1.3 Legislative Setting

During the 1950s through to the mid-late 1980s, two threads of legislation impacted on land and water: ‘Water and Soil’ (Soil Conservation and Rivers control Act 1941, Water and Soil Conservation Act 1967) and ‘Town and Country Planning’ (Town and County Planning Act 1954 and 1977). While there was considerable scope, and need, to bring these two threads together, at least on the ground, a truly integrated approach never developed. In 1991 these two threads merged under the Resource Management Act.

An audit of New Zealand's environmental management by the Organisation for Economic Co-operation and Development (OECD) in 1980 highlighted the need to improve environmental management. There followed a growing appreciation that environmental legislation, including the Water and Soil Conservation Act and the Town and Country Planning Act, needed to be reviewed.

Alongside this wider economic and policy reform saw the Government shifting responsibilities from national to regional, including environmental management. In 1987 Government shifted administration and funding of water and soil conservation in this direction, and removed the requirement for National Soil and Water Conservation Authority (NWASCA) to approve and allocate subsidy money for individual catchment authority projects. It closed NWASCA that year, expecting to shift its functions either to the new Ministry for the Environment or to the regional catchment authorities (which later became regional councils under RMA).

The Resource Management Act (RMA) was passed in August 1991. It repealed 78 statutes and regulations, and amended numerous others (including Water and Soil and Town and Country Planning legislation), to provide a single piece of legislation for the management of land, water, soil and air throughout New Zealand.

Water and Soil policies and practices would become somewhat defocused within the wider ambit of MfE and the RMA, and the regional catchment authorities became subsumed into the regional councils. Within this, there were at least two decisive shifts of emphasis that impacted on the context for land inventory and land use capability:

- The defocusing on national consistency and standards that arose from the increased regionalisation associated with government economic policy and the RMA. While it is probably true that many regional councils (and perhaps districts) saw value in working to national standards and shared approaches, there was limited national-scale policy mechanism, or shared funding, to enable this, and no other incentives to give national frameworks a priority.

- In terms of land use, focus in the RMA shifted from remedial works (soil and water) or planned (zoned) land use approach (town and country), to one of regulating to minimise adverse effects. A land use or management practice was no longer deemed unacceptable because it fell within a planning zone, but by a decision that a proposed activity on a site might have unacceptable adverse effects on environment or community, known as an adverse effects-based approach.

This change in emphasis has raised questions around how well the NZLRI and the related LUC classification that were conceived and established to support planning land use in (say) a catchment, zoning for land use in a regional or district scheme under the Water and Soil Planning Act 1967 and Town and Country Act 1941 and 1977 might now support the equivalent activities under the RMA 1991 more focused on assessing adverse impacts.

While LRI and LUC tends to be very informative of the relationship between land use or practices and the land and water resource, it may lack the specificity to do this well.

1.4 Need for review

The NZLRI was awarded “nationally significant database” status in 1993 (FRST, 1993), reflecting its importance over the preceding 20 years in supporting land use management. The conferring of nationally significant databases status provided base funding for on-going maintenance and management of the dataset (FRST 1993).

However, while still widely used, the NZLRI contains inventory data that is out of date (vegetation, erosion) or has been superseded by more modern, higher quality data (slope, vegetation and to some extent geology and soils). It represents a data set designed and implemented in the 1970’s, based on methods developed in the 1950s, essentially around hard copy map concepts, even though from a very early stage it was digitized and stored in a computerised format. In addition, for a variety of pragmatic reasons, the LUC extended legends for the NZLRI mapping are regionally-based. This initially had advantages in meeting short-term mapping targets during database establishment, and providing island wide overviews was managed through inter-regional correlation tables (e.g., Page, 1985).

As recently as the late 1990s, when reviewing information gaps and future upgrades, the regional legend approach remained at the forefront of strategic views of the future of the dataset, in the sense that the regional LUC extended legend system was central to discussions and options for the future.

From about the mid 1990’s, after the Wellington, Northland, Marlborough and Gisborne-East Coast upgrades were completed, funding for new (updated) regional-scale LRI mapping ceased, and the national dataset became static with no new work, and minimal maintenance.

Alongside the NZLRI, some Regional Councils, and their predecessors have developed and maintained a body of farm-scale LRI plans on a higher resolution than the national dataset. These farm-scale maps rely on the regional land use capability extended legends to define the LUC units, although there may be some modifications with increased scale (e.g., sub-dividing some units).

Currently training in land resource mapping is provided by a small group of experienced consultants, and all practitioners use the 3rd Edition LUC Handbook (Lynn et al 2009). However, there is no formal quality assurance oversight of these data between councils, so these detailed farm-plans represent a discontinuous source of variable quality mapping that has never been integrated with the national scale dataset.

2 History and Current Status of Mapping and Data management Technologies

2.1 Traditional Mapping techniques

NZLRI is a vector data set designed and implemented essentially around hard copy map concepts, even though from a very early stage it was digitized and stored in a computerised GIS format. Rather than create a series of independent data overlays of the individual inventory parameters that could be individually upgraded/improved, the mapping concept was for a single spatial layer containing multiple inventory attributes. These multiple attributes also included the LUC classification and other interpretive classifications (e.g., *Pinus radiata* site index). All these multiple attributes can be extracted to produce single factor overlays.

Vector boundaries were mapped through stereoscopic aerial photographic interpretation of the landscape on the basis of landform, particularly slope and rock type, with soil knowledge from existing mapping or soil-landscape relationships applied where possible. Line work would then be recompiled onto available topographic base maps (1:63,360 for Edition 1 and 1:50,000 for Edition 2) and a preliminary inventory compiled. Once office preparations were complete, field mapping included: checking of boundaries; full recording of inventory factors including checking soil and rock type information; and assigning preliminary LUC classifications based on the appropriate regional extended legend (see section 2.2).

While all reasonable effort was expended when field checking line work, inventory and classification for the NZLRI, the intention was to acquire data suitable for national, regional and district scale, but not farm-scale application. Most NZLRI polygons were never physically visited, and much mapping was carried out visually, “from-a-distance”, particularly in rougher terrain. In particular soils, slope, vegetation and erosion inventories rely heavily on the mapper acquiring key knowledge from on-ground observations in detailed sample areas and then using that acquired knowledge to infer what couldn’t be observed directly. The mechanisms used to QA the NZLRI are often not appreciated by newer users of the NZLRI who assume NZLRI polygons were actually visited.

Final map compilation and checking of map sheets was followed by a QA assessment by the leader of each regional mapping project. Once field sheets were approved, they were submitted for drafting and digitizing or scanning (see section 2.7).

It is worth noting that this approach is: labour intensive; relies heavily on expert assessment (is subjective); and does not lend itself to part remapping (e.g., upgrading a single inventory factor and reassessing LUC accordingly). Approximately 85,000 mapping units were identified at 1:63,360 scale and the total cost of mapping in creating the Edition 1 national coverage is estimated to have been at least 90 person years (roughly equivalent to $15 million at 2012 labour costs). Regional remapping at 1:50,000 to Edition 2 standards was more expensive per unit area as the spatial resolution was increased along with a substantial decrease in the minimum map unit size, both by the change to 1:50,000 scale and by the increased expectations and time available for improved Edition 2 mapping.

2.2 LUC Classification and inventory

2.2.1 Edition 1

Edition 1 mapping was carried out between 1972 and 1979. The North Island was divided into 10 regions and the South Island was mapped as a single region. Mapping was carried out at a field sheet compilation scale of 1:63,360, with an initial view to publishing paper maps at 1:253,440 scale. However, this was soon changed and the maps published at their compilation scale – hence their identification as 'worksheets'. This change in publication scale had a significant impact on map unit resolution standards with some areas being remapped prior to publication.

A total of 85,000 map units were identified in the LRI throughout New Zealand (excluding Stewart Island) with a mean map unit size of 335 ha (maximum 61,265 ha) and minimum map unit size targeted at 15 ha (although there are approximately 300 edition 1 polygons of less than 10 ha). From an early stage GIS storage was developed and adopted to compliment the traditional hard copy map production. These were bi-colour, with a selective brown monochrome topographic base under blue map unit boundaries with the land resource inventory and LUC classification codes on the map face. Standard coding was used except for erosion severity depiction. In the North Island severity was assigned to each erosion type recorded whereas in the South Island the mapping unit was assigned an overall erosion severity value.

