Manaaki Whenua
Landcare Research

Scoping a national land-use intensity indicator

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Scoping a national land-use intensity indicator

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Contents

Summary

Project and client

- The Ministry for the Environment (MfE) contracted Manaaki Whenua – Landcare Research (MWLR) to scope the development of a land-use intensity (LUI) indicator for environmental reporting.

Objectives

1 To design, run, and report on a national LUI indicator workshop.

2 To propose a definition for land-use intensity.

3 To review relevant land-use data sets and provide commentary on their availability, accessibility, content, and quality for developing LUI indicators.

4 To recommend a *current state* LUI indicator for national reporting [but see rescoping below]. The indicator should be a national data set that is scalable to the catchment level.

  - Describe the indicator method and rationale and indicate where underlying data can be sourced.
  - Make recommendations for indicator improvement (including barriers and limitations to use), update frequency, and how to 'analyse the data for the indicator'.

5 Recommend a *future state* LUI indicator for national reporting [but see rescoping below]. The indicator should be a national data set that is scalable to the catchment level.

  - Provide commentary and recommendations regarding data sets.

Post-workshop rescoping (revised objectives 4 and 5)

A consensus was reached at the workshop that it is unlikely that a single indicator can be used to represent land-use intensity across all land-use types. This had major implications for the achievability of key project deliverables, and neither party was interested in developing and recommending weak indicators simply to meet project objectives. The project was therefore rescoped (July 2019) for a broader outcome, the result of which is paraphrased as a single new objective 4, replacing objectives 4 and 5:

4. Identify and describe potential LUI indicators and provide recommendations for two sets of indicators. Set one will include currently feasible indicators, and set two will include potential indicators that require future development.

Methods

- A 1-day LUI indicator workshop involving MfE, Statistics NZ, and other subject matter experts was held to scope the development of a LUI definition, identify potential LUI indicators, and help identify what data sources may be available.
- A literature review was undertaken to identify and propose a land-use intensity definition.
- LUI indicators that have been used or developed in NZ and elsewhere were identified.
- A summary of data sets that have potential utility for developing LUI indicators was prepared from MWLR land-use reports and unpublished material.

Results and conclusions

- The workshop provided only limited insight into definitions and potential indicators. An early consensus was that it is unlikely that any single indicator could be developed to represent land-use intensity across all land-use types (i.e. there are no silver bullets). No clear LUI definition was forthcoming, and the range of LUI indicators identified through the workshop was small relative to the number of indicators that have been developed and used in NZ.
- More than 24 land-use intensity definitions were drawn from the literature, most of which focused on agricultural intensification.
- We identified a large number of potential indicators from councils. Further work is required to determine the feasibility of developing key council indicators for national reporting purposes. We also point out that some of the existing national indicators already strongly qualify as LUI indicators, and we offer suggestions on how they can be improved.
- Data accessibility for developing LUI indicators is a significant issue, both for the project and for NZ in general, because it limits the extent to which indicator potential can be explored. Data sets do exist, but access is limited by commercial licensing, confidentiality and, in some cases, limited standardisation across agencies. There are also uncertainties relating to data types, completeness, and quality. Some industries are prepared to discuss data sharing, but only as data shared in aggregate form.

Recommendations

1 The development of LUI indicators should continue, but the approach and time frame need to be reappraised. The workshop demonstrated that land-use intensity and related indicator development is a large and complex area, and despite our best efforts we have only touched the surface. We echo a view from the workshop that the workshop should be regarded as a first but important step, but further work is required in a staged way towards a cumulative, high-quality goal.

2 We recommend defining land-use intensity as a **measure of human activity concentrated per unit area and time**. Human activity can be measured as inputs (e.g. amount of fertiliser), outputs (e.g. yields), emissions (e.g. nitrogen, phosphorus, *Escherichia coli*, air emissions), efficiencies, frequencies (e.g. cultivation), or densities (e.g. housing density).

3 We also recommend investing in improving existing national indicators that already qualify as LUI indicators. Suggestions are made for 13 current and recent national indicators from both the freshwater and land domains, which we consider eligible as LUI indicators.

4 There are very few LUI indicators that we consider suitable for immediate or near-immediate reporting to a national indicator standard. Potential options include:

   a reporting *Agriculture Production Survey / Census statistics by special catchment aggregations*, where the degree of aggregation is optimised to remove the risk of tripping Statistics NZ confidentiality rules (the example in this report demonstrates catchment LUI indicators for dairy numbers, fertiliser use (super phosphate and urea), irrigated land, cropping area, and dairy effluent land application area)

   b reporting *the extent of artificially drained land in NZ* – drainage of wet soils and wetlands allows land to be used more intensively for agricultural or recreational purposes, and the extent of artificially drained land has been estimated and may qualify as a case study, or as supporting information

   c developing new LUI indicators from *enhanced land-use layers*, to improve reporting accuracy and detail.

5 Options for developing new LUI indicators are far greater, but our ability to fully explore their potential is again constrained by having limited data set access, especially for those relating to urban environments. Key options with a strong spatial dimension include:

   a indicators from *enhanced land cover mapping* to capitalise on advances in remote sensing, for more detailed monitoring of changes in riparian, soil conservation, bush fragments, and within-paddock covers, and for the development of new intensity indicators such as pasture productivity – this is an active research area and we expect new types of indicators to emerge in the next 2–3 years

   b *national farm stocking rate* (livestock) is a key indicator – while easy to calculate, significant data quality concerns currently limit further development as a national indicator, although this may be resolvable using a multi-data cross-validation framework that brings together and validates livestock data from commercial interests (e.g. Agribase), government (e.g. Farms Online and NAIT), and the livestock industry.

c *value of improvements* (investment in infrastructure, etc.) as a potential LUI indicator, as it can be readily calculated from valuation data and expressed in map form at the parcel ownership scale – this indicator has been proposed through the workshop, but further work may be required to more fully explore the link with freshwater quality

6 Land-use data and indicators that are specific to regional or territorial authorities could offer new opportunities for national LUI indicator development. We have begun identifying such opportunities but recommend further investigation to more fully examine existing indicators, land-use data sets, and the potential for council reporting for a collective national LUI purpose.

7 A working group should be established to collectively investigate the challenges to freeing up data access for indicator testing and development. A working group is necessary as:

a no single entity holds all the data

b Considerably more progress could be made simply by having this access to explore LUI indicator possibilities. Until there is wider access we can only make broad suggestions, inferred from incomplete metadata, about what might be possible.

c Consideration should be given to developing a collaborative exploration initiative with industry, councils, and other ministries of 'what might be possible' if data from multiple sources were made available for LUI indicator development under strict usage agreements like those used by Statistics NZ (e.g. data lab conditions). This would allow a deeper dive into solutions and their feasibility.

1 Introduction

The Ministry for the Environment (MfE) and Statistics New Zealand (Stats NZ) have a mandated responsibility to publish regular reports on the environment under the Environmental Reporting Act 2015 (the Act). A key component of environmental reporting is having a robust suite of national indicators, which are necessary to provide insight into the pressure on, state of, and environmental impacts across the five domains of air, atmosphere and climate, freshwater, land, and marine.

National indicators are constantly being updated, refined and added to as part of the Act's cyclic reporting process. A single domain report is produced every 6 months, with each successive report contributing to the publication of an overarching synthesis report once every 3 years. Ongoing refinements are important, as indicators and reporting provide NZ with the evidence needed 'to enable an open and honest conversation about what we have, what we are at risk of losing, and where we can make changes' (MfE & Stats NZ 2019, p. 7).

Land use and land-use intensity are arguably the most pervasive expression of human activity affecting the environment. Livestock grazing, urban expansion, cultivation, deforestation, and other land-use activities all represent substantial modifications to the natural ecosystem, and constitute pressures on the condition and quality of environmental resources such as freshwater. While land-use *intensity* is internationally acknowledged as a complex and multi-dimensional phenomenon (Kuemmerle et al. 2015), the development of indicators of land-use *pressure* are still an important – if not critical – inclusion in any national suite of indicators.

