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Land indicators for national environmental monitoring – Part 1:

Monitoring sustainable land use in the eastern Taranaki hill country.

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Signposts for sustainability

LAND INDICATORS FOR NATIONAL ENVIRONMENTAL MONITORING - PART 1:

MONITORING SUSTAINABLE LAND USE IN THE EASTERN TARANAKI HILL COUNTRY

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EXECUTIVE SUMMARY

The Taranaki sustainable land use monitoring approach (Taranaki approach) has provided relevant, viable environmental information useful for assessing the state of physical resources in hill country. This information has helped the Taranaki Regional Council formulate environmental policies and evaluate the effectiveness of these. The Taranaki method involved analysing 25 9 km^2 monitoring sites covering 8.4 per cent of the region, using 1994 colour aerial photographs, and photographs dating back to 1951, to map land use, vegetation, and physically sustainable land-use classes.

The parameters monitored were land-use and vegetation class. The critical parameter was land use, of which seven classes were mapped: horticulture/cropping, dairying, sheep and beef, marginal sheep and beef, plantation forestry, protection forestry and water. The location and area of each parameter was mapped. Changes in the location and area of each parameter between 1951 and 1994 were also determined.

The indicator used to measure sustainability in the Taranaki approach was land use relative to the New Zealand Land Resource Inventory (NZLRI) land use capability (LUC) unit, or land use relative to its capability for the use. The rule-set for LUC unit definition was refined on the basis of slope angle. The more detailed rule-set for LUC units was needed to align the current study with results from underpinning research.

The most significant research results were: soil slip erosion scars are more prevalent on slopes steeper than 28 degrees; eroded areas increase in size with slope angle; on uneroded slopes, pasture growth declines with increasing slope angle; soil fertility differs between uneroded and eroded sites, but differences in soil fertility appear to have less effect on pasture growth than do scar age (i.e. length of time pasture has had to re-establish) and soil depth (i.e. soil water storage capacity); substantial differences in annual pasture production can be largely explained by differences in soil depth; on eroded sites where soil water storage is not a limiting factor, pasture production recovers to the uneroded level in 40 to 80 years; and on eroded sites where soil water storage is a limiting factor, pasture production remains depressed by about a quarter compared to the uneroded level.

Williams and Mulcock (1996) propose that 'intactness' and 'soil health' are composite indicators for land environment monitoring. The concept of intactness expresses whether soils are staying in place or not, and what pressures may be contributing to soil movement. 'State' intactness indicators include soil slip erosion and sediment load in rivers. 'Pressure' indicators are surrogates in the form of the risk of soil loss, where an indicator of 'land use relative to its capability for use' is a pressure indicator of intactness. Soil health indicators need to be a mix of simple indicators (such as acidity) and more complex indices derived from modelling and calculations of nutrient budgets.

The Taranaki approach is not capable of ascertaining state intactness and soil health indicators, but the method does provide a pragmatic and cost-effective way to assess pressure indicators of intactness for large areas of land, allowing land-use changes to be recorded in relation to their physical sustainability. Where there was a risk of unsustainability, one or more of the following would prevail: soil slip erosion; degradation in soil fertility; depressed levels of pasture production; reduced net financial returns; increased levels of fertiliser, pesticide and herbicide use; inappropriate form of land use; presence of weeds or scrub; and changes in vegetation cover. Maps could be produced of the monitoring sites showing where a pressure indicator could exceed an acceptable sustainability level. The Taranaki method buys time by using readily available historical aerial photographs which allow past land uses to be mapped, and which indicate past levels of land-use sustainability. The Taranaki method provides a means of assessing pressure soil health indicators by enabling land-use intensification to be recorded and related to the capability of the land to support land-use changes. Maps showing where soil health thresholds may have been exceeded could be produced.