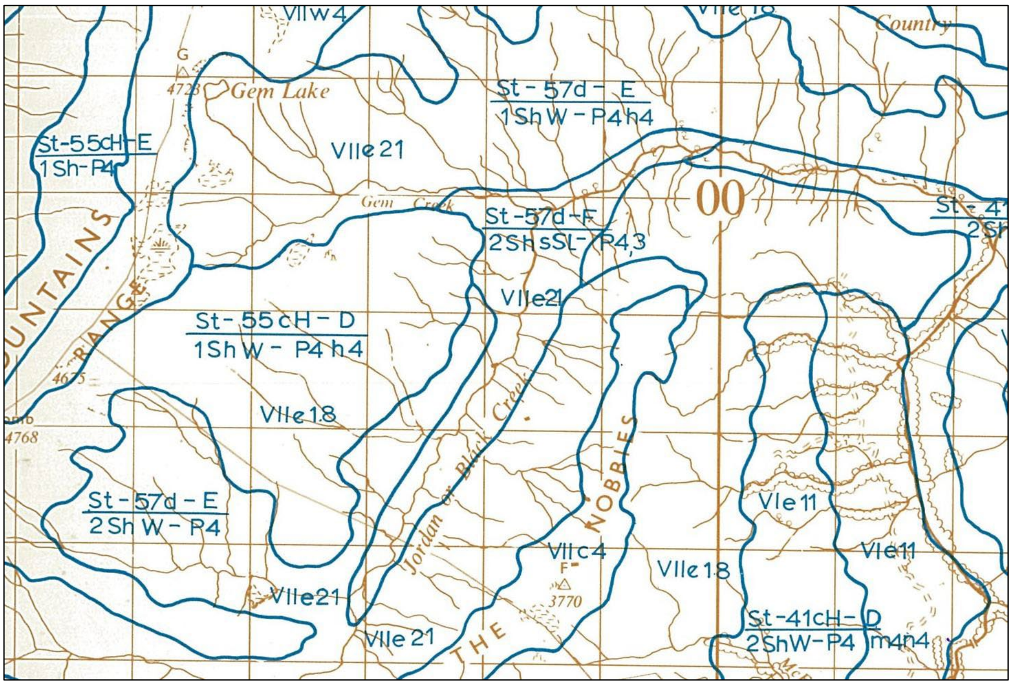
Part of the Waikato region was remapped during 1980-84, with some minor additions to the regional extended legend and published in 1986. This part-regional upgrade should really be considered 1st Ed data as it uses;

- 1st Ed rock type codes (Crippen & Eyles 1985),

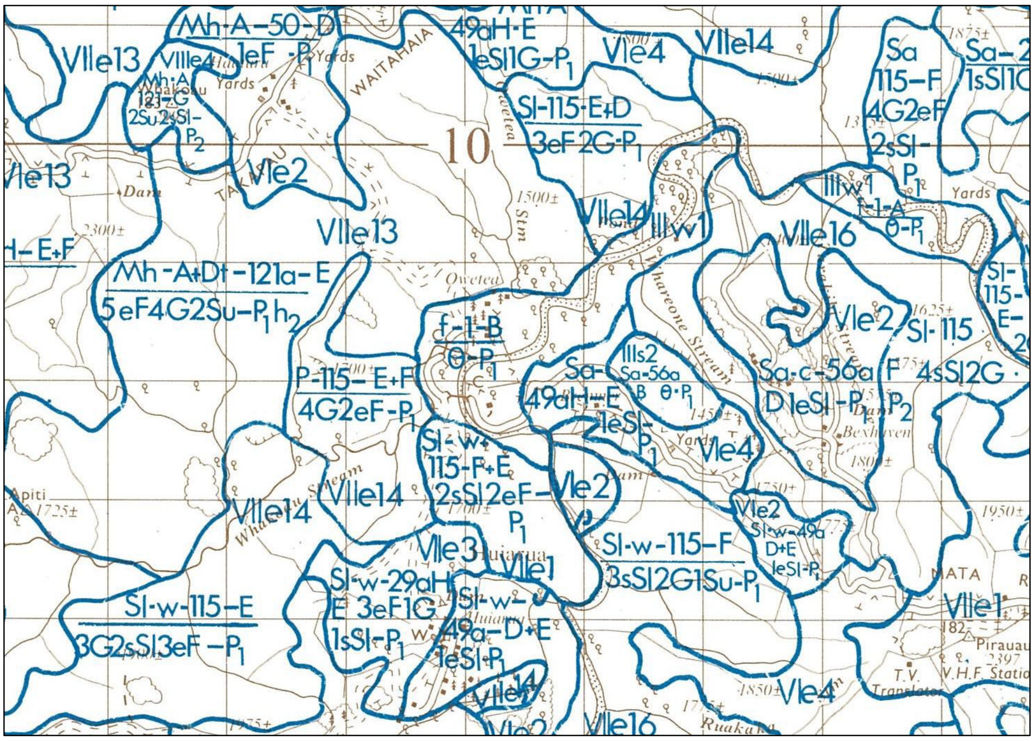
- 1st Ed vegetation codes and percentage criteria,

- is mapped and published at 1:63,360.

Map 1: Example of1st Ed NZLRI Worksheet symbology and coding – South Island. Note the single erosion severity code relating to all erosion types (e.g., 2ShsSl).



Map 2: Example of1st Ed NZLRI Worksheet symbology and coding –North Island. Note the multiple erosion severity codes for each erosion type (e.g., 5eF4G2Su).



2.2.2 Edition 2

Edition 2 mapping was carried out between 1988 and 1998 in four regions: Northland, Gisborne-East Coast, Wellington and Marlborough. Each region had an upgraded or new regional extended legend (see section 2.5), field sheet compilation was carried out at 1:50,000 scale. The more detailed mapping scale and time available lead to a significant change in map resolution from edition 1. A total of 37,000 map units were identified across the four regions with a mean map unit size of 97 ha (maximum 3,327 ha) and minimum map unit size targeted at 5 ha (although there are approximately 360 edition 2 map units of less than 5 ha).

The mapping process was essentially the same as for Edition 1, except for the use of

- New regional LUC Extended Legends
- A national rock type classification (Lynn & Crippen 1991)
- The recording of soil by NZSC to Subgroup level for Gisborne East Coast instead of soil series or set
- North Island style erosion severity recording in Marlborough (e.g. 3Sc2Sh1G cf. 3ScShG)
- A new and more detailed vegetation coding (Page 1987) and the recording of percentage cover to the nearest 10%.

Paper maps were only published for Edition 2 Northland region. For the other regions 2nd Ed data is available through the GIS only.

2.3 Handbooks and ancillary documentation

There is a variety of published and unpublished material supporting or relating directly to the NZLRI database and the LUC classification system. This includes 3 editions of a Land Use Capability Survey Handbook (SCRCC 1969, 1974, Lynn et al 2009), handbooks on the vegetation (Hunter and Blaschke 1986, Page 1987), rock type classifications (Crippen & Eyles 1985, Lynn 1985, Lynn & Crippen 1991), and erosion (Eyles 1983, 1985), 2 editions of a Data Dictionary (Newsome et al. 2008) and a Regional Legend publication for most regions (Trustrum 1974; Page 1975, 1976, 1995; Prickett 1978; Steel 1979; Noble 1979; Fletcher 1981; NWASCO 1983; Jessen 1984; Harmsworth 1996; Lynn 1996; Jessen et al 1999). Much of this material is available through Manaaki Whenua Press.

2.4 Regional mapping and Regional Legends

Experienced senior staff with an island wide knowledge enabled the design and implementation of a single NZLRI LUC extended legend for the South Island. This island-wide legend of 219 LUC units is more appropriate for national than regional and district use as evident by the fact that 152 LUC units were established for the 2nd Ed Marlborough region.

Because of a lack of island-wide knowledge in the North Island mapping team, and in order to make significant early progress, it was decided to prepare and map to regional classifications in the North Island (Eyles pers. com 2012), hence the 10 North Island NZLRI regional legends with independently numbered LUC units.

Table 2 and map 3 indicate the region names, number of units described in each region and the relationship between NZLRI Regions, regional government boundaries in the 1980s, and regional government boundaries as at 2013.

Although the LUC Regions shown in map 3 where similar to the regional boundaries at the time of mapping, they don’t exactly match. In addition, subsequent changes to regional council boundaries have exacerbated this situation.

In terms of LUC unit numbering, regional legends are devised to include only those LUC units that represent a significant area in the region. This creates boundary issues where a recognisable component of the landscape may be uniquely differentiated as a LUC unit on one side of a regional boundary because that landscape is common in that region, while that landscape may be non-uniquely amalgamated into a “most similar” LUC unit on the other side of the regional boundary because that landscape is rare in that region. A number of Regional Council specific LUC correlations have been prepared (e.g., Harmsworth and Page, 2009) to provide regional government with a legend that relates more accurately to their current region and has greater utility for facilitating consistent regional planning implementation. *These Region-specific correlations have not been propagated through into the national dataset, even though they may be incorporated into farm-plan mapping in some Regions.*

2.5 Correlations

A correlation table was prepared by Page (1985) which assigns all 1st Edition LUC units from the 10 North Island NZLRI regions to a set of 443 North Island-unique LUC unit descriptions. The results of this analysis have been incorporated into the NZLRI dataset in the form of the LCORR attribute (page 9, Newsome et al., 2008). While the LUC attribute may be compound (i.e., a map unit may contain a combination of more than one LUC unit), LCORR gives the dominant correlated LUC code (i.e., LCORR always contains one only LUC code).

The South Island extended legend was prepared as a single island-wide legend (Pricket, 1978). The 2nd edition Marlborough regional LUC units (Lynn 1996) are correlated to the 1st Edition South Island legend to populate the LCORR field for Marlborough. Note that for the remainder of the South Island the LCORR attribute equals the dominant LUC code.