Sixteen years ago the Parliamentary Commissioner for the Environment (PCE) lamented that NZ lacked a well-developed set of (agricultural) intensity indicators, and that the data necessary to support the development of these indicators were lacking. Some advances have since been made (discussed in this report), but the scope of land use is still largely focused on agriculture. Further, while NZ follows an ever-growing digital wave of data collection, management and application, there are still persistent challenges to the availability and quality of land-use data needed to build quality national indicators (MfE & Stats NZ 2019; PCE 2019).

2 Background

2.1 New Zealand's environmental reporting framework

NZ's environmental reporting framework is now well consolidated and has been described in considerable detail (e.g. MfE 2014; MfE & Stats NZ 2016; 2020). Our purpose here is not to reiterate what is already available, but to highlight key components relevant to the context of this report.

- Environmental reporting is now captured as a mandatory requirement under the Environmental Reporting Act 2015 (the Act).
- The Act recognises five environmental domains: air, atmosphere and climate, fresh water, land, and marine.
- The Secretary for the Environment (MfE) and the Government Statistician (Stats NZ) have a joint responsibility to develop and publish one domain report every 6 months (on any one of the five domains) and a 'whole of environment' synthesis report every 3 years.
- Topics for environmental reporting were introduced under the Environmental Reporting (Topics for Environmental Reports) Regulations 2016. Topics identify key areas of interest within each domain ('things we want to know about the environment') and promote consistency and continuity (MfE & Stats NZ 2016).
- Indicators are measures that provide insight to the topics. They are used to synthesise and simplify otherwise detailed data and statistics into useful and meaningful information (Hammond et al. 1995).
- New Zealand uses a Pressure–State–Impact (PSI) model to organise environmental indicators. This is an adaption of the Driving force–Pressure–State–Impact–Response (DPSIR) model (EC 1999) developed from the earlier Pressure-State-Response models used by the OECD and NZ for state of the environment (SoE) reporting.
- Environmental *pressure* indicators are particularly relevant to this report. They describe an activity, situation or condition that is causing or contributing to the state of something of interest (in our case land-use pressures on the state of freshwater).
- Environmental indicators are selected and developed according to six criteria (relevance, accuracy, timeliness, accessibility, coherence/consistency, and interpretability) based on considerations for Tier 1 statistics (Stats NZ 2007) and good practice guidelines (Stats NZ 2009).
- NZ has completed one full cycle of environmental reporting under the 2015 Act, culminating in the publication of *Environment Aotearoa 2019* (MfE & Stats NZ 2019) as the synthesis report. The second cycle is underway.

3 Project scope and design

3.1 Project aim

The aim of the project is to understand what is achievable regarding:

- the potential for developing a current national land-use intensity indicator based on current data sets (what is possible with what we currently have?)
- the potential for future national land-use intensity indicators (what might the ideal indicator look like, and what data would be required?).

Any proposed indicator would need to be suitable for environmental reporting under the Environmental Reporting Act 2015. Of primary interest is the development of indicators that provide insight into the pressure of land-use intensity on freshwater quality, with a secondary focus on insights into pressures on marine ecosystems, climate, and air quality). Any proposed indicator(s) would ideally be applicable to all land-use types (e.g. agricultural, urban, natural), and spatial such that it/they can be expressed as a national map, and the indicator(s) can be aggregated to catchment scale for reporting.

3.2 Objectives

- To design and run a national LUI indicator workshop.
- To define land-use intensity (LUI).
- To review national land-use data sets and provide commentary on their availability, accessibility, content, and quality for developing LUI indicators.
- To identify and describe existing LUI indicators from NZ.
- To recommend two sets of LUI indicators. Set one will include currently feasible indicators, while set two will include potential future indicators.

3.3 Approach

The project was divided into four interconnected investigations:

- National LUI Indicator Workshop (section 4)
- definition of land-use intensity (section 5)
- LUI indicator identification and evaluation (section 6)
- evaluation of national data sets for LUI indicator development (section 7).

Each investigation has been treated separately, with its own structure and write-up. Key methods include literature review, evaluation against national standards, and the design and implementation of a national workshop.

4 National Land Use Intensity Indicator Workshop

4.1 Introduction

A national 1-day workshop was required as a key investigation method. The purpose of the workshop was to bring together MfE, Stats NZ, and other subject matter experts, to scope *three themes*:

- a definition for NZ land-use intensity
- potential indicators of NZ land-use intensity
- data resources to underpin the development of any potential indicator(s).

The intention of the workshop was to lay the groundwork for developing a national land-use intensity indicator, according to the following criteria.

- The ideal solution would be a *single indicator* that covers all types of land use and land-use intensity.
- The indicator must meet standards and guidelines for *Tier 1 statistics*.
- The indicator must provide insight into the *pressure of land-use intensity on freshwater state* (and, as a secondary aim, insights into pressures on marine ecosystems, climate, and air quality).
- The indicator should be spatial, such that it can be expressed as a national map and aggregated to catchment level for reporting.

4.2 Methods

4.2.1 Workshop preparation

The project was initiated late in 2017 (19 December), and the workshop was scheduled for 13 February 2018. To offset the potential of people being unavailable due to extended leave either side of the holiday break, MWLR initiated a quick invitation via email to possible attendees on 20 December to get early commitment and an indication of likely numbers.

The list of potential attendees was put together in consultation with MfE and Stats NZ, and was aimed at diverse representation. In the end, 25 of the 26 invitees were able to attend:

- Adam Tipper (Stats NZ)
- Anne-Gaelle Ausseil (MWLR)
- Bronwyn Newton (Stats NZ)
- Christine Harper (MWLR)
- Corina Jordan (Beef+Lamb NZ)
- Dave Hodge (Stats NZ)
- Tom Stephens (DairyNZ)
- Deb Burgess (MfE)

- Evan Harrison (MfE)
- Ewan Kelsall (Federated Farmers)
- Fiona Curran-Cournane (Auckland Council)
- Gerald Rhys (Ministry for Primary Industries)
- Haydon Jones (Waikato Regional Council)
- James Barringer (MWLR)
- Kelsey Wood (MWLR)
- Lauren Long (MfE)
- Mike Scarsbrook (Fonterra)
- Nick Pyke (Foundation for Arable Research)
- Richard McDowell (representing Our Land & Water and AgResearch)
- Robyn Simcock (MWLR)
- Stephen Groves (Stats NZ)
- Ton Snelder (LWP Ltd.)
- Andrew Manderson (MWLR)
- Baz Paker (MfE)
- Mike Judd (Land Information NZ)
- Cullum Taylor (Land Information NZ).

4.2.2 Workshop support material

In addition to organising the workshop, MWLR were contracted to prepare a workshop programme and presentation material. The following material was prepared and circulated to attendees before the workshop date:

- a workshop programme (including an additional descriptive version for the organisers).
- workshop primer notes to provide further background for both the project and the workshop
- a workbook that covered the main themes and fundamental questions of the workshop (the idea of the workbook was to provide attendees with clear, structured expectations, and an alternative opportunity/media to provide feedback and contribution)
- a 'master' PowerPoint presentation – two additional 'special topic' presentations were compiled and delivered by MfE (Lauren Long) and Stats NZ (Bronwyn Newton).

All workshop material was checked and approved by MfE and Stats NZ. A copy of all the material is supplied as Appendix 1.

4.2.3 Workshop implementation

The workshop was successfully run on 13 February 2018. It was structured into three sessions based on themes (section 4.1), subdivided into a series of information-gathering questions confirmed by MfE and Stats NZ. PowerPoint-based introductions were used for each session, followed by either open-floor discussion or group-based activities (the choice of which was determined by audience response). Christine Harper (MWLR) chaired the workshop and Kelsey Wood (MWLR) recorded detailed notes throughout the day.

4.3 Results

Results are reported by theme according to key points of focus and discussion. Ten participants provided more detailed replies by filling out the workbooks.

4.3.1 Theme 1: Defining the scope of a national LUI indicator

Workshop participants felt that ***land use should be defined before considering an LUI definition***. When pressed, people were interested in which land-use types should be considered and the level of classification detail. Three land-use groupings were offered by those who completed workbooks. They are repeated here not because they are recommended, but rather because they offer insight into the level of land-use classification that was considered during the meeting:

- agriculture (dairy, sheep & beef, specialist livestock), plantation forestry, orchards & vineyards, annual cropland, arable, market gardens, urban, lifestyle blocks, mineral extraction (mining)
- urban (including metropolitan, peri-urban, suburban), rural (including horticulture, forestry, pastoral livestock, pastoral non-livestock, cropping)
- urban, rural, natural, peri-urban.