The Taranaki approach uses a land/ecological spatial framework as the underlying database. This framework, a database of physically sustainable land-use areas, is based on the NZLRI LUC

classification.
To develop the Taranaki approach to incorporate soil health and ecological functionality more effectively, the following would be required:

- research to identify detrimental on-site changes in soil health (such as soil structure decline) associated with land use; to determine soil characteristics that will permit soils to be classified according to their ability to withstand land use and management pressures; and to determine pressures of land use on ecological functioning such as increase-**s** in weed and pest populations.
- development (through research and current knowledge) of a matrix of key off-site environmental effects likely to be associated with land use for each LUC unit. Such effects could include water quality decline, reduced base flows and sedimentation.
- establishment of a method to monitor land use regularly for every property. MAF Quality Management's AGRIBASE and the Land Cover Database could possibly be used for this.
- agreement on an appropriate method of dividing a region into land/ecological units as a basis for land-use sustainability and environmental monitoring.
- development of an environmental indicator model to map pressures on intactness, soil health and ecological functioning. Spatial outputs from the model would require changes in land use to be related to well-defined land/ecological units.

For the Taranaki approach to be used successfully across slip-prone hill country in New Zealand, an appropriate level of nation-wide soil slip frequency and erosion-pasture production, a unified NZLRI LUC unit classification, and a source of up-to-date and historical aerial photographs would need to be established. We believe that the Taranaki approach can be used across the country because:

- sufficient erosion-pasture production research has been completed (in Wairarapa, Wairoa and Taranaki) to redefine NZLRI LUC unit descriptions with some degree of confidence for about 50 per cent of the North Island, and for the hill country areas in the north-east of the South Island. (Forty per cent of New Zealand is hill country. Twenty-six per cent of New Zealand hill country had soil slips between 1973 and 1979.) However, to apply the method to all New Zealand slip-prone hill country up to 1000m above sea-level, South Island hill country not in the north-east, and areas in Northland, would need to be characterised in terms of soil slip magnitude and frequency, and their pasture recovery curves would need to be re-calibrated using existing pasture measurement datasets;
- development of a unified LUC unit classification for the whole country is relatively easily accomplished. The 10 NZLRI first edition (1:63360 scale) LUC classification regions have already been correlated. Correlation of the first edition South Island region and second edition (1:50000 scale) LUC unit classifications remain to be completed; and
- all New Zealand hill country was covered four to five times in routine aerial photographic surveys undertaken between the 1930s and 1987**.** A number of regions of New Zealand have recently been covered by aerial photography undertaken for local authority consortiums.

CONTEXT AND TERMS OF REFERENCE

This report is one of eight produced as part of a consultancy for the Ministry for the Environment. The consultancy consists of a review and policy analysis of current land monitoring for national environmental indicators, and a prioritisation of land monitoring parameters and indicators which provides recommendations for a preliminary core set of land indicators. The consultancy is funded by the 'Green Package' National Environment Indicator Programme.

The terms of reference for this report (Part 1) are:

Review the Taranaki Regional Council approach to monitoring sustainable land use in the hill country:

- To define what is being monitored (the parameters);

- To identify the indicators that are being used to measure sustainability;
- To identify the research relationships and information requirements underpinning the monitoring and indicators;
- To identify the connections and gaps between the Taranaki monitoring approach and those indicators recommended in the NEIP Land report for 'intactness' and 'soil health';
- Given that the Taranaki monitoring approach has a specific aim that may fit with recommendations for 'intactness', identify the steps that would be required (over time) to add other parameters to the monitoring approach such as those recommended for 'soil health' (eg nutrient balance etc), and ecological functionality; and
- To establish how applicable the Taranaki monitoring approach would be across New Zealand's regions in terms of monitoring sustainable land use.

INTRODUCTION

Section 35 of the Resource Management Act 1991 imposes a duty on local authorities to gather information, monitor and keep records. Many councils are currently grappling with the implications of section 35, in particular with the more general requirement to monitor the state of the environment. Land issues tend to vary considerably in nature and significance from region to region. As a result, the question of what should be monitored and how monitoring should be undertaken has become the subject of considerable debate.

The Taranaki Regional Council's (TRC's) approach to monitoring requires that any monitoring programme should be focused and should deal with a specific local issue. Accelerated erosion in Taranaki eastern hill country and the associated loss of productivity is a high priority for the Council according to its Regional Policy Statement. This issue is addressed largely through the promotion of sustainable land-use practices, primarily on high risk land, on an individual farm basis.

Given the significance of accelerated erosion in the region, the TRC required a cost-effective monitoring technique to measure the extent of land-use changes and physical sustainability in the eastern Taranaki hill country. Rather than adopting a comprehensive programme of soil sampling to measure depth and fertility as an indicator of the physical sustainability of land use, the starting point for the TRC was to build on existing research, systems and initiatives in the region.