Table 2: *LUC regions and total number of LUC units defined for each region1st and 2nd Ed where mapped.*

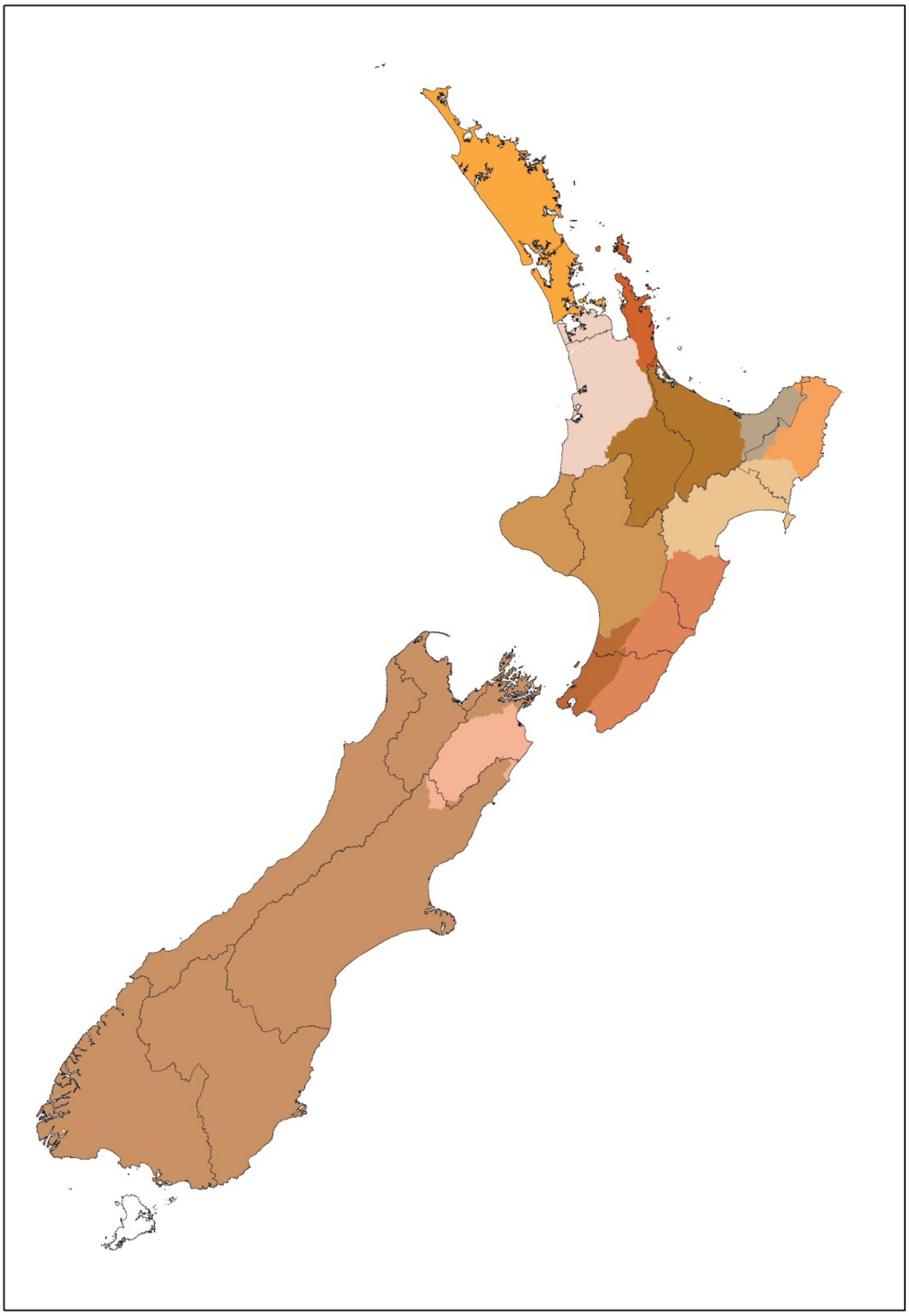
Region	**1st Ed**	**LUC units**	**2nd Ed**	**LUC units**
Northland	NWASCO 1984	71	Harmsworth 1996	91
Waikato	Walsh 1977	79	Jessen 1984	88
Coromandel – Great Barrier Island	Trustrum 1974	39	na	
Bay of Plenty – Volcanic Plateau	Steel 1979	116	na	
Eastern Bay of Plenty	Page 1975	22	na	
Gisborne – East Coast	Driver 1974	62	Jessen et al 1999	104
Northern Hawke's Bay	Page 1976	86	na	
Southern Hawke's Bay – Wairarapa	Noble 1979	89	na	
Wellington	Trustrum 1975	44	Page 1995	70
Taranaki – Manawatu	Fletcher 1987	153		
Total units		761		
North Island (correlation)		443		
South Island	Prickett 1978	219	Part South Island - Marlborough Lynn 1996	154

2.6 Digitizing and Scanning

Digitizing of the NZLRI Edition 1 was initially carried out on smaller format digitizing tablets (approx.. A3) with field sheets having to be cut into 4 quarters for digitizing and later joined digitally. Later digitizing was carried out on large format digitizing tablets (approx. A0) from final 1:63,360 or 1:50,000 scale map sheets. Manually digitizing data at the scale of field compilation from hardcopy using an A0 digitizing platen imposed some simple physical limitations on the accuracy of digitizing. Errors may occur in identifying boundaries in the field or on aerial photograph (particularly where these boundaries are not clear cut), compiling those boundaries to the topographic map field sheets (at 1:50,000 scale a 1mm wide line on the field sheet is 50m wide on the ground), and finally in trying to follow that line during the digitizing process. Bolstad and Smith (1992) quote figures of 20-55 feet (6-10 metres) for manual digitizing error from 1:24,000 scale maps. Digitizing manually at 1:50,000 or 1:63,360 scales would undoubtedly result in errors in the order of 50-100m or more.

Early Edition 2 maps were also manually digitised, but Edition 2 Marlborough and Gisborne-East Coast map units were drafted onto clear foil, scanned and vectorised and only the inventory and LUC classification data were manually entered into the GIS database.

Map 3: The map below highlights the difference between the NZLRI Regions (coloured patches), the regional government boundaries at the time of the main LRI mapping campaign (thin black lines) and the 2008 (current) regional boundaries (thick gray lines).



3 Strengths and Weaknesses

3.1 Strengths

There are a number of strengths of the NZLRI/LUC in its existing form. These are as follows.

1. The mapping is promoted as being a nationally consistent approach to land resource evaluation.

2. The NZLRI/LUC integrates key factors for land use planning into a single layer that can be interpreted in a variety of ways to make wise land management decisions.

3. The data has been gathered at a scale that is detailed enough for use at regional and district levels, and can also be used for national planning purposes.

3.2 Weaknesses

While there remain some strong proponents of the NZLRI/LUC in its existing form, there are a number of serious weaknesses that can be readily identified. These are briefly discussed below.

1. The data in the NZLRI is now at least 20 years old and in some cases as much as 30-35 years old. While this may mean it is gaining some value historically, it is steadily losing value as a contemporary picture of New Zealand's current land resource status. While many of the underlying factors (e.g., rock, slope and soil) do not change rapidly over human time-scales, our ability to map and interpret them has improved. For example, slope can now be mapped to a much higher resolution and accuracy via digital elevation models than was previously the case, and could have a significant impact on the LUC of any given parcel of land. The differences between the older NZLRI/Soil Survey/Fundamental Soil Layer (FSL) and associated attributes, and the new S-map soil data and interpretations (particularly in lowland areas), are also likely to have a significant impact on the LUC assessment of parcels of land. Other factors such as vegetation and erosion do change over relatively short time frames, and the existing database is now becoming seriously out-of-date in many areas.

2. The NZLRI has a static database design, so that in its current form it can only be updated by a complete remap to draw and digitise new lines/polygons within which to record attributes. This mapping approach is does not reflect current best practice and is not a realistic option for an upgrade in terms of time, cost or human resources.

3. There are inconsistencies in the recording of attributes between the North and South Islands (e.g., erosion severity, 1st Edition), between editions (e.g., vegetation cover codes and percentages), and between regions (e.g. Gisborne-East Coast soil and vegetation). There is also an increase in resolution between Edition 1 and Edition 2 mapping. Finally with one South Island and 10 North Island regional extended 1st edition legends and four 2nd edition extended legends, LUC unit codes can mean different things in different parts of the country. The first edition North Island

regional extended legends were correlated by Page (1985). The LCORR code (LUC correlation) in the NZLRI database attempts to address this issue, but needs revision.

4. The original edition 1 data for Northland, Gisborne-East Coast, Wellington and Marlborough regions was removed from the dataset and archived. This should really have been maintained within the dataset as an earlier version, to at least enable users to have the option of using the dataset in its original nationally 'consistent' form, or as a best available data option. However, representation of versions was not available at the time of regional remapping.

5. The NZLRI has never had a formal system for managing error reporting and corrections. Garth Harmsworth has done considerable work across the North Island Regional Councils to provide corrections, updates and regional correlations where Regional Legend boundaries no longer coincide with Regional Council boundaries, so that the same LUC unit codes meant different things within a Regional Council's area. Little or none of Garth's work has been propagated into the main NZLRI dataset. This lack of corrections and updates has led to a loss of recognition in some quarters, particularly in some Regional Councils, that the NZLRI is an authoritative dataset.

6. In addition there are bodies of valuable LRI/LUC knowledge now held within Regional Councils that have developed in a "disconnected" way from the original NZLRI. Landcare Research lacks any real understanding of what data might exist in this form and how it may relate to, or have value for, a potential update of the NZLRI. However, at the same time there are certainly questions of quality and consistency of farm plan data and of quality assurance procedures, both within, and between Regional Councils.