One conclusion was that all land uses need to be considered, but that a balance is needed between too much detail versus losing important information by becoming too generalised. Several land-use classifications are being used in NZ, and it was felt that these should be examined to determine suitability for LUI indicator development.

The consensus of the workshop was that ***it is unlikely that a single indicator can represent land-use intensity across all land-use types***. As one participant remarked, 'One indicator for all land use types is unlikely. Agriculture – perhaps yes – but together with urban [and other land uses], then no.' Others remarked that a single indicator for development may be analogous to 'putting your eggs all in one basket' and therefore not advisable.

In lieu of a single indicator, it was felt that efforts should be directed at identifying one or more indicators per key land use. Some expressed this as investigating the development of a suite of LUI indicators. However, a small, dissenting and perhaps insightful few noted that the meaning of intensity may differ between land uses (e.g. dairy farming intensity means something different to forestry intensity), but that we should also recognise that there are higher-level commonalities that can bridge multiple land uses. *Capital value of investments* was offered as an example (discussed in section 6.3.6).

An argument was offered that ***land-use intensity is not necessarily indicative of environmental impact*** and so might not be a suitable basis for indicator development. For example, two farms with the same land-use system and operating at the same levels of intensity could, in principle, have quite different environmental footprints due to differences in natural resources (soils, climate, etc.) and management (e.g. adoption vs non-adoption of good management practice).

However, it is well known that there are recognised relationships between indicators of (agricultural) intensity and water quality (Larned et al. 2018, 2019), and that 'land use intensity' may be measurable as farm environmental outputs (e.g. nitrate leaching, sediment runoff) as well as the more conventional input and pressure measures (e.g. fertiliser per hectare, stock units per hectare).

Participants were asked to contribute to a whiteboard list of 'what intensity means'. The mix of contributions was eclectic, but limited:

- concentration
- pressure
- inputs and resources
- economy using resources
- measure of effect – the yield
- measure of inputs
- outputs per unit
- inputs
- product per unit area.

Some asked, ***'Do we need a definition of land-use intensity?'*** Can we develop indicators without having a definition of land-use intensity? It was argued that LUI is a subjective idea and everyone seems to have their own interpretation, and so a pathway forward may be to simply provide clear communication of what is meant for the purposes of environmental reporting. However, definitions are important to avoid confusion and ambiguity, and the basis for a quantifiable indicator (or suite of indicators) should be defined.

It was proposed that ***any indicator developed should be consistent with that of other countries*** because we need to report back to the Organisation for Economic Co-operation and Development (OECD). However, this should be considered as a larger ambition rather than an objective, as achieving a common indicator between multiple countries would need to overcome a wide range of differing contexts, issues and data sets.

Is land-use intensity the best way to measure what MfE are endeavouring to represent? A suggestion was made to steer away from focusing on land use *per se* and start referring to indicators of 'land use impacts on freshwater'. This suggestion also relates to the argument that intensity may not be a universal indicator of impact in all scenarios, and that we should drop intensity and focus on output-type indicators (nitrogen leaching, phosphorus runoff, etc.).

4.3.2 Theme 2: Potential LUI indicators

Workshop participants were divided into four groups to explore and propose potential LUI indicators. Specifically, they were asked to list and describe any ideas for LUI indicators while considering both current and future indicators, and multiple land-use types. Each group, of course, interpreted this task in slightly different ways.

The first group focused on one indicator – *capital value of improvements* – and how it could be expressed as a relationship (Figure 1). This group comprised mostly scientists. They proposed that capital value of improvements, expressed as dollars per hectare (or $/ha by LCDB, LUC, or urban zoning) is suitable because it can be applied to all land uses, including urban, and the data sets already exist to allow immediate reporting.

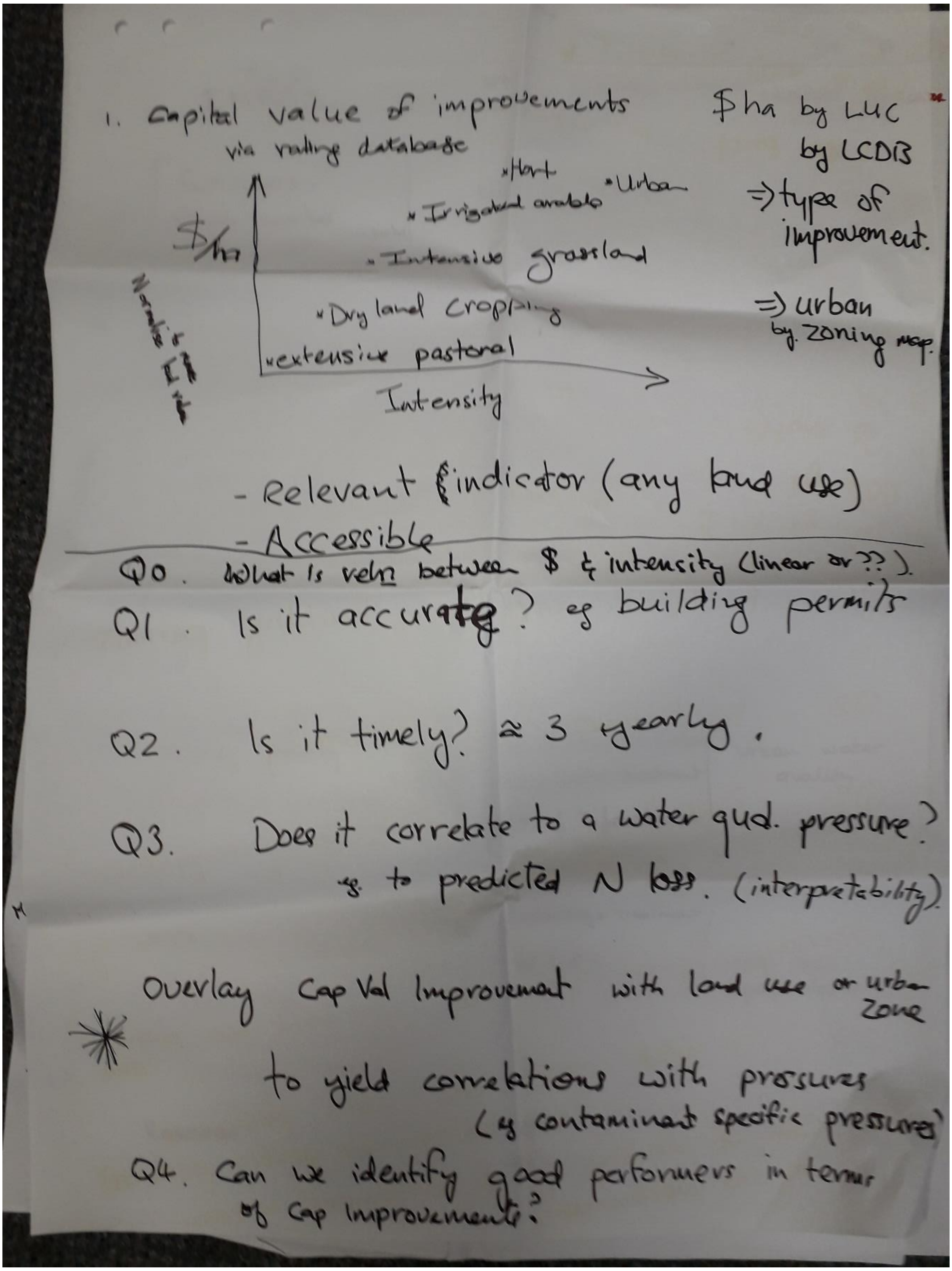

Figure 1. Group 1 notes outlining their proposition for 'capital value of improvements'.

We believe the group meant to refer to *value of improvements* rather than 'capital value of improvements' (section 6.3.6).

The second group was characterised as having notable indicator expertise, and this shows through in the presentation of what they described as a preliminary indicator framework (Figure 2). They proposed four broad land-use groupings (agriculture, forestry, urban, and natural), with suites of indicators divided into subgroups as inputs, efficiencies, and outputs. Potential indicators are added to the master list for discussion in section 6.