Landcare Research and the TRC developed a monitoring technique utilising a physically sustainable land-use database created by the former DSIR, and the TRC's extensive 1994 colour aerial photographic database of the region (O'Leary *et al.* 1996). This venture, based on a successful pilot project, was completed in March 1995 (Stephens *et al*. 1995), and was partly funded by the Ministry for the Environment's Sustainable Management Fund.

OBJECTIVE AND METHOD OF MONITORING IN TARANAKI HILL COUNTRY

The objective of the TRC monitoring project was to:

- develop an indicator of sustainable land use in North Island hill country which provides relevant, viable environmental information which can be used to assess the state of resources in the region, and to help the TRC formulate environmental policies and evaluate the effectiveness of these; and
- develop a standardised state of the environment indicator and monitoring technique which can be adopted by other regional councils and integrated into a national state of the environment monitoring and reporting framework.

The method involved analysis of 25 3 km x 3 km monitoring sites located as closely as possible to the intersection of New Zealand Map Grid northings and eastings, drawn at 10 km intervals and excluding unrateable land. The monitoring sites covered 8.4 per cent of the hill country region area. An analysis of the location of the monitoring sites indicated that they were highly representative of the physically sustainable land-use classes within the area of rateable Taranaki hill country (O'Leary *et al.* 1996). Using the TRC's extensive 1994 colour aerial photographic database, the sites' land use, vegetation, and physically sustainable land-use classes were mapped at a scale of 1:20000 to create a 1994 baseline database. For 17 of the 25 sites, historical data was available, and the same mapping procedure was employed for all photographs, regardless of when they were taken. The earliest aerial photographs were taken in 1951. Digital coverages were created and stored in a geographic information system (GIS). This enabled the analysis of the spatial data to produce statistics on land-use changes and on the physical sustainability of these changes.

WHAT WAS MONITORED

The parameters monitored were land-use and vegetation classes (see Table 1); the critical parameter with respect to sustainable land use monitoring was land use. Using up-to-date aerial photographs of the 25 monitoring sites, the location and area of each land use and vegetation class were mapped. Changes in location and area of each land use and vegetation class between 1951 and 1994 were also determined.

Land-use and vegetation classes

Two key factors determining the type of land-use and vegetation class were mapped. First, these parameters needed to be represented for the eastern hill country. Secondly, they needed to be made visible by a visual interpretation of colour and black-and-white aerial photographs.

Table 1: Land-Use and Vegetation Classes Mapped

Land-Use Classes†	**Vegetation Classes†**
Horticulture / Cash Cropping	Pasture
Dairying	Crops
Sheep & Beef	Plantation Forestry
Marginal Sheep & Beef	Indigenous Forest
Plantation Forestry	*Old* Indigenous Scrub
Protection Forestry / Non-productive Indigenous	*Young* Indigenous Scrub
Water	Rushes
	Water

† see Appendix 1 for definitions.

INDICATOR USED TO MEASURE SUSTAINABILITY

In the TRC hill country sustainable land use monitoring approach, the locations and areas where land-use changes were deemed physically sustainable was determined by comparing the nature of land-use changes with the physically sustainable land-use database for the Taranaki Region.

The physically sustainable land-use database was developed by Blaschke *et al.* (1992). This database was originally mapped at a scale of 1:250000. For each monitoring site, the database was reinterpreted to the scale of land use and vegetation mapping from the aerial photography (i.e., to a 1:20000 scale). The resulting classification of physically sustainable land-use classes was based on the existing 1992 New Zealand Land Resource Inventory (NZLRI) land-use capability classification (LUC) for the Taranaki region (see Appendix 2 and accompanying report Part 1A). The classification was supplemented by research undertaken between 1984 and 1988 by the Ministry of Agriculture and Fisheries, the Ministry of Works and Development and the Taranaki Catchment Commission. This research generally involved determining the relationship between soil slip erosion, pasture production, slope, and land use. The present sustainable land use classification comprises seven broad physically sustainable land-use classes (see Table 2). As mapping units, these classes do not represent single land uses but indicate the most intensive physically sustainable land use of a range of land uses.