7. The LUC classification itself (embodied in the 12 extended legends) is now somewhat dated – it was established within a land management context targeted at addressing land use issues related particularly to accelerated erosion perceived as a serious threat to sustainable land management. A more modern version of LUC would give additional weight / consideration to other current issues (e.g., nitrate leaching, irrigation, etc.). A modern LUC classification system might be one interpretation/classification, but other concepts such as vulnerability, versatility and suitability might have more value because they can be targeted at specific uses or issues.

   There are those who will advocate that the LUC is in fact obsolete as a concept, and that we should not be constrained to continue with this classification system. Yet a recent stakeholder workshop indicated that key groups of stakeholders (e.g., Regional Councils) are still very strongly aligned to the use of LUC in its traditional form. The updated LUC Handbook 3rd Edition was only completed in 2009, suggesting total deprecation of LUC as a mapping classification, despite obvious weaknesses, would be unwise.

8. Some of the ancillary attributes added to the LRI, most notably land production indices such as Pinus radiata site index [PRSIR, PRSIC and PRSIAV] and stock carrying capacity estimates [CCAV, CCTO, CCPO]), are also badly out-of-date and mostly represent a historic view of land capability and production rather than a useful contemporary indication of the ability of parcels of land to support stock or trees.

Despite not being fit for purpose, they are still being used. Ancillary attributes need up dating in the light of current best practice. For example, the concept of 'Site Index' has largely been superseded by the '300 Index' for Pinus radiata. Stock carrying capacity estimates for extensively grazed South Island high country are clearly optimistic and reflect 1970's thinking whereas carrying capacity values for intensively farmed lowlands and North Island hill country still represent the 'best available' and are central to Horizons One Plan and used in OVERSEER.

4 Design Principles

We have briefly described the history and current status of the NZLRI, and identified a number of significant general and specific shortcomings. In now proposing a Roadmap to move the NZLRI forward we would like to identify a number of broad design principles that we believe should be followed. In most cases these design principles have been developed from the recommendations, some unanimously supported, some not, of the NZLRI Roadmap workshop (Barringer et al., 2013).

1. Any changes proposed, both technical and conceptual, should, where appropriate, be tested, proven and accepted by the user community before being widely implemented.

2. Any changes in the NZLRI should represent an EVOLUTION rather than REVOLUTION. In this context we mean that there is recognised value in the existing NZLRI data set despite the short-comings described above, and it is still widely used as a result. For this reason any future development should leverage off this legacy rather than discard it entirely. This means that we should utilise existing information relating to errors and omissions in the NZLRI to bring the NZLRI dataset up to an acceptable standard, and we should then make forward plans that retain backwards and forwards compatibility both technically and conceptually (i.e., in terms of geospatial data structures and in terms of LUC unit descriptions and possible additional/new classification schema) so that wherever possible comparisons of trends between the old and new are valid and not confounded by known but uncorrected errors in the original NZLRI dataset. Essentially we advocate an evolution that embraces new techniques and approaches. This does present a significant, but by no means insurmountable, design challenge to maintain the old while also embracing the new.

3. Any new development of the NZLRI should look at a more automated approach to mapping on readily available base data sets such as digital elevation models and their derivatives (slope, landforms, etc.), climate surfaces, land cover, and contemporary soils data (e.g., S-map). This would also permit the NZLRI to be updated at relatively low cost whenever new base data becomes available. This is recognised as a contested view and therefore should particularly accord with 4.1 and 4.2 above.

4. Any new development of the NZLRI/LUC should aim to deliver a truly consistent national data set with one national extended legend [down to the LUC unit level] and consistent mapping resolution. This would mean that each LUC unit code would be unique and would always mean the same thing.

5. Any new development of the NZLRI should be properly versioned and have a formal and regularly used process for the reporting, evaluation and correction of errors and changes. The NZLRI should have a formal NZLRI Database Manager who manages and oversees this process.
6. Any new development of the NZLRI should enable multiple interpretations/ classifications to be generated from the core datasets lending the new NZLRI a degree of flexibility to deal with a wider range of future demands for land information, many as yet unknown. In order to meet other principles already outlined, at least one of the interpretations/classifications should be LUC.

5 Issues that need to be Addressed

5.1 Governance group

The NZLRI requires a formal Governance body incorporating representatives of the data provider(s) and the data users. With the complexities of a national scale data set and local scale farm plans using the LUC approach at a finer scale being prepared by a significant number of Regional Councils, there is considerable value in establishing a Governance body that assists in managing the NZLRI dataset into the future.

5.2 Database Administration

The NZLRI requires a formal Database Manager whose duties should include, but not necessarily be restricted to:

- Requirements gathering and planning of database hardware and software;
- Liaising with informatics regarding technical support;
- Planning and implementing an agreed database structure;
- Monitoring and optimizing the performance of the database;
- Implementing database upgrades with science staff;
- Implementing and managing error corrections;
- Managing an archive (including original compilations, etc.); and
- Planning and implementing backup and restoring of database.

5.3 Data Archive

The NZLRI requires formal curation and archiving of original field sheets and any other relevant physical or hard copy data/information/knowledge that can be retrieved from informal storage. Archiving should include digital capture (scanning) of any hard copy as well physical archiving. Currently there is no one with responsibility for managing an archive or formal archiving processes e.g. cataloguing, access control, etc.

5.4 Temporality and Versioning within the Database Structure

We strongly recommend implementation of a temporal data structure that facilitates storage of deprecated data. The current data structure delivers "best currently available data". Any deprecated data is removed from the database and (hopefully) archived. There is no existing capability to store and display historical views of the database along with the "best currently available" view.

5.5 Uncertainty within the Database Structure

The NZLRI database structure should also incorporate the capability to assign locational and attribute metadata on a per-feature basis describing uncertainty, thus enabling data users to estimate uncertainty for analyses based on the NZLRI database. If this recommendation is followed, then it is imperative that equal effort be given to communicating that uncertainty to users and in a way that is easily seen, understood and used appropriately to understand the impact of uncertainty on the results of complex analyses.

5.6 Error Correction protocols

To facilitate the task of Database Manager we strongly recommend that formal protocols be established for identifying, moderating and implementing error corrections and/or updates, and that this be compatible with the temporal database structure identified above. Such error protocols need to accommodate everything from corrections provided by a recognised scientific authority to crowd sourced feedback on data accuracy.

5.7 National Extended Land Use Capability Legend

We recommend that a nationally consistent extended LUC legend be developed which utilises the current regional extended legends and North and South Island ("National correlations"), but also "modernizes" these to match contemporary standards. There is quite a variance between unit descriptions in existing regional legends, some of which describe units in terms that can rapidly become dated. For example referring to land use patterns at the time of preparation of the legend and including land use recommendations relating to specific – now superseded legislation. In other extended legends unit descriptions are less specific and descriptions still apply equally well today as 30 years ago. In addition this process should also involve rationalizing the units and descriptions so that each description uniquely describes a unit in New Zealand. So a "4e12" will mean exactly the same thing wherever it occurs in New Zealand, rather than the current situation where "4e12" may have a different description in different regions.

5.8 Erosion rethink

We recommend that options for recording erosion be investigated. Main options are upgrading using a similar methodology to give a current and consistent coverage of erosion severity, adoption of a land stability approach that some Regional Councils are using, or moving to an erosion hazard/risk approach that would be a "permanent" land attribute (i.e., once done would not need to be repeated to remain current). As not all Regional Councils that are using LUC in farm plan mapping are taking the same approach, we will need to have agreement/support from the end-user community in what we advocate. Therefore we need a document that provides a clear and compelling vision for what our preferred method of erosion mapping might look like and how it might be implemented.

5.9 Farm Plans

We recommend that the potential for integrating and updating the existing NZLRI by incorporating farm plans prepared by regional councils be investigated. There is a substantial resource of Regional Council farm plans, most certainly at a larger scale than the national dataset, but also of largely untested quality, and possibly with access restricted by privacy issues. The ability to incorporate information from this source has never been tested, but should be.

5.10 Specific Data Interpretations

We recommend that the new NZLRI data structure be designed to facilitate options for specific interpretations of the underlying inventory factors relating to specific land management issues to complement the standard LUC classification. LUC is a classification schema that was originally designed for supporting decision-making around agricultural land use in the face of accelerated soil erosion and vegetation depletion which had been identified through the middle part of the 20th century as a key environmental issue in New Zealand.

Since that time there has been a significant rethink on erosion and vegetation depletion issues, while other issues such as climate change, nitrate leaching, and biodiversity loss have emerged as more pressing. Through this dynamic "issues domain", the LUC classification has been reinterpreted by others for a wide variety of purposes, sometimes inappropriately. In part this also reflects the pre-GIS thinking of the database design and the fact that some of the LUC experts developed their expertise in this setting; many are strongly wedded to this approach.

While there are still some very strong proponents of maintaining the status quo with any specific interpretations built on top of LUC, there are equally strong proponents for moving towards specific data interpretations, founded on appropriate combinations of land inventory factors, but optimised to answer specific questions.