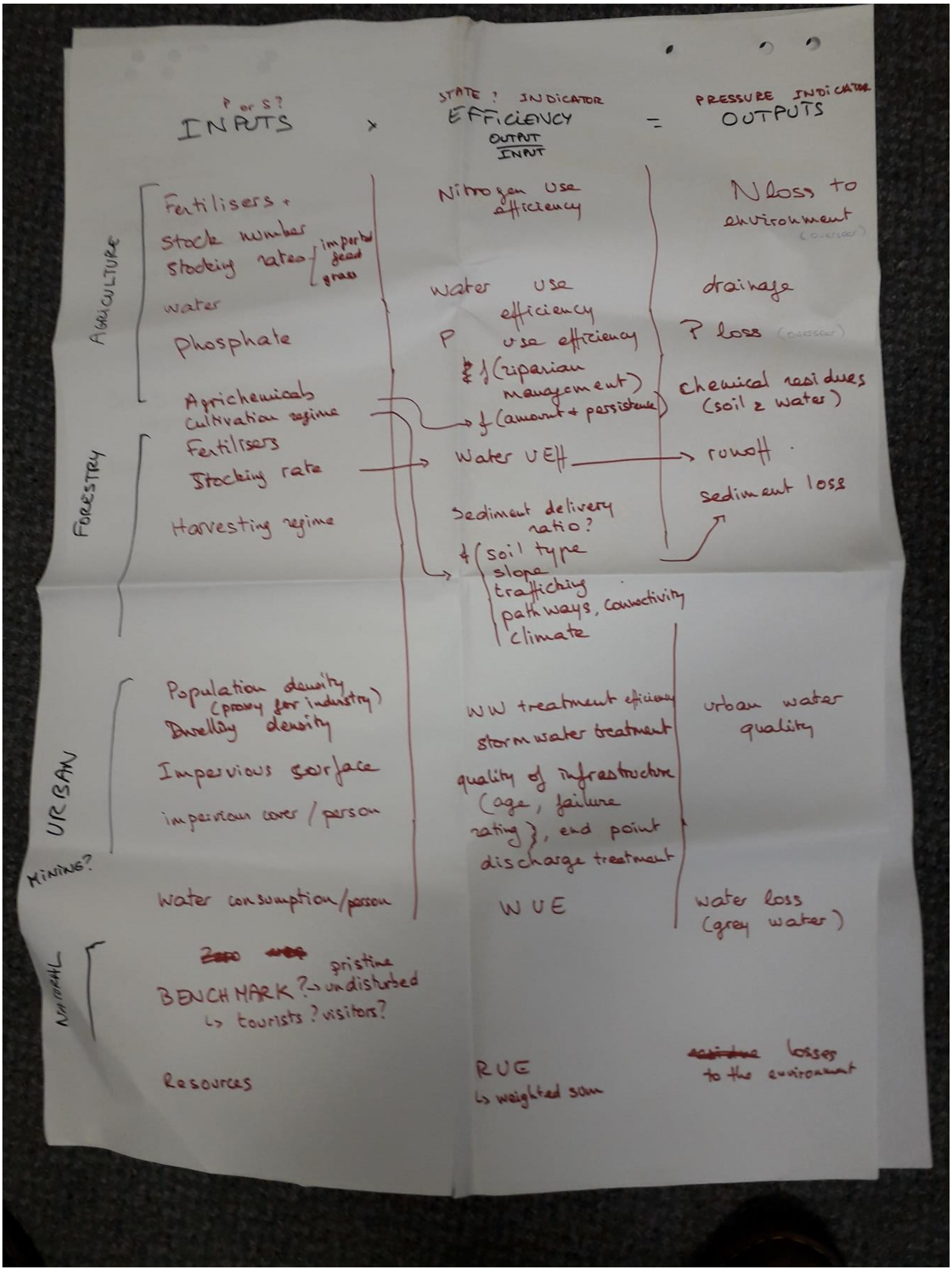

Figure 2. Preliminary indicator framework from Group 2.

Of note is the introduction of urban intensity indicators, including population density, impervious surfaces, infrastructure quality, water consumption, and wastewater. Mining required further consideration in terms of where it might be able to fit within the framework. Natural conditions were proposed as the benchmark.

Group 3 comprised mostly Stats NZ people, and we were unable to secure a copy of their group notes. Understandably this group raised concerns about data representativeness (e.g. data from GST-registered land users vs all land uses), along with privacy and accuracy issues. They suggested that input data types used to parameterise the Overseer Nutrient Budgets model would be good indicators for *rural* land-use intensity, while sediment yield was offered as an important LUI indicator for *forestry*. *Urban* land use could be sub-categorised (e.g. industrial, suburban). Data from urban remote sensing was considered an option, and so called 'self-reporting' (similar to citizen science), in a sustainable natural accounting sense using real-time data, was offered as an option but challenged as a reliable and accurate source of data.

Group 4 involved mostly policy people, who adhered to the brief more than the other groups. They adopted an input/output approach. Land cover was proposed as an indicator but at a finer resolution, with more classes, going down a scale that captures environmental mitigations such as riparian planting, stock exclusion, and perhaps soil conservation plantings.

'Natural' was suggested as a potential indicator, expressed in terms of slope, climate, and geology. Possible data sources suggested included the River Environments Classification (REC) and the NZ Land Resource Inventory (NZLRI). Similarly, 'soils' was offered as an indicator, particularly through the expression of drainage and attenuation potential. Physiographic units (e.g. Rissmann et al. 2018) were suggested for consideration.

Urban indicators included direct connectedness of impervious surfaces (this presumably refers to connectedness to water natural or artificial water courses/bodies), count of wastewater overflows, and number of stormwater/wastewater networks. Similarly, number of consents and/or permitted discharge characteristics from industrial areas was suggested.

Rural indicators included livestock numbers and/or stocking units, calculated from the Agricultural Production Survey (APS), although it was recognised that this data set has confidentiality considerations. Fertiliser use was another (also from the APS), along with riparian metrics, including riparian length and width, potentially derived from remote sensing. Stock exclusion as an adjunct to riparian protection was also proposed. Output indicators included loads for phosphorus (P), nitrogen (N), sediment, *Escherichia coli* (*E. coli*), and heavy metals.