To improve the relationship between land type and soil slip erosion/pasture productivity, a more detailed rule-set was established for the hill country LUC units. The resulting LUC units were divided into more than one physically sustainable land-use class on the basis of their slope angle. The intactness (pressure) indicator used to measure sustainability was land use relative to the NZLRI LUC unit, or land use relative to its capability for the use**.** The rule-set for LUC units was refined on the basis of slope angle.

Table 2: Range of physically sustainable land uses in the Taranaki region.

Sustainable Land-Use Class	Most Intensive Sustainable Land Use	Range of Sustainable Land Uses						
IH	Intensive horticulture	Intensive horticulture	Cash cropping	Dairying	Drystock grazing	Pasture and trees	Forestry	Protection
CC	Cash cropping		Cash cropping	Dairying	Drystock grazing	Pasture and trees	Forestry	Protection
DY	Dairying			Dairying	Drystock grazing	Pasture and trees	Forestry	Protection
GR	Drystock grazing				Drystock grazing	Pasture and trees	Forestry	Protection
PT	Pasture and trees					Pasture and trees	Forestry	Protection
FO	Forestry						Forestry	Protection
PR	Protection							Protection

RESEARCH UNDERPINNING THE TARANAKI MONITORING APPROACH

Research undertaken in the Taranaki hill country which is relevant to sustainable land use monitoring comprises investigations which determine the relationship between pasture production, soil fertility, slope angle, soil slip erosion processes, soil slip frequency, land use, and the NZLRI LUC unit. Past research was separated into three categories: soil slip erosion, pasture production and financial viability. The results of the first two categories of research have been summarised by Hicks (1996), and are reproduced here in part.

Soil slip erosion (from Trustrum and DeRose 1988; DeRose *et al*. 1991; Blaschke *et al*. 1992; DeRose *et al.* 1993; and DeRose 1994).

- Soil slip erosion scars are concentrated on slopes steeper than 28 degrees, and the eroded area increases with slope angle.
- Erosion rates are greater in concave swales than on convex spurs.
- Ridges and footslopes are generally stable.
- Deep forest soil profiles are gradually changing into shallow grassland soil profiles.
- The rate of soil slipping is initially fast after forest clearance, but slows down as more and more of a hillside is covered by shallow soil profiles. The soil's rate of slipping is strongly influenced by rainfall intensity, and is more rapid on steeper slopes.

Pasture production (from Blaschke *et al*. 1992; DeRose *et al.* 1995)

- On uneroded slopes, pasture growth declines with increasing slope angle.
- Soil fertility differs between uneroded and eroded sites, but differences in soil fertility appear to have less effect on pasture growth than do scar age (i.e. length of time pasture has had to re-establish) and soil depth (i.e. soil water storage capacity).
- Substantial differences in annual pasture production can be explained as a result of fertiliser history and of differences in the range of soil depths.
- On sites where soil water storage is not a limiting factor (i.e. gentle slopes or deep soils in concave sites), pasture production recovers to the uneroded level (for equivalent slope angle) in 40 to 80 years. On sites where soil water storage is a limiting factor (i.e. steep slopes or shallow soils), pasture production remains depressed by about a quarter compared with the uneroded level.

Financial viability (from Gane *et al.* 1991, Anon 1992)

- Continued viability of many traditional sheep and beef farms is under threat from declining pasture productivity, declining product prices and increasing production costs.
- There are likely to be opportunities to achieve good financial returns on farms through careful selection and matching of livestock classes with types of land capabilities.
- Trees provide greater protection to soils against erosion than pasture in this [Taranaki eastern] hill country, and environmentally sensitive commercial forestry operations are feasible on most of this land.
- Planting of commercial forestry (using *Pinus radiata*) can increase the net farm cash flows by up to five times, once the forestry crop is in production. Integration of forestry with continued farming on suitable land can increase net farm cash flows by 3-4 times, and is a promising diversification.
- For farmers, there are sound physical and financial reasons for implementing agroforestry, but some disadvantages (length of time before benefits accrue, increased complexity of management, and financial risk) will need to be overcome.

Past research undertaken in the Taranaki hill country provides the connection between magnitude and frequency of landsliding, slope angle, pasture recovery rates (on the slip scars), land use, and the NZLRI LUC unit. From this research, the physically sustainable land-use database was created, and the rule-set for the LUC class definition established.