We advocate developing a database structure that maintains LUC as a valuable general interpretation of the original inventory factors, and a vital link in terms of backward compatibility of interpretations, but that also encourages, where appropriate, the use of a range of specific interpretations optimised to deliver the best available assessment for specific issues. These would be based upon the best available data layers extending well beyond the original 5 inventory layers. The new NZLRI database structure and extended classification schema must have the flexibility to permit new interpretations for issues that have not yet arisen, or are currently not considered sufficiently important to warrant specific attention.

5.11 LUC Expertise, Succession and Training

There is a major concern regarding on-going support for the NZLRI/LUC beyond 2020. The cohort of scientists and Regional Council practitioners who developed and implemented the NZLRI are rapidly approaching retirement age. This ageing pool of expertise highlights an urgent need for documentation and training to pass on as much as possible of the deep knowledge and understanding behind LUC and how it has been applied in New Zealand to a new generation of researchers and practitioners who can use and maintain the database into the future as appropriate.

5.12 Online Presence of NZLRI/LUC

Currently the NZLRI can be downloaded from the LRIS Portal (http://lris.scinfo.org.nz) and a number of interpretations can be viewed in on the Our Environment website (http://ourenvironment.scinfo.org.nz). Some consideration might be given, in the fullness of time, to presenting the NZLRI in its own dedicated portal, similarly to S-map Online, with simpler interpretations still provided in the Our Environment portal.

6 New Data Sources and Mapping Techniques

As explained earlier, the NZLRI as it currently exists is very much a product of the 1970's and 1980s. While a number of datasets (e.g., DEMs, LENZ, LCDB) have been developed over the intervening years no single dataset, or combination of datasets, or derivative of any dataset(s) has ever replaced the NZLRI as the definitive land resource dataset for New Zealand. There are at least two main reasons for this.

The primary technical reason for this probably remains the sheer amount of background material across many disciplines that needs to be assimilated to enable one to confidently interpret the landscape (regional geology, geomorphology, soils, climate, primary production systems etc.) and the consequent difficulty in implementing automated mapping procedures. However, there is clearly also a reticence amongst land mappers and users to move away from a strongly field-based approach to LRI mapping which, while acknowledged as being more subjective, is seen as more reliable because the mapper has visited the field or at least "manually" assessed every polygon. Particularly in the context of farm-scale mapping, the presence of an expert evaluator in the field is seen by many to trump any developments in automated mapping.

Given that the relative complexity of the extended legend classifications has probably been a limiting factor in moving the NZLRI forward, one option might be to investigate discarding this classification in favour of something less complex and more flexible. However, given how deeply the existing classification system is embedded in local government and central government legislation, let alone practitioners thinking, indicates that such revolutionary change should only be contemplated if no other viable options are available. The first and preferred option should be for evolution of the existing system.

Even taking into account the comments above, it is clear that over the last 20 years or more there have been some very significant developments in geostatistics, DEMs, GIS-based spatial modelling, remote sensing and image analysis that indicate considerable scope for revisiting the use of new data sources and more automated mapping techniques in the traditional NZLRI context. The following sections provide brief summaries or relevant developments in key areas.

6.1 Terrain analysis from DEM

There is a rich pool of relevant research literature undertaken in:

- Landcare Research (e.g., Dymond and Harmsworth, 1994; Dymond and Luckman, 1994; Dymond et al., 1995; Harmsworth et al., 1995; Barringer and Lilburne, 1997; Barringer et al., 2002; Lynn et al., 2002; Leathwick et al., 2003; Shepherd and Dymond, 2003; Schmidt and Hewitt, 2004; Schmidt et al., 2005; Schmidt and Andrew, 2005; Barringer et al., 2008; Hewitt et al., 2010);

- New Zealand (Brabyn, 1997, 1998);

- Australia (Gessler et al., 1995; Wilson and Gallant, 1998, McKenzie and Ryan, 1999; Wilson and Gallant, 2000; McKenzie and Gallant, 2006);

- Internationally (Wood, 1996; Zhu et al., 1997; Burough et al., 2000; McMillan et al., 2000; Zhu et al., 2001, Shi et al., 2004; Qi et al., 2006; Iwahashi and Pike, 2007; Minar and Evans, 2008; Strobl, 2008; Dobos and Hengl, 2009; Dragut et al., 2009; Hengl and Reuter, 2009; Evans et al., 2009; McMillan and Shary, 2009; Zhu et al., 2010; Behrens et al., (2010); Geng et al., 2012).

Essentially all of methods proposed bring together DEM representations of the landscape and derive from that representation, through a variety of complex methods, landform characteristics (e.g., slope, aspect, curvature) and landform classifications that divide the landscape up into components. These can then be related to other relevant environmental information (e.g., geology, climate, erosion risk) to automatically create a land inventory.

In this context it is also important to keep in mind the options for improved DEM resolution. In the New Zealand context a national topographic base which delivers 20m contours has meant working mainly with DEMs in the 10-100m resolution range, and DEMs that are relatively smooth in terms of representing the landscape at that scale. The highest resolution contour-based national DEM currently available appears to be an 8m resolution commercial product available from Geographx[1]. Newer technologies, namely high resolution satellite imagery (e.g., ALOS PRISM, GeoEye, etc.), can give resolutions of 1-10m, while LiDAR can potentially deliver spatial resolutions of < 1m and vertical accuracy in centimetres.

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[1] http://geographx.co.nz/_wp/wp-content/uploads/2012/12/GX-Terrain-Metadata.pdf - $800 under license.

While national coverage of LiDAR in the short to medium term seems unlikely, combining data sources – contour-based for mountain lands, satellite imagery for hill and strongly rolling terrain, and LiDAR for low lying plains and downlands – could provide sensible resolutions and accuracies for characterising the landscapes in question. However, analysis methods will need to be optimised to data quality.

A significant issue that needs to be addressed is that the bulk of the terrain analysis research carried out up until now has used contour-based DEMs at 25m and 15m which because of their source data are effectively created smoothed and simplified to a spatial resolution of around 75m-150m (say 1:25,000 to 1:50,000 scale). Deriving DEMs from stereoscopic imagery using soft photogrammetric approaches enables the user to by-pass the contour step and creates DEMs that are not constrained by conforming to assumptions associated with contours. LiDAR-based DEMs use a different technology but in a similar way are not constrained by the contour model. As a result the DEMs are not as smooth so not only do they have a finer resolution but they contain a great deal more microscale relief information that may confound terrain analysis tools optimised for use with contour-based DEMs.

6.2 Availability of high resolution orthorectified imagery (e.g., KiwImage)

In the context of the NZLRI it is also important to acknowledge that the existing national dataset was predominantly mapped onto the 1:63360 (“inch-to-mile”) topographic map series. This was based on panchromatic stereoscopic aerial photograph interpretation with, at best, a ground resolution of around 5 metres (e.g. 400 pixels per hectare). Newer mapping in Northland, Gisborne, Wellington and Marlborough, carried out at 1:50,000 scale used similar resolution aerial photography, and almost exclusively in a hard copy form.

Today, although not yet nationally available, a significant proportion of the entire country has KiwImage[2] satellite imagery which is multispectral and has a pan-sharpened ground resolution of 0.65 metres. This gives around 60 times more pixels per hectare (23668 vs. 400) and these image data can be used in a digital setting which removes many of the practical limitations associated with hardcopy photos and scale. Nonetheless these data still have a range of mapping scales that must be adhered to. For farm-scale manual mapping, or indeed any manual mapping approach, the combination of these high resolution data and heads-up on-screen digitizing offer very significant advances over the earlier hardcopy process. However, the provision of a digital equivalent to stereoscopic viewing of imagery requires additional technology not normally available or the use of additional information, for example DEMs and derivatives such as slope, aspect and landform.

For automated mapping, the likelihood that such high quality imagery would offer significant gains for automatic mapping of visible features is tempered by the challenge of dealing with “noise” from texture and other similar features of high resolution data. Most standard image classification techniques were developed for pixel sizes where canopy texture, often of multiple targets, is embedded in the spectral signature of a single pixel. With higher resolution imagery a single target may be represented by many pixels with different spectral signatures depending on sun angle, surface roughness and target geometry. The classification

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[2] http://kiwimage.govt.nz/

challenge changes from picking targets out of a complex spectral signature into aggregating multiple related pixels with varying spectral signatures into a single identified target.

This issue is broadly analogous to that described for DEMs (e.g., contour-based versus LiDAR) in the previous section.

6.3 Land Cover, Vegetation mapping (LCDB and EcoSat)

Since the original NZLRI mapping in the 1970s and 1980s where vegetation mapping was carried out as part of the wider land resource mapping process, there have been a number of more recent attempts to specifically map vegetation and/or land cover.

The Land Cover Data Base (LCDB)[3] is satellite based although still predominantly manually mapped. The LCDB series has been mapped 3 times since 1996 with minor modifications to the classification each time. It potentially has a much finer spatial resolution (around 20m pixels = 0.04 ha) but maps only dominant cover in 16 cover classes in LCDB1), 43 in LCDB2 and 33 in LCDB3. Version 4 is due to be published in 2014 based on 2012/13 imagery.

EcoSat represents an "early" attempt by LCR to develop an automated approach to LCDB style mapping. Important innovations include standardised reflectance mapping to remove the impact of topography on apparent spectral signatures of targets. This substantially improved classification accuracy and a more automated approach to classifying image pixels, rather than defining a classification scheme prior to analysis. It is expected that the most useful elements of this type of approach will be incorporated into LCDB versions 4 and 5.