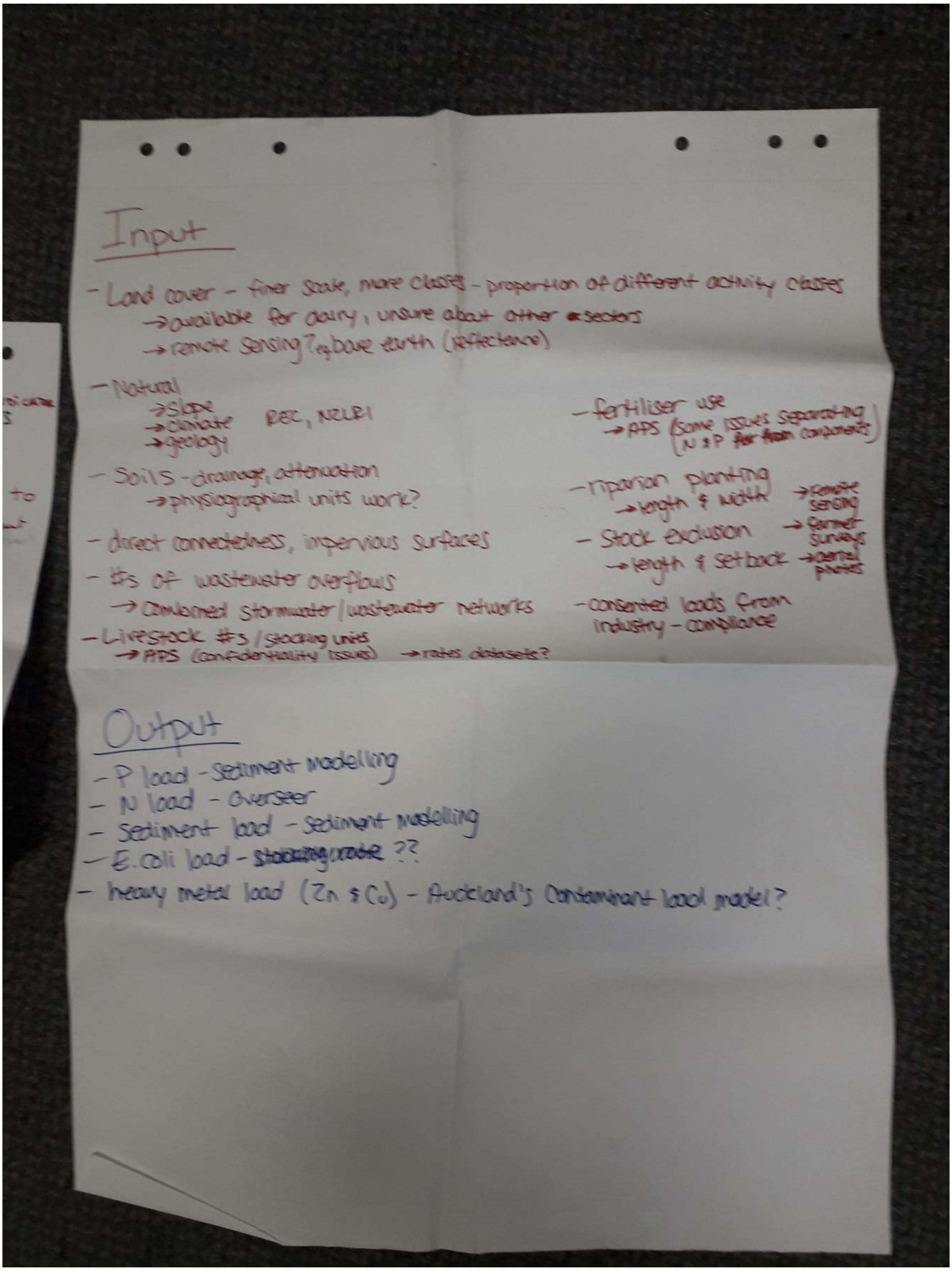

Figure 3. Group 4 – proposed indicators by inputs and outputs.

Those who filled out the workbooks also offered indicators and insights for indicator development.

- One option suggested was to develop LUI indicators for each different freshwater contaminant (N, P, *E. coli*, sediment) rather than LUI indicators for each land use. For example, 'a LUI indicator for N-loading pressures on freshwater might look like…'. This is an alternative view and worth investigating.
- Another option was to investigate the development of an index that presents a single value derived from many other indicators.
- Indicators especially noted as being worthy of further investigation included:
    - value of improvements
    - an 'index of inputs for agricultural land'
    - indicators that describe 'concentration of use' (e.g. fertiliser use, stocking rate, irrigation volume, urban population, percentage impervious surface)
    - rural fragmentation (and rate of urban encroachment)
    - change in built-up area
    - change in planned development (from urban planning and rezoning).
- Another suggestion was to sort out and evaluate the traditional LUI indicators first (e.g. land cover, land use, animal numbers) before exploring new indicators.
- Measure and report indicators in a catchment context: this could include percentage of high-producing pasture at the catchment scale, number of dairy farms in a catchment, and animal numbers at the catchment scale.
- For rural LUI indicators, input types used to parameterise the Overseer Nutrient Budget model were proposed as indicators, particularly if access to the Overseer data sets could be achieved.

4.3.3 Theme 3: Potential LUI data sources

MWLR had pre-circulated a list of the data sets we considered potentially relevant to the development of national LUI indicators. These data sets are discussed in section 7. Following are some of the key points of discussion during the workshop.

- Farms Online and National Animal Identification and Tracing (NAIT) are two related data sets that are managed under the Biosecurity Act 1993 for the broad purpose of emergency response to disease. In principle these data sets could represent a rich data source for livestock numbers in NZ. Access (managed by the Ministry for Primary Industries, MPI) is difficult to obtain, so it is difficult to appraise relevance or data quality.
- Climate data are available via NIWA's Cliflo database, and NIWA offer a number of added-value climate products. MetService may be an alternative source for similar data. However, it is not clear if climate indicators qualify as LUI indicators for freshwater.
- Council land-use data could include ratings data, and special council-only data sets, especially those relating to urban and planning, wastewater, and resource consents. It was noted that councils could hold some very valuable data, but the challenge is

identifying what relevant data councils hold and the degree of consistency between councils. Limited initiatives are underway to standardise data types, collection and data management across some councils and some data types, specifically for indicator development (see Manderson 2017).

- MfE are currently running a data stewardship project that may offer some insight or access to LUI-relevant data sets. The project is looking at establishing data flows and standards relating to the Freshwater National Policy Statement between councils and other agencies.
- The Foundation for Arable Research (FAR) maintains its Production Wise database, which contains very detailed farm- and field-scale data on cropping management. However, not all cropping farmers subscribe, and there are likely to be very strong caveats if ever the data could be shared for LUI indicator development.
- Farm riparian data held by Dairy NZ and Fonterra could be made available in the near future. At the time of the workshop, discussions were occurring on how to transfer data safely, the need to have registered users, and allowing farmers to opt out. The comment was made that, provided the data are anonymised, it is foreseeable that the data could be released to 'robust organisations'. It is proposed to provide national coverage. A similar system is being created for greenhouse gas (GHG) reporting. Depending on the nature of the LUI indicator and the level of anonymisation, there is a potential for dairy riparian data to be made available for LUI indicator development.
- Another possibility is valuation data collected by agencies such as Quotable Value (QV). A lot of data reside behind the valuation process but are generally not accessible unless purchased. LINZ do not hold the data, but rather manage the cadastre framework (ownership parcels as spatial data), which valuations are linked to. Data are 'refreshed every three years'. The full valuation data set can be obtained from Corelogic. LINZ is currently investigating to improve accessibility as, in principle, these are public data. Improved access may require a legislation change. LINZ are also considering new work to improve the consistency between valuations – described as a mass appraisal tool using estimation methods not necessarily involving a property visit (i.e. estimated or modelled data).
- The Agricultural Production Survey (APS) is a national census and survey of approximately 25,000 (annual survey) and 60,000 (4-yearly census) GST-registered farms. It has achieved an 85% response rate, although this does not mean forms are correctly filled in. The APS is broken down by land type and land use. Described as one of the richer farm data sets available, it is managed by MPI, who specify the content, and Stats NZ, who run the survey and manage the data. Access is restricted under the Statistics Act 1975, and data are only ever published at the aggregate level to protect farmer anonymity. The Statistics Act is currently under review, including a re-examination of sharing and confidentiality. The APS contains aspatial data, which can be spatialised by address and location matching with some success (but with far from universal/perfect matching). The next APS is likely to include a unique property identification to help spatialisation.
- Urban data sets: workshop participants were vague regarding the types of urban data that might be available.
- Overseer was mooted as a potential data source. Overseer is now an 'in the cloud' application, whereby users enter their data online and both the input data and the

modelling results are stored in a central cloud database. This would be a rich source of farm data for an LUI indicator if these data could be accessed (highly unlikely). Also, not all farms would be represented, and Overseer is unlikely to distinguish between actual valid data and data entered to explore scenarios (junk data).

- New data from advances in remote sensing: Deb Burgess remarked that the improved availability of multi-temporal data and advances in data mining and other analytical techniques could offer new types of data for LUI indicator development.

4.3.4 End of workshop suggestions

At the close of the workshop, participants were invited to reflect on the day. Some went further to offer suggestions for a pathway forward (paraphrased).

- It would be useful to have insights from other sectors, such as market gardening, horticulture, urban from a data perspective, forestry, and ecological interests such as the Department of Conservation.
- At the end of the day we are still not 100% clear on a definition of land-use intensity. More work is needed here.
- What can be done to bridge the data consistency problem between councils? It seems like a waste if different councils are monitoring the same things but the data can't be compared because of different standards or data management systems, and there is a duplication of efforts.
- There seems to be a political aspect to accessibility for some of the national data sets. Today we had some insight, but overall I think we're in the dark because there seems to be a lot of Ministry attention on these data and their governing Acts at the moment.
- It's a complex proposition (national LUI indicators). Perhaps it could be tackled with a multistage or phased approach. Today we've made a start exploring the problem. What's needed now is an idea of what we can deliver in the next few years. So we don't come back here in a few years. A key part is finding out how much of the government data we can unlock.