Applying the 'land use relative to its capability for use' intactness indicator in this approach tells us where there is a risk of unsustainable land use. Areas at risk will contain one or more of the following:

- soil slip erosion
- degradation in soil fertility
- depressed levels of pasture production
- reduced net financial returns
- increased levels of fertiliser, pesticide and herbicide use
- inappropriate form of land use
- presence of weeds or scrub (gorse, manuka, fern)
- changes in extent of vegetation.

CONNECTIONS AND GAPS BETWEEN THE TARANAKI MONITORING APPROACH AND INTACTNESS AND SOIL HEALTH INDICATORS

Williams and Mulcock (1996) proposed three composite indicators for land: intactness, soil health and ecological integrity.

Intactness

The Williams and Mulcock (ibid) concept of intactness expresses whether soils are staying in place or not and criteria which may be contributing to soil movement. Such soil movement creates an environmental pressure which contributes to the OECD pressure-state-response environmental indicator model. Williams and Mulcock proposed the term 'intactness' in preference to 'erosion' because they found 'intactness' could comprise indicators of soil characteristics that implicate a decreased propensity for loss. Examples of direct state intactness indicators include soil slip erosion, sediment load in rivers, and dust levels. For pressure indictors, surrogates which would relate to the risk of soil loss were deemed appropriate. An indicator of the link between land use and its capability for use was an example of such a surrogate indicator.

The Taranaki sustainable land use monitoring approach is not capable of recording (and monitoring changes in) first-order state intactness indicators such as extent and frequency of slipping. Rather, the Taranaki technique provides a pragmatic and cost-effective means of assessing first-order pressure indicators of intactness for large areas of land. The Taranaki technique enables land-use changes to be recorded and the physical sustainability (associated LUC) of these changes to be assessed. Maps showing sampling sites where there was a risk that a pressure indicator may exceed a sustainability level could be produced.

One feature of the Taranaki approach is that it buys time by using readily available historical aerial photographs, enabling past land use and vegetation to be mapped to determine earlier sustainability levels.

Soil health

In the Williams and Mulcock (ibid.) framework for core environmental indicators, soil health was defined as "the continued capacity of soil to function as a vital living system, within ecosystem and land system boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health". They proposed that soil health indicators would need to be a mix of simple indicators (such as acidity) and more complex indices derived from modelling and calculations of nutrient budgets at the national level.

The Taranaki monitoring approach is not capable of recording (and monitoring changes in) first-order **state** soil health indicators. However, the approach does provide a method to assess first-order **pressure** soil health indicators for large areas of land by enabling land-use intensification to be recorded and related to the capability of the land to support land-use changes. As for the intactness indicator, maps showing soil health indicators for all land (in a area of interest) could not be produced. Maps could be produced of the monitored sites showing where there was a risk of a pressure indicator exceeding an acceptable sustainability level. These maps could provide a basis for more detailed mapping/investigation to determine first order state indicators (such as nutrient status relative to use by land system/ecosystem) or second order state indicators (such as pH relative to use, ratio of organic carbon:total carbon).

An important similarity between the Taranaki monitoring approach and that proposed by Williams and Mulcock (1996) is the land system/ecosystem framework. The Taranaki approach uses a land/ecological spatial framework as an underlying database. This framework, a database of physically sustainable land-use areas, is based on the NZLRI LUC classification.

IMPROVING THE TARANAKI MONITORING APPROACH

To have a system capable of monitoring soil health indicators and 'ecological functionality', the approach to sustainable land use monitoring in the eastern Taranaki hill country needs to be modified.

Ecosystems constitute systems of interacting organisms and their natural and physical environment. They comprise a mix of biological and physical components, and interlinking processes and pathways, and they occupy a particular geographic area. Ecosystems are dynamic and change over time, with or without human impacts (Hunter *et al*. 1996). 'Ecological functionality' in the above sense describes how ecosystems function, and indicates their tolerance of (human) disturbance.