While it would be true to say that these alternative sources of land cover data offer more up-to-date (contemporaneous) knowledge and certainly a greater spatial resolution, it would also be true to say that the NZLRI has a relatively rich thematic basis by comparison, particularly in terms of indigenous forest and developed / semi developed grassland. NZLRI has 53 classes (Edition 1) and 58 classes (Edition 2) compared with a maximum of 43 classes in LCDB version 2. The NZLRI classes include 11 Indigenous forest classes to only one in the LCDB and 8 crop classes compared with 3. The NZLRI also contains information regarding percentage cover of each vegetation type within combinations of up to 5 vegetation types occurring within a mapped unit which delivers 1000s of unique vegetation code combinations. However, the NZLRI is not specifically a vegetation or land cover map, the mapped units being closer to geomorphological units with a minimum unit size of approximately 2.5 ha.

Determining how to integrate this combination of greater spatial resolution, with a land cover rather than vegetation classification, and with lesser thematic resolution into any upgraded NZLRI is a major issue which needs research.

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[3] http://www.lcdb.scinfo.org.nz/about-lcdb

6.4 Geostatistical derivation of climatic surfaces (LENZ and NIWA)

Climate and other related factors were built into the NZLRI, particularly at the level of unit descriptions in the extended legends (e.g., South Island 2s1 is described as "low terraces and floodplains with fertile, moderately deep soils in cool moist districts"). Rainfall isohyet maps, elevation/contour maps and other climatic factors based on manual mapping from data points, most commonly NZ Meteorological Service (now NIWA) climate stations, were the basis for this (e.g., NZMS, 1973a, b). Use of climatic knowledge in NZLRI mapping would not have involved GIS overlay of any of these maps, but would rather have been through expert interpretation and integration with other data sources. For example, information on the presence of podsolization in soils at a particular location (implying a degree of wetness and leaching) would be taken in conjunction with available isohyet maps to determine the extent of a soil series which might influence LUC unit assignment.

It has now become common to automate the creation of climate surfaces by using geostatistical interpolation to objectively estimate climatic parameters between climate stations. In most cases these interpolations will use covariates to assist in explaining spatial variation. Commonly this may include factors like elevation, latitude, distance from coast, etc., which help to explain variation in key climatic parameters.

The first step in New Zealand was the creation of the Land Environments of New Zealand (LENZ) dataset which utilised a set of long-term (30 years to 1980) climate records for New Zealand climate stations (Leathwick et al., 2002). More recently NIWA have created a virtual climate network and a variety of climatic surfaces[4] representing both current climatic conditions and in some cases predicted climate conditions under climate change scenarios. However the availability of these surfaces for use by other agencies is an issue or involves an associated and reasonably significant monetary cost.

6.5 Soil mapping

Soils and soil properties are a key component of the NZLRI classification. Since the NZLRI was created a significant amount of work has been carried out improving New Zealand soil mapping resources. This includes: new and/or updated surveys of key areas (e.g., Plains and Downs of Canterbury): regional initiatives (e.g., Topoclimate South and growOTAGO); and national initiatives (e.g., Fundamental Soil Layers (FSL) and S-map). Establishing how best to integrate these data into an updated NZLRI, like the erosion rethink, requires research.

Initial research has found considerable difficulty in linking the older and now less acceptable FSLs with S-map to create a best available soils data layer for New Zealand. This is exacerbated by the significant change in classification schema and approach between the Soil Series and Soil Type recorded in the FSLs, a naming schema related more to the older New Zealand Genetic Soil Classification system, and in the Soil Family and Sibling naming schema related to the newer New Zealand Soil Classification system. The link between Soil Series/Type and Soil Family/Sibling is certainly not a one-to-one relationship. This means

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[4] http://www.niwa.co.nz/our-science/climate/our-services/mapping

that a significant rethink may be required to link Soil Family/Siblings to LUC units, but also to explain how an LUC assigned under the Soil Series/Type system would relate to the LUC assigned under Soil Family/Sibling for backwards compatibility.

6.6 Fuzzy logic and inference tools

A possible solution to using GIS overlay analysis of large numbers of complex contributory spatial layers to determine LUC classification may be the use of inference or fuzzy logic tools to cope both with multiple criteria, uncertainty in source data, and in terms of propagation of error through modelling. These approaches are already being applied in some terrain analyses (see 7.1) and in Digital Soil Mapping (DSM).

6.7 Erosion rethink

We propose developing and replacing the current erosion layer with an erosion risk layer that reflects the long term risk of erosion and its effect on soil properties and capability for agricultural production (including horticulture and forestry). It would be somewhat analogous with potential erosion but be clearly defined and quantitatively derived from a series of base layers of data, and a permanent landscape attribute – once developed there would be no requirement for updating. In New Zealand landscape response to erosion is a function of climate, topography, and rock type and is influence by land cover and land use. Developing a GIS-based model of the interaction between these factors would provide a tool for land managers to map spatial variation in susceptibility to erosion and provide an index of the long term consequences of erosion. This could be used as a basis for determining suitability for different land uses especially in the erodible hill country.

The approach would likely be a combinatorial classification using the following.

- Climate: using a combination of rainfall intensity-frequency-duration statistics and accounting for antecedent moisture conditions;
- Topography: we now have some good datasets showing the relationship between landslide density-frequency and slope (for Wairarapa, Hawkes Bay, Manawatu);
- Rock type: reanalysing the classification of rock type in relation to erosion susceptibility;
- Land cover and land use: being specific about erosion hazard under different land covers and land uses using the best available historic data.

The aim would be to develop a national, consistent coverage that would sit alongside the NZLRI rather than be incorporated in it, and would probably replace the erosion terrain layer.

GNS has developed a somewhat similar tool, the probabilistic rainfall-induced landslide hazard model (PRILHM) for New Zealand (Dellow et al. 2010). It is probably more detailed than we need but has much in common with what is suggested here. Also it does not deal with other types of erosion.

7 Requirements and risks

7.1 Financial Resources

There has been no indication of the likely resources that might be made available for any of the work options discussed in this document, so the view taken is that this is a “brain-storming” exercise that is unlimited by funding constraints. Thus the options discussed are not restricted if they seem to be complex or potentially large bodies of work. Further work may need to be given to some options to determine the amount of effort required, priorities, and, of course, there are clearly some inter-dependencies between the activities.

7.2 Human Resources

If anything is to be done to remedy many of the existing problems and/or to move ahead with developing a revised LUC classification as suggested in this document it needs to be done now. This is because the number of staff with any experience of LUC classification is set to diminish rapidly. There are currently only 2 staff members with any experience in developing an LUC extended legend (Garth Harmsworth and Ian Lynn) plus one potentially available to assist at GNS (Mike Page). There are only 3 further staff with any experience of field mapping of the LRI/LUC (Peter Newsome, Les Basher and James Barringer). Within as little as 3-5 years half of these people may be retired (Ian, Mike, and Les). Grant Hunter, another scientist’s familiar with LRI/LUC retired in May 2013.

7.3 Interpretations

The trend amongst several Regional Councils has been to use LUC as a key underlying characteristic for significant policy initiatives (e.g., Horizons OnePlan) for which it was not specifically designed (e.g. nitrate leaching risk). Because such initiatives may rely on regional farm-scale mapping issues of scale this may be less important than they might have been had the NZLRI national dataset been used. However, regional farm plan LUC uses the NZLRI Extended Legend classifications. Using the general land use capability classification in the regulatory environment to assign a specific suitability, risk or vulnerability interpretations raises concerns over how well the interpretations being derived from LUC can be supported by the underlying data/knowledge of the LUC. In such setting, use of a specific suitability or risk assessment based on the best available knowledge would be preferable. For example, S-map contaminant management assessments for leaching vulnerability.

8 Anticipated Scenarios

Here we attempt to describe how the changes suggested in this Roadmap are likely to manifest in anticipated scenarios. These scenarios should be seen also in the context of drivers of the need for improved land resource data such as the Land and Water Forum recommendations for water quality and water quantity, freshwater and Resource Management Act reform currently underway, all of which are responding to on-going land use change and intensification in New Zealand and what is needed to ensure the relevance of a future NZLRI-type database in this dynamic setting.

8.1 Status Quo positive

Under this scenario a Governance Group is set up, but struggles to maintain a coherent approach to land resource assessment across national and regional scale stakeholders. There is a continuation of the disconnect between Regions and LCR/Central Government. Each region goes its own way – possibly with a predominance of old-style mapping in regions, though with some trying innovations and others not using LRI at all. This creates considerable potential for variable mapping standards between regions. Meanwhile Landcare Research champions a modernized approach nationally which receives patchy support from the Regions at best. NZLRI/LUC attracts enough funding to survive but, while still widely used as a planning instrument, becomes increasingly irrelevant.

8.2 Status Quo negative

Under this scenario a Governance Group is set up, but it struggles to maintain a coherent approach to land resource assessment across national and regional scale stakeholders. The disconnect between Regions and LCR/Central Government approaches becomes more and more marked as each region goes its own way – possibly with a predominance of old-style mapping in regions, though with some trying innovations and others not using LRI at all. As a result Landcare Research finds it difficult to attract funding to champion a modernized approach nationally and regionally mapping approaches and standards become so variable that LUC loses its credibility. Over time LUC becomes much less widely used as a planning instrument, the national dataset becomes of historical interest only, and any consistent national overview of land resources is lost.