There was also general agreement that the workshop participants would like to continue involvement in the project (if it continues).

4.4 Discussion

Participants enjoyed the workshop and rated it a success. Several commented that they were glad they had made the effort to attend, and in the words of one particularly seasoned work-shopper, 'Certainly one of the better workshops I've been part of'. Workshop design and all support material were prepared to a high standard (Appendix 1), including contribution and signoff from both MfE and Stats NZ.

The workshop allowed us to scope the development of LUI indicators, although possibly not as deeply as we would have wished. Certainly no clear definition of land-use intensity emerged. This should not be surprising, as land-use intensity is a complex and multi-dimensional phenomenon (Kuemmerle et al. 2015), unlikely to be solved by a 1-day workshop. However, important components and ideas were discussed that will help definition development. The snippets presented here provide some insight, but the development and proposition of a land-use intensity definition in a national indicator sense will require additional lines of enquiry.

There were also several conceptual challenges raised for an LUI definition, which, due to either complexity or newness, could not be addressed immediately and conclusively on the day.

- A consideration of LUI indicators should include emission outputs for N, P, sediment, and *E. coli*. On the one hand, it may be that, for example, N-leaching can be interpreted as an indicator of pressure on freshwater quality. The higher the N-leaching from surrounding farms, the higher the pressure on freshwater quality. On the other hand, such outputs are not generally considered as pressure indicators and are not often described in intensity terms. For example, it does not make immediate sense to state that 'land use intensity has increased because nitrate leaching has increased'. N-leaching (as the amount of N transported by soil drainage) can be increased by other factors (e.g. high rainfall), and indeed, even if the soil nitrate pool stayed the same year-to-year, we would still expect large variations in annual N-leaching due to seasonal differences in climate. In this case, N-leaching is not a good intensity indicator because it will vary by environment, independent of land-use intensity.
- Land-use intensity does not necessarily equal environmental impact. This is the reverse of the above, in that intensity levels can be the same but differences in environmental conditions can produce different levels of impact. Again, we are in two minds, but would suggest that pressure indicators tend to be more general, as they are usually applied at the activity end of the spectrum.

For the indicator component of the workshop we felt that only a limited range of indicators were developed through the workshop process. This is perhaps to be expected, as the participants all have expertise in their respective areas but this may have been the first time they have been asked to direct it at developing LUI indicators. Possible indicators identified from the workshop are examined further in section 6.

Nor did we gain any insights into the differentiation of current and potential LUI indicators (i.e. what can be achieved now versus indicators that could be used in the future if better data were available). Again, this may simply highlight the degree of familiarity with the various data sets. Given that access to most is very limited, few people would be able to provide commentary on what is actually possible without having some familiarity with the data.

The session on data sets did not identify any new sources, but it did reinforce limited data access as the major constraint for indicator development. Some reassurance was provided in that efforts are underway to free up data at the political and legislative levels to promote data standardisation across councils, and that industry-good groups such as DairyNZ and Fonterra are considering sharing aggregate data if they can. However, we believe this area of 'freeing up access' to data needs to accelerate to keep pace with the demands for environmental data across multiple domains and platforms.

4.5 Conclusions

- A concise definition of land-use intensity was not forthcoming from the workshop.
- There may be conceptual challenges regarding the validity of using contaminant outputs (e.g. farm emissions of N, P, sediment, and *E. coli*) as indicators to describe land-use intensity as a pressure on freshwater quality.
- A small set of potential indicators were identified for further examination through the workshop process.
- Data accessibility for developing LUI indicators is a significant issue. Data sets exist, but access is limited for commercial reasons (AgriBase, Corelogic valuation data), confidentiality (NAIT, FarmsOnline, Agricultural Production Survey, industry-good data sets), and in some cases due to limited standardisation across agencies (council data). There are also uncertainties relating to data types, completeness, and quality.

4.6 Recommendations

- Undertake an extra review to identify and propose a definition of land-use intensity applicable to pressure indicator development (section 5).
- Undertake an extra review to identify a wider range of potential LUI indicators from the literature (section 6).
- Continue the development of LUI indicators, but reappraise the approach and time frame. The workshop demonstrated that land-use intensity and related indicator development are complex and deeper than expected. We echo participants' views that the workshop should be regarded as a first, albeit important, step, but further work is required in a staged way towards a cumulative, high-quality goal.
- Establish a working group to collectively investigate the challenges to freeing up data set access. We suggest that considerable progress could be made towards LUI indicators simply by having the access to explore and test the data. Without access we have limited ability to explore what might be possible.

5 Land-use intensity definition

5.1 Land use and intensity

A clear definition was not forthcoming from the workshop process. In this section we examine the fundamentals underpinning 'intensity' and 'land use', and extract definitions from the literature to examine how they have been combined in practice. These are then considered together to propose a land-use intensity definition for environmental indicators.

5.1.1 Land use

Land use describes the human activities or economic functions that occur on land (MfE 2007). This is similar to the definition used by the OECD: 'Land use is based on the functional dimension of land for different human purposes or economic activities. Typical categories for land use are dwellings, industrial use, transport, recreational use or nature protection areas' (OECD 2007, p. 439).

In NZ the most generalised land-use categories can be described as agriculture (or rural), urban, natural, and forestry. More detail is available in classifications used with spatial data sets, such as Land Use NZ (LUNZ – 25 classes), Land Use for Rural NZ (LURNZ – 11 classes), and the Agribase (approximately 36 classes). Most of these intermediary or mid-level classifications can now be reproduced on demand with the latest data using the Pyluc Land Use Classifier (see Manderson et al. 2018), subject to data availability.

More detailed classifications are available through valuation data sets. *Actual property use* recorded as part of the valuation process has 84 potential classes, while *property category codes* can include upwards of 400 classes (LINZ 2010).

Stats NZ uses the Australian and New Zealand Standard Industrial Classification (ANZSIC) as the basis for land-use categories. This is a very detailed system that endeavours to represent all potential business types as units of classification (ABS & Stats NZ 2006).

5.1.2 Intensity

Intensity implies the concentration of something relative to a reference (e.g. amount or strength per unit). Dictionary definitions include:

- 'The quality of being felt strongly or having a very strong effect. The strength of something that can be measured such as light, sound, etc.' (Cambridge Dictionary)
- 'The quality or state of being intense, or, the magnitude of a quantity (such as force or energy) per unit (as of area, charge, mass, or time)' (Merriam-Webster Dictionary)
- 'Strength, as in the strength of colour, sound, light, or temperature, or as in a very strong level of thought and attention' (MacMillan Dictionary)

- 'The state or quality of being intense. Extreme force, degree, or amount' (Collins Dictionary)
- 'The state or quality of being intense. The measurable amount of a property, such as force, brightness, or a magnetic field' (Oxford Dictionary).

5.2 Land-use intensity definitions

We have listed common land intensity definitions extracted from the literature. This is not an exhaustive list, and most of them tend to apply to agricultural intensification simply because the concept of intensification in land use often, although not exclusively, refers to agriculture (Lambin et al. 2000; Zhang & Li 2016).