The long-term steps required to improve the Taranaki approach of monitoring sustainable land use so that it could also be used to monitor soil health and ecological sustainability within the Taranaki region, include:

- Underpinning research completed to:

    a) identify (by soil type) detrimental on-site changes in soil health associated with land use and land management practices. Such soil health changes could include increase in soil acidity, soil structure decline, nutrient depletion, organic matter decline, reducing biological index, and increased soil contaminant concentrations (for example, heavy metals);
    b) determine soil characteristics that will permit soils to be classified according to their ability to withstand land use and management pressures; and
    c) determine pressures of land use and land management on ecological functioning. Such pressures could include: increase in weed and pest populations, decrease in biodiversity.
- Developing (by research and pooling current scientific knowledge) a matrix of key off-site environmental effects (pressures) likely to be associated with land use and land management by land type. Such off-site effects could include: water quality decline, reduced base flows, and sediment deposition.
- Establish a method to regularly monitor land use and land management practices for every property, so that this information could be easily compared with spatial (GIS) databases of the same area. MAF Quality Management's AGRIBASE (a recently completed national spatial database which has land use information for each farm), may well provide the land use/land management information required. To provide information regarding exotic forestry land use, the Land Cover Database would be appropriate.

- Get agreement on an appropriate method of dividing the region into land/ecological units as a basis for land-use sustainability and environmental monitoring.
- Use knowledge from above-mentioned research and investigations to develop an environmental indicator model. This model would be used to map pressures on intactness, soil health and ecological functioning. Spatial outputs from the model would require changes in land use and land management to be related to soil and land types.

APPLICABILITY OF USING THE TARANAKI SUSTAINABLE LAND USE MONITORING APPROACH THROUGHOUT NEW ZEALAND

The Taranaki sustainable land use monitoring approach has been successful because of three key factors:

a) appropriate soil slip erosion-pasture production research had been undertaken;
b) the area was within one NZLRI regional LUC classification (there are 12 of these for New Zealand); and
c) up-to-date and historical aerial photographs were available.

To use the Taranaki approach for other areas of New Zealand, a similar level of information for thes key factors is required.

Soil slip erosion-pasture production research

As well as research in the Taranaki hill country, similar erosion-productivity research has been conducted in the Wairarapa (Trustrum *et al*. 1984) and Wairoa (Douglas *et al*. 1986) soil slip-prone hill country. The Taranaki hill country research (summarised by DeRose *et al*. 1995) post-dated research at the other two North Island locations. The relationship between soil slip erosion and pasture production in Taranaki confirmed previous findings from Wairarapa and Wairoa. A comparison of pasture recovery curves between the Taranaki research sites and those from Wairarapa and Wairoa indicate that soil slip scars recover to a similar production level, despite differences in lithology, climate and measurement technique. Taranaki pasture recovery on soil slip scars was a little slower than in the other two regions, probably due to the harder sandstone bedrock from which (new) soil has to be formed.

The North Island erosion-pasture productivity research was conducted on hill country which had the following characteristics: moderately consolidated Tertiary sediments (silty sandstone to mudstone), intensely dissected since uplift, annual rainfall from 1025 mm (Wairarapa) to 1800 mm (Taranaki), and mean annual temperature range of 12 to 14 degrees, below 1000 m altitude, and subject to high intensity rainstorms which cause soil slips. This type of hill country covers 54 per cent of the North Island (Trustrum *et al*. 1990). Forty per cent of New Zealand consists of hill country below 1000 m altitude (Blaschke *et al*. 1992) - see Appendix 3. Twenty six per cent of this hill country in New Zealand had been mapped (NZLRI) as having present soil slip erosion from 1973 to 1979 (Eyles 1983).

We believe that sufficient erosion-pasture production research has been completed to use the Taranaki approach (using land use relative to LUC as the indicator of intactness pressure) with some degree of confidence for about 50 per cent of the slip-prone hill country of the North Island, and for hill country areas in the north-east of the South Island (see Appendix 3). To apply the approach to all New Zealand slip-prone hill country below 1000 m altitude (i.e., 40 per cent of New Zealand), those South Island hill country localities not in the north-east, and areas in Northland, would need to be better characterised in terms of soil slip magnitude and frequency, and the pasture recovery curves would need to be re-calibrated to account for lithology, soil, climate and maybe differences in erosion processes.