8.3 A shared future

The Governance Group reshapes links between national and regional data providers and data users so that we see a refreshing and convergence of the national and regional approach to LUC mapping, while maintaining proper links with the existing datasets (maintaining backwards and forwards compatibility as far as possible) so that the NZLRI/LUC approach remains a cornerstone of national and regional planning. At the same time, where appropriate, modernizing the approach to mapping and increasing funding support a reinvigoration of the NZLRI/LUC system as a key part of an easily maintained and updated land planning toolset that is flexible enough to include a range of assessment methods (not just LUC) that can be used wherever most appropriate.

9 Challenges

9.1 Resistance to modernization of approach

With an ageing cohort of expertise within New Zealand and significant technical challenges in modernizing the approach to mapping (e.g. automated mapping inputs) and equally significant challenges in genuinely delivering forward and backwards compatibility so that existing LUC assessments can be couched in modern terms and vice versa, it is certain that some users (possibly many) may resist change. Experience with S-map indicates that rapid and significant change may be viewed by some users as excessive. To get stakeholder agreement or at least to acknowledge stakeholder concerns, it will be highly desirable to retain elements of the old approach while at the same time opening up new approaches. This is a key reason for retaining an LUC classification where some might advocate moving completely to single purpose specific evaluations only.

9.2 Ageing of expertise and training

Whether or not traditional mapping practices remain the mainstay of LRI/LUC, there is a very real problem with the ageing of experts. This is most obviously manifested by the fact that the only Regional level LRI/LUC mapping training currently being offered is being delivered by 2 retired experts, and by the fact that there are only 3 experts who have any experience in developing a regional LUC extended legend, the last of which was completed nearly 15 years ago. In addition 2 of those 3 experts have moved on to other areas of research/endeavour. Further, because there has no new mapping at the national scale in 15 years no new expertise is being developed to take over from the aging cohort.

9.3 Funding

It seems likely in the current funding climate that acquiring sufficient funds to support the dataset in its current state will be challenging, so resourcing additional developments/ improvements will present even greater challenges for the Governance group and Landcare Research. It is critical that we are able to demonstrate the value of the dataset now and its much greater value if improvements happen.

10 Major Innovations

The following describes the major innovation theme(s) required to a) respond to shifts in client requirements and b) overcome limitations along with an assessment of relative importance/urgency.

1. Governance group: a formal managing body to support NZLRI/LUC extended legend, and Regional LRI/LUC farm-scale mapping.

2. Database Manager: to bring rigour to the management of the wider NZLRI/Regional LRI/LUC databases which currently have very limited database management.

3. National Extended Legend: to provide a nationally consistent classification that is a clear and concise as possible, where an LUC unit description is unique anywhere in New Zealand (e.g., 4e12 always means exactly the same thing wherever it occurs).

4. Multi-scale data structure: create an environment that can hold data of multiple-scales and combine as needed. This structure should allow querying on scale attributes to either show all data of specified scales, and/or derivation of national-scale LRI from farm-scale LRI, or using DEMs, S-map and climate surfaces to assist in defining map unit boundaries or map unit attribute values.

5. Multi-temporal data structure: provide the flexibility/capability to store multi-temporal data and attributes so that queries can be used to show the dataset at different points in time by combining Edition 1 and Edition 2 NZLRI data into a single data structure that can also accommodate any new mapping (automated or traditional method).

6. Multi-layer data structure: provide a database structure that can accommodate and utilise knowledge from a range a data types (raster and vector) and data layers as required.

7. Automated mapping: develop techniques to permit (where appropriate) the use of automated mapping techniques to optimise remapping capability.

8. Specific data interpretations: in support of traditional LUC classification, and where appropriate, investigate the utilisation of specific data interpretations. Leaching risk for example may be best approached by a specifically soil-based interpretation, rather than a reinterpretation of LUC which is 'a systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production'!

9. Uncertainty: provide details on uncertainty to describe both locational and attribute uncertainty within the NZLRI data structure.

11 Projects and Sub-Projects Required

This section lists the range of projects that will help the NZLRI advance in a useful direction increasing its utility and value. There are some challenges in prioritizing these projects. Some are of high priority but are quite challenging and require substantial planning and resources (e.g. erosion rethink). Others are moderate to high priority, fairly simple to implement but still require a substantial funding commitment (e.g. appointment of a Database Manager). Yet others may not be of the highest priority, but are low cost and relatively easy to implement (e.g., scanning and archiving original printed maps). Given limited resources of both expertise and funding, establishing a good mix of these projects should ensure progress towards the overall goal while being realistic about what can be achieved. However, we need to bear in mind the time-bomb drawing ever closer that is the loss of capability through retirement.

Priority 1

11.1 Governance Group

Following on from the NZLRI Roadmap workshop in October 2012 it was agreed that a Governance group should be formed. A set of draft terms of reference were developed and circulated for discussions after that meeting. It is crucial that regional government as a major user of the NZLRI, shoulders its share of its future direction.

Once formed it is expected the Governance group would have a role in setting its own agenda based on the ToR, rather than following a pre-set agenda. The group might meet annually, review and/or recommend research and implementation activities, and lobby for and assist with acquiring funding for high priority activities. There seems to be an assumption that Landcare Research would provide the secretariat for the Governance Group. However, this might be a role for the National Land Resource Centre, resources permitting.

Timeframe

The Governance group should be formed no later than October 2013 depending on the ability of key groups (land management, land monitoring and special projects groups) to nominate representatives.

11.2 Database Manager

We recommend the appointment of a Database Manager. This sub-project would be directed at establishing a position description which would include deciding whether there should be a full-time appointment for Database Manager to manage multiple databases, or a part-time Manager just for the NZLRI/LUC.

Tasks include developing a job description(s), getting approval to advertise the position, running of interviews and a recommendation for appointment(s).

Timeframe

Decide option and develop job description(s) by June 2013.

11.3 Archiving/Digitizing Original Printed Map Series and Field Work Sheets

The original Edition 1 NZLRI field sheets compiled by the Ministry of Works do not appear to have been kept. Thus the nearest equivalent to the raw data of the NZLRI are the published worksheet series on the NZMS1 1:63,360 scale topographic base. It is proposed that all of these maps (337 sheets), along with any Edition 2 field maps stored at Palmerston North and at Lincoln be scanned to high resolution PDF or TIFF and compressed JPEG format, and that the JPEG format should be clipped to map rectangle (remove titles, legends, and map surrounds) and georeferenced to create a seamless image of the Edition 1 NZLRI dataset to check the existing dataset to – particular in the vicinity of the boundaries between Edition 1 and 2 mapping.

Two phase project – Map sheets scanning – Clipping and georeferencing.

Timeframe

Phase 1 by June 2013, Phase 2 by December 2013.

11.4 Error Correction protocols/correct previously identified errors

Phase 1: Develop processes for identifying and verifying errors in core datasets, and how to make corrections within the database structure, preferably retaining the original incorrect data within the database structure (either as temporal data or as a table of corrections, so it is possible to undo corrections or query to see the original data error).

Phase 2: Once suitable protocols are established, this project should move on to implement error corrections for the backlog of previously identified errors. These are mostly recorded on the "Master Copy" sets of hard copy LUC maps in orange folders held in Palmerston North.

11.5 Develop National LUC Extended Legend

Bring together all regional legends into a single legend – reassign LUC codes so these are unique across the whole of New Zealand, with careful attention to semantic links between previous Regional – Island – National correlations. This is a major project and identified as a key requirement by the 2012 NZLRI Roadmap Workshop. It will build on previous work by Mike Page (North Island correlation), Ian Lynn (Marlborough to South Island correlation) and various commercial projects by Garth Harmsworth (North Island Regional correlations) as well as more recent work by James Barringer and Alistair Ritchie organising Regional Legend knowledge.

Timeframe

Phase 1: Organising all existing knowledge – July 2013

Phase 2: Create national extended legend – July 2014

11.6 Erosion rethink

The goal of replacing the NZLRI erosion component could be met by developing an erosion risk layer that reflects the long-term risk of erosion and its effect on soil properties and capability for agricultural production (including horticulture and forestry). It would be somewhat analogous with potential erosion but be clearly defined, quantitatively derived from a series of base layers of data, and a permanent landscape attribute – once developed there would be no requirement for updating. In New Zealand landscape response to erosion is a function of climate, topography, and rock type and is influence by land cover and land use. Developing a GIS-based model of the interaction between these factors would provide a tool for land managers to map spatial variation in susceptibility to erosion and provide an index of the long term consequences of erosion. This could be used as a basis for determining suitability for different land uses especially in the erodible hill country.

The approach would likely be a combinatorial classification using the following data.

- Climate: using a combination of rainfall intensity-frequency-duration statistics and accounting for antecedent moisture conditions;
- Topography: we now have some good datasets showing the relationship between landslide density-frequency and slope (for Wairarapa, Hawkes Bay, Manawatu);
- Rock type: reanalysing the classification of rock type in relation to erosion susceptibility; and
- Land cover and land use: being specific about erosion hazard under different land covers and land uses using the best available historic data.