- 'More intensive refers to the increasing use of inputs (e.g. fertiliser, energy, water for irrigation, knowledge or capital) into farming systems to produce more food from the same area of land. Intensive farming is usually characterised by the repeated cultivation and/or grazing of land and the addition of a large number of inputs per hectare to maintain or increase production every year' (PCE 2004).
- 'Agricultural intensification can be defined as "an increase in agricultural production per unit of inputs (which may be labour, land, time, fertilizer, seed, feed or cash)". For practical purposes, intensification occurs when there is an increase in the total volume of agricultural production that results from a higher productivity of inputs, or agricultural production is maintained while certain inputs are decreased (such as by more effective delivery of smaller amounts of fertilizer, better targeting of plant or animal protection, and mixed or relay cropping on smaller fields)' (FAO 2004, p. 5).
- 'We refer to intensification as any increase in farm inputs or farm production off-takes per unit area of land, irrespective of trends in relative efficiency of off-take per unit input' (Moller et al. 2008, p. 254).
- 'Agricultural intensity can be defined as the level of inputs and outputs of an agricultural system' (Temme & Verburg 2010).
- 'Agricultural intensification is a process of raising land productivity over time through increases in inputs of one form or another on a per unit area basis' (Shriar 2000).
- 'Intensification is a process of increasing the utilization or productivity of land currently under production, and it contrasts with expansion, that is, the extension of land under cultivation' (Netting 1993).
- 'Increased output on currently used land, and degree of yield amplification as related to changes in levels of inputs and outputs' (Zhang & Li 2016).
- 'Intensification as it relates to constant land, is the substitution of labour, capital or technology for land, in any combination, so as to obtain higher long-term production from the same area' (Brookfield 1993).
- 'Intensity is usually measured in terms of output per unit of land or, as a surrogate, input variables against constant land. Thus, one can distinguish between input intensification, which measures the increases in input variables, e.g., chemical fertiliser, pesticides, etc., and output intensification, which measures the increases in production against constant units of land area and time, e.g., food-tonnes or number of calories/hectare/number of years' (Turner & Doolittle 1978).

- ‘Put simply, agricultural intensity is defined as the degree of agricultural input or output per unit of area and time’ (Turner & Doolittle 1978).
- ‘Land-use intensity is the extent to which land is used. It is an indication of the amount and degree of development in an area, and a reflection of the effects generated by that development’ (City of Raleigh 2001).
- ‘Land use intensity can refer to the land area farmed, the frequency of cultivation, the amount of capital-related inputs (e.g. fertilizer, irrigation, technology, or mechanization), the crop yields from a particular area, or the share of ecosystem productivity that is appropriated by humans’ (Kuemmerle et al. 2015).
- ‘Agricultural intensity is defined as the ratio of inputs and outputs within an agricultural system, i.e., in terms of yield per land area and per input unit, or alternatively, as the sum of different categories of input costs and the total usable agricultural area of the farm. Therefore, either output-oriented (production) or input-oriented (utilisation) measures can be used to describe agricultural intensity’ (Ruiz-Martinez et al. 2015).
- ‘Urban intensification is defined as increasing the density of dwellings within existing built areas’ (Melia et al. 2011).
- ‘Agricultural land-use intensification is the increase of land productivity due to human activities’ (Dietrich et al. 2012).
- ‘Farming intensity is defined as production per hectare (kg milk solids per hectare for dairy farms, kg meat and/or fibre per hectare for sheep/beef farms). It follows that, changes in farming intensity can be decomposed into changes in stocking rates and changes in production per animal’ (Anastasiadis & Kerr 2013).
- ‘Urban land-use intensity is defined as the degree of yield amplification that results from improving management strategy and optimal land-use structure within a city under current economic and technological conditions’ (Gong et al. 2014).
- ‘Land use intensity is defined here loosely as the degree to which humans interfere with the land’ (Freibauer et al. 2013).
- ‘Land-use intensity can also be defined as the magnitude of impact of land-based production on biodiversity, water quality, or carbon’ (Erb et al. 2013).
- ‘Land use intensity is defined as the degree of impacts of land use on biodiversity’ (Braat & Ten Brink 2008).
- ‘Intensification and dis-intensification are the processes by which production per unit area can be altered through an increase or decrease in inputs, such as fertilizers, labour, technology, or outputs’ (Eitelberg et al. 2015).
- ‘Residential intensification can refer to all high-density developments. Others define it as construction on previously developed land, or as any new residential development within the existing built-up urban fabric’ (Burchfield 2010).
- ‘Definition of “intensive land use” includes all activities that generally exclude indigenous biodiversity. For example, areas actively managed to the general exclusion of terrestrial native biodiversity (i.e. crops, roads, etc.)’ (Lee & Allen 2011).
- ‘Intensification may refer to labour intensity, economic intensity, disturbance intensity and other sorts of intensity’ (Bellingham et al. 2016).

5.3 Proposed definition

Most definitions identified relate to agriculture and tend to describe intensity in terms of the degree of agricultural input or output per unit of area and time. Those involving urban use tend to focus on density (e.g. housing, buildings, infrastructure, population, or traffic), while those framed in ecological terms tend to include emissions and impacts.

Many definitions have been proposed, but few have received wide acceptance. As a result, there is a lack of a commonly shared definition and terminology regarding land-use intensity (Erb et al. 2013). This has led to the development of all-encompassing frameworks and models that aim to accommodate the diversity and complexity apparent with land-use intensification (Erb et al. 2013).

We add to the definition debate by offering our own interpretation. However, we offer a suitably broad definition that can be applied to many expressions of intensification.

We define land-use intensity as ***a measure of human activity concentrated per unit area and time***. Human activity can be measured by:

- levels of inputs (e.g. more fertiliser, more labour, more technology, more financial investment)
- levels of production outputs (e.g. higher yields)
- levels of emissions (e.g. N, P, *E coli*, sediment)
- efficiencies (e.g. maintained input with increased output or reduced emissions through technology or improved management)
- frequencies (e.g. more regular irrigation, cultivation)
- densities (e.g. higher stocking rates, populations, housing density).

We recommend this definition be tested by applying it in the development of LUI indicators.

6 Review of land-use intensity indicators

Potential indicators identified through the workshop were somewhat limited relative to the breadth of environmental indicator development in NZ and overseas over the past three decades. Indeed, as a nation we already report on some land-use intensity indicators for freshwater, although they may not be described as such. Further, other NZ agencies have a statutory obligation to monitor the environment, and many have produced their own suites of indicators as part of annual reporting or state of the environment (SoE) reporting.

This section aims to consider a fuller and broader range of potential indicators that might have potential for national reporting in a land-use intensity sense. The method used involves reviewing readily sourced SoE reports. This work is beyond contract requirements, and is not intended as a comprehensive review, as there are potentially upwards of 80 agencies – including central government – producing SoE reports. Some of these councils, however, especially city councils, may be using indicators and data sets of particular relevance to new urban pressure indicators.

6.1 Existing indicators

6.1.1 National indicators of land-use pressure on freshwater

Environment Aotearoa 2019 (MfE & Stats NZ 2019) and related domain reports, particularly for freshwater (MfE & Stats NZ 2017) and land (MfE & Stats NZ 2018), already contain 13 indicators relevant to land-intensity pressures on freshwater (Table 1). Most are reported as state indicators under the land domain.

Table 1. Current and recent national indicators that may qualify as LUI indicators

Pressure indicator	Domain	Quality	LUI suitability rating
Trends in N leaching from agriculture	Freshwater	National indicator	High
Geographic pattern of ag nitrate leaching	Freshwater	Case study	High
Consented freshwater takes	Freshwater	National indicator	Medium
Wetland extent	Freshwater	Supporting information	Medium
Agricultural and horticultural land use	Land	Case study	Medium
Change in farm numbers and farm size	Land	Supporting information	Medium
Change in livestock numbers	Land	National indicator	Medium high
Irrigated land area	Land	Supporting information	High
Land cover	Land	National indicator	Medium high
Soil quality and land use	Land	Case study	Medium high
Use of public conservation land	Land	Case study	Medium high
Nitrogen and phosphorus in fertilisers	Not stated	Not stated	High
Indigenous cover, protection and threatened environments	Land	Supporting information	Medium high

The indicators listed in Table 1 are those that we consider most readily describable as LUI indicators[1]. Both *livestock numbers* and *nitrogen and phosphorus in fertilisers* are explicitly referenced in *Environment Aotearoa 2019*, used as indicators to support statements such as 'farming has intensified', and 'recent intensification of farming has increased the risks of water pollution' (MfE & Stats NZ 2019, p. 52). Reference is also made to changes in stocking rate as an intensity indicator, although we found no reference elsewhere to stocking rate as a national indicator.

Trends in N leaching from agriculture is a strong potential LUI indicator because, as an output indicator, it provides an overarching summary of farm inputs and activities as a cross-farm indicator that aggregates tidily to catchment and national reporting scales. It is, however, a derivative indicator that appears to have limited reference or support material to explain or justify its compilation (see Stats NZ 2020b), and thus properly qualifies as a national indicator according to indicator development guidelines (e.g. Stats NZ 2009).