The NZLRI LUC classification regions

Of the 11 NZLRI first edition (1:63360 scale) LUC classification regions, 10 are in the North Island. The North Island regional LUC units from the NZLRI have been correlated to identify LUC units that are essentially the same or similar (Page 1985). There are 706 LUC units in the 10 North Island LUC regional classifications, and these have been reduced to 443 North Island correlation LUC units, 190 of which relate to hill country. This correlation was undertaken so that national scans of data based on the LUC could be undertaken easily, and for those local authorities whose administrative boundaries did not coincide with the regional LUC classification boundaries. The correlated North Island and the South Island LUC classification regions have yet to be correlated. This would be a relatively straightforward task.

The second edition (1:50000 scale) NZLRI mapping has been conducted for three NZLRI LUC classification regions , Northland, Wellington and part South Island (eastern part of Marlborough District), and is currently in progress in the Gisborne East Coast region. These classifications have not been correlated with the first edition mapping, but this could be accomplished.

Given available soil slip erosion-pasture production research results and re-calibrated pasture recovery curves (for some South Island hill country), a physically sustainable land use database similar to the Taranaki sustainable land use monitoring approach could be created for New Zealand. This would involve using LUC units correlated across all LUC classification regions.

Availability of aerial photography

Routine aerial photographic surveys of New Zealand commenced in the 1930s (Stephens *et al*. 1991). Prior to 1987, the Department of Lands and Survey co-ordinated aerial photographic surveys, and all of New Zealand (except, perhaps, for the steeplands) was photographed four to five times. After 1987 (when implementation of the 'user-pays' principle and the restructuring and corporatisation of government departments commenced), routine aerial surveys of large areas was undertaken by local authority consortiums. A number of regions of New Zealand have now been covered by this these post-1987 aerial surveys, providing an up-to-date source of land use and vegetation cover information.

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Appendix 1. Definitions of land-use and vegetation classes mapped

Land-use classes

Horticulture / Cash cropping: Horticulture and cash cropping.

Dairying: Dairy farming.

Sheep and Beef: Sheep and beef (meat and wool) farming, drystock grazing.

Marginal Sheep and Beef: Land that has been farmed recently and is in the process of revegetating. It is assumed that this land will revert to indigenous forest in the long term.

Plantation Forestry: Production forestry including woodlots, agroforestry and shelter belts.

Protection Forestry / Non-productive Indigenous: Non-productive indigenous forest.

Water: Includes: the sea, rivers, streams, lakes, and ponds (> 0.3 ha).

Vegetation classes

Pasture: Sheep and beef farming and dairy farming.

Crops: Horticulture and cash cropping.

Planation Forestry: Production forestry including woodlots, agroforestry and shelter belts.

Indigenous Forest: Non-productive indigenous forest.

Old *Indigenous Scrub*: Shrubland which includes emergent indigenous trees.

Young *Indigenous Scrub*: Shrubland which does not include emergent indigenous trees but does include areas of exotic scrub, i.e., gorse.

Rushes: Extensive areas of rushes with little pasture.

Water: Includes: the sea, rivers, streams, lakes, and ponds (> 0.3 ha).

Appendix 2. Relationship between Land Use Capability and Sustainable Land Use Class (see Table 2)

LUC Unit	Sustainable Land Use Class
1c1,3	IH
1w2	IH
2c2,3	IH
2e1	IH
2s3	CC
2w1,2	IH
2w3	CC
2w4	IH
3c4	DY
3e1,2	CC
3e6	DY
3s1	CC
3s3,5	DY
3w2,4,5	DY
3w3	CC
4c3	DY
4e2,3,7	DY
4e8,10	GR
4s1	DY
4w1,2	DY
4w3	GR
5c1	DY, GR
5s1	DY
6c5	PR
6e1	GR
6e3,6,8,11,14,17,20	PT
6e7*,10*,12*,13*,21*,23*	PT,FO
6e22,24	GR
6e25	PT
6s3	DY
6s4,6	GR
6w1	DY
7e1,14	PT
7e3,5	FO
7e9*,11*	FO,PR
7e15	FO
7e17	FO,PR
7e18	PR
7e20*	FO,PR
8c1	PR
8e1,3,4,7,8,9	PR
8w1	PR

* Those land-use capability units where slope has been used as a means of allocating them to sustainable land-use classes.

Appendix 3. Showing area of hill country below 1000 m altitude. Location of North Island erosion-pasture production trial sites. [From Blaschke *et al.* 1992]