The aim would be to develop a national, consistent coverage that would sit alongside the NZLRI rather than be incorporated in it, and would probably replace the erosion terrain layer.

This is the top priority to fill a significant gap in the nation's resource databases, but needs to be staged with phase one being to work up a full proposal. This project should be considered the top priority for future development of the NZLRI.

Timeframe

Phase 1: Planning/proposal – December 2013

Phase 2: Implementation – dependent on phase 1

11.7 Test feasibility of incorporating Farm Plan data into a multi-scale NZLRI

Farm Plans are regularly being prepared by many Regional Councils but have never played a role in updating or improving the NZLRI. We propose to carry out a series of targeted pilot studies to determine if the Farm Plans available from different Regional Councils can easily be integrated into a multi-scale NZLRI instance where data can be displayed based on the scale it has been mapped, and/or whether the Farm Plans are executed to sufficient data quality standards (both spatially and in terms of LUC classification) to be used in the context of upgrading national LRI/LUC data.

Should the pilot studies indicate the merging of Farm Plan and national NZLRI data are valuable then this project would recommend a preferred implementation plan including clarifying issues of IP and privacy in using Farm Plan data in the national dataset.

Timeframe

June 2015

Priority 2

11.8 Demonstrating automated mapping techniques

This is potentially a VERY large body of work, which has at this point not got universal support from the user community. However, as funding for manual mapping on as national scale will never eventuate, this is the only approach that will be viable in the future. Landcare Research has considerable experience in automated mapping of soils, but there has never been a genuine attempt to formally demonstrate for this approach for LUC and therefore to get a properly informed evaluation of this option from peers and stakeholders. We recommend that a series of limited pilot projects be undertaken to develop some examples of applying automated mapping techniques in an LRI/LUC context for selected terrain and environmental types. This should involve differing input quality (e.g. utilising 15m DEM vs. 8m Geographx DEM vs. 5m ALOS Prism DEM for segmenting landscapes) for deriving updated NZLRI/LUC mapping and/or more specific data interpretations of suitability, limitation or risk with a view to presenting these case studies to the Governance Group and more widely to NZLRI/LUC stakeholders through workshops, scientific papers and conference presentations.

Timeframe

At least one substantive case study by June 2015

11.9 Implement temporal database structure

We propose to establish a PostGIS version of NZLRI with a suitable database structure and that uses date attributes (e.g., creation date, replacement date and/or elimination date) to support temporal queries that give temporal views of the NZLRI at any given point in time (so far as temporal data are available). For example all Edition 1 units will be assigned a single set of dates, while units in each of the four Edition 2 regions will have to be given a single date for mapping in that region. However, subsequent mapping could, if it is deemed appropriate, have unique creation dates for individual map units and the attributes associated with them.

This PostGIS temporal version of the dataset should take over as the core dataset once it has been successfully implemented to acceptable data quality standards. Tasks to be undertaken include the following.

- Design database structure;
- Populate database with existing spatial datasets;
- Check edition 1 boundaries against scanned and georeferenced edition 1 maps (see 12.3 above);
- Populate database with temporal attributes;
- Design and script (automate) key temporal queries;
- Semantic links (make explanations of regional to national LUC correlations).

Timeframe

June 2014

11.10 NZLRI/LUC Marketing – Stakeholder Updates

LCR needs to "use" the Governance group, presentations at appropriate fora (e.g., NZARM Annual Conference) and perhaps more regular workshops (perhaps biennially) to ensure the development if the NZLRI/LUC meets users' needs and that stakeholders extract maximum value from the data as it is improved.

Timeframe

Ongoing.

Priority 3

11.11 Uncertainty and the NZLRI/LUC

Investigate options for incorporating uncertainty into the NZLRI/LUC, both in terms of spatial uncertainty (precision and accuracy of spatial representation) and attribute/classification/interpretation uncertainty for aspatial elements of the database.

Timeframe

By June 2014.

12 Innovation Progression-Priorities and Cost Estimate Summary

There is a considerable disparity in the size and cost of some of these sub-projects but it seems important that the Governance group be established as soon as possible to give the key stakeholders a say in the future of the NZLRI. Beyond that priorities are set mainly through the current mandate from stakeholders at the 2012 NZLRI Roadmap Workshop (e.g. national extended legend) and/or ease of achievement (e.g., archiving original map series).

The intention of this progression would also be to utilise the ageing NZLRI/LUC expertise in the next 3-5 years before key staff retire and are no longer readily available to assist with the process of future-proofing the existing datasets and preparing the way to allow the NZLRI/LUC system to remain relevant and useful for the foreseeable future.

13 Summary

This roadmap attempts to identify a way forward for land inventory mapping, land use capability and other more specific land evaluation interpretations, particularly focusing on the NZLRI and the LUC classification. It acknowledges the long recognized value of the NZLRI and LUC in the New Zealand land management setting, but also recognizes the shortcomings of the dataset as it currently stands and improvements that might be made. In this respect this Roadmap seeks an evolutionary rather than revolutionary path. Incremental change and trying to retain useful elements of the existing system while taking advantage of potential improvements or new approaches. There is also a strong element of trying to organize and “tidy up” the existing NZLRI/LUC dataset and classification so that the current ageing cohort of LRI experts can pass on the dataset to future generations of users in a way that gives the best chance of making the dataset retain its utility into the future.

A key element of the Roadmap is to improve governance and communication between the scientists, the practitioners and the users through establishment of a Governance Group to provide on-going guidance to the NZLRI/LUC system. In addition, the appointment of a more formal Database Manager to oversee the dataset and ensure that it is properly curated and managed would be an important step in ensuring a strong future for the underlying dataset(s), that should include much needed improvements to handling errors and corrections, and improvements in database structures to better deal with multi-temporal, multi-scale, and potentially multiple single-factor data sources.

Seeking national consistency is another key theme of this Roadmap. As it currently stands the claim that the NZLRI/LUC is nationally consistent is difficult to support and yet this is supposed to be a major strength. Preparation of a National Extended Legend is considered a crucial step in support of this goal, and one that gained universal support at the recent NZLRI/LUC Roadmap workshop.

In addition revisiting the approach to recording erosion and testing automated mapping approaches to facilitate accurate, rapid and efficient remapping, and the ability to develop specific evaluations in addition to the more general LUC classification are important themes for innovation in the NZLRI/LUC setting.

The various projects proposed in this Roadmap represent approximately $300k of work over 3-5 years (excluding the possible salary costs of a Database Manager). The projects suggested are, we believe, all important and necessary, but are not all reliant on completion of other projects. Work on a number of projects could easily be deferred without jeopardizing completion of the highest priority activities. However, there is a clear imperative to complete most of this work within a 3-5-year timeframe since a number of key staff are reaching retirement age and without their expertise our ability to properly complete these projects will be significantly hampered.

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Appendix 1

Examples of LUC use in land management

Northland Regional Council

http://www.nrc.govt.nz/upload/3465/Land%20and%20Soils.pdf

Whangarei District Council

http://www.wdc.govt.nz/PlansPoliciesandBylaws/Plans/SustainableFutures/Documents/Sustainable%20Environment/Whangarei-District-Land-Use-Report.pdf

Manukau City Council

http://www.manukau.govt.nz/tec/district/planchange/PC14ProposedApp5.pdf

Waikato Regional Council

http://www.waikatoregion.govt.nz/Environment/Natural-resources/Land-and-soil/Managing-Land-and-Soil/

Gisborne District Council

http://www.gdc.govt.nz/assets/District-plan-text/Chapters/Chapter06LandDisturbanceandVegetationClearanceDOCSn77572v1.pdf

Hawke's Bay Regional Council

http://www.hbrc.govt.nz/LinkClick.aspx?fileticket=94KVpMsil5o%3D&tabid=271&mid=1298

Horizons Regional Council

http://www.horizons.govt.nz/assets/horizons/Images/Council/Environment/15%20April%2009/correctfiles/09-52%20Completion%20of%20two%20projects%20in%20relation%20to%20Land%20Use%20Capability%20Classification.pdf

http://www.horizons.govt.nz/assets/publications/about-us-publications/one-plan-publications-and-reports/factsheets/IntensiveLandUseandoneplanFactsheet.pdf

http://www.horizons.govt.nz/assets/1plan_eoh-report/Dr-Alec-Donald-Mackay-End-of-Hearing-Technical-Report.pdf (also refers to Southland)

Taranaki Regional Council

http://www.trc.govt.nz/assets/Publications/information-sheets-and-newsletters/land-management-information-sheets/07landresourceinventorymapping2.pdf

Greater Wellington Regional Council

http://www.gw.govt.nz/assets/Resource-Consents/Form-6e-Land-Use-Consent-Application-for-Tracking-Logging-Land-Clearing.pdf

Tasman District Council

http://www.tasman.govt.nz/document/serve/Report%20REP05-06-07%20Soil%20Intactness%20Monitoring.pdf?path=/EDMS/Public/Meetings/EnvironmentPlanningCommittee/2005/2005-06-01/000000182379

Environment Canterbury

http://ecan.govt.nz/publications/Reports/estimating-nitrate-nitrogen-leaching-rates-under-rural-land-uses-000910.pdf

Otago Regional Council

Environment Southland

http://www.gw.govt.nz/assets/Resource-Consents/Form-6e-Land-Use-Consent-Application-for-Tracking-Logging-Land-Clearing.pdf