Geographical pattern of agricultural nitrate leaching calculated by MWLR (Dymond et al. 2013; Ausseil & Manderson 2018) has similar strong potential but is currently constrained by access to good-quality spatial data (see section 7). Both indicators represent slightly different expressions of N-leaching loss as an indicator.

As an indicator, *consented freshwater takes* is rated as having only medium suitability as an LUI indicator, because the relationship with intensity is indirect. There are also considerations regarding actual versus consented volumes and rates. *Wetland extent* is similarly rated, as its relationship with agricultural intensification is no longer as clear as it once was. Further, current debate regarding the definition of what constitutes a wetland could dramatically change *wetland extent* if, for example, all Gley Soils were included.

Agricultural and horticultural land use in its current form is a medium LUI indicator due to it limited categorisation, especially as an indicator for monitoring long-term trends. Currently it includes three broad livestock classes, one class for forestry, and three horticultural classes. In our view it would qualify more highly as the overarching NZ LUI indicator if it reported a wider number of land uses. A more useful indicator describing land-use type and extent would include urban sub-categories (e.g. change in area of industrial, residential, net urban expansion), and improved agricultural sub-classifications to differentiate farming intensities (e.g. low, medium, and high output dairy farms). We acknowledge challenges include multi-enterprise farms, and how this 'next tier of detail' data can be collected, but this should not overshadow the ongoing need to improve how we classify land use. A good national land-use classification promotes insight and understanding, while a poorly designed classification promotes misinterpretation.

Change in farm numbers and farm size as an indicator is a little confusing in that it is reported in a land-use activity context (e.g. the number of farms with dairying activity). Without the land-use context this indicator has only an indirect link with intensification (it

[1] We refer to 'current and recent' indicators to include those used in the first cycle of domain reporting. This includes both pre- and post-2018 indicator lists maintained by Stats NZ on their website.

conveys more about the changing structural and socio-economic dynamics of NZ agriculture).

Change in livestock numbers is a strong pastoral agriculture LUI indicator, especially when expressed by stock type (e.g. deer, dairy, cattle, sheep). It is perhaps, however, too simple to provide all but the broadest indication of intensity changes, as the unit (a 'livestock') does not discern between male or female, young or old, milking or dry, etc. A far stronger indicator would therefore be *stocking rate*, defined here as the density of a standardised livestock unit per unit area. Stocking rate accounts for differences in livestock type, age, weight, and feed demand, and is thus a superior indicator of net livestock pressure on a per unit area basis (section 6.3.5). Stocking rate has been demonstrated as an important variable for explaining trends in freshwater quality (Julian et al. 2017).

Irrigated land area is a strong LUI indicator, as many of NZ's farms experience seasonal soil-moisture deficits that limit production. Overcoming deficits through irrigation can dramatically boost production, by 80% or more (e.g. McBride 1994). The current method of data collection has a strong manual bias that we believe could be improved through next-generation remote sensing.

Land cover is a useful LUI indicator with considerable opportunity for improvement. A key strength of the method is that it is largely a quantitative measure of the state of land cover. Higher-resolution mapping for new cover classes and the use of temporal profiling are examples of some of the techniques currently being examined (section 6.3.1).

Indigenous cover, protection and threatened environments provides an indication of the proportion of indigenous covers remaining according to historical ecosystems. It was first developed by Walker et al. (2006), then updated by Cieraad et al. (2015). It includes a reclassification of the LCDB into indigenous and exotic vegetation (which could be a stand-alone LUI indicator itself), protected land (section 6.2.3), and Land Environments NZ (LENZ) combined to produce a Threatened Environment Classification (Walker et al. 2006). The indicator is rated as 'supporting information', which could perhaps be re-evaluated to take into account improvements in estimating the accuracy of LCDB class changes (Dymond et al. 2017).

We rated *soil quality and land use* as a medium to high indicator of land-use intensity due to the difficulty of obtaining data on the seven sub-indicators (representative sampling approach). However, of the seven, we would rate Olsen phosphorus (Olsen P) as having a high LUI indicator suitability, because it represents the concentration of P in soils. P is a key farm productivity driver, and soil-particulate P is a well-known major source of freshwater P-contamination in agricultural areas (McDowell et al. 2007). Also, industry regularly collects Olsen P data that could contribute towards a national Olsen P indicator.

Use of public conservation land provides some insight into the changing intensity of use of what is traditionally considered a low-intensity land use. The current metrics are limited, but we believe the indicator itself deserves further investigation and refinement.

The indicator *nitrogen and phosphorus in fertilisers* has a misleading name, because it refers to the amount of fertiliser applied to land rather than fertiliser composition. It is a strong LUI indicator because N and P from fertiliser are well known as both minor but direct contaminants to freshwater, and indirect but major contaminants via increased production-based leaching and run-off losses (e.g. Ledgard et al. 1996).

6.1.2 Land-use intensity indicators from regional authorities

NZ's regional councils also have a statutory obligation to monitor the state of the environment under Section 35 of the Resource Management Act (RMA 1991) and to make the results publicly available every 5 years. Accordingly, most councils develop and maintain their own indicators and produce SoE reports. They also have access to different types of data not necessarily available to ministries and other national agencies.

Northland Regional Council (NRC) report land cover change from the LCDB, and various livestock, land-use, and production statistics that are otherwise publicly available from , for example, Statistics NZ and DairyNZ / Livestock Improvement Corporation (LIC) (NRC 2015). Northland, along with Hawke's Bay, also monitors Olsen P (soil fertility) as part of soil quality monitoring (NRC 2012; HBRC 2015). Auckland is similar for some indicators (Table 2), but also includes *land use* from valuation data, *housing density*, and *rural fragmentation* of property parcels. The Auckland indicators are currently under review (AC 2018).

Waikato Regional Council (WRC) uses several potentially useful LUI indicators (Table 3), but we were unable to locate meaningful indicator descriptions or methodologies. This contrasts with previous years, when WRC provided clear and detailed online indicator descriptions. Hence, while several indicators sound promising, we are unable to determine if they are repeatable and credible, especially those that are likely to be compound-type indicators.

Horizons Regional Council reports changes in stock numbers from APS data, land cover from LCDB, and land use, but is not clear about its data source (HRC 2019). Similarly, Taranaki use more of a discussion approach in their most recent SoE report (TRC 2009), and it is difficult to untangle specific indicators, data sources, and methods of calculation. Both Otago and Southland regularly monitor freshwater state, but we were unable to readily identify the use of pressure indicators (relevant to LUI).

Table 2. Potential LUI indicators from Auckland Council (AC 2015)

Indicator	Source	Metrics
Land cover	LCDB	Ha or % of built-up area, exotic forest and scrub, horticulture, indigenous forest and scrub, other, parkland, pasture, wetlands and water
Land use	Valuation data	Ha or % of commercial, community services, industrial, lifestyle, other, recreational, residential, rural industry, transport, utility services
Housing density	NZ Census	Number of occupied dwellings, persons per ha
Rural fragmentation & land use	LINZ property parcels	Change in parcel number and size
Intensity of dairying	APS, Dairy NZ & LIC	Farm count, area, herd size, stocking rate
Livestock numbers	APS	Percentage change

Table 3. Potential LUI indicators from Waikato Regional Council (WRC 2020)

Indicator	Source	Metrics
Land use	LCDB	Area
Stock density	Agribase	stock unit (su) per ha
Soil stability	?	?
Stock access to waterways	Riparian characteristics survey	?
Stream bank vegetation	Riparian characteristics survey	?
Fertiliser use on farms	?	?
Nitrogen losses from land	?	?
Sources of nutrients in rivers	?	?

Greater Wellington Regional Council (GWRC) has 16 clear environmental indicators that are reported individually and collectively as the Healthy Environment Index (GWRC 2020). Unfortunately, few qualify as LUI pressure indicators for freshwater. *Landfill waste* is of interest (kg of landfill material from commercial and residential sources, divided by the estimated resident population). Likewise, GWRC maintains a soil quality SoE monitoring programme, which uses a regional sampling approach to monitor, among other things, land use, Olsen P, and trace elements (Gordon 2018). We also note that GWRC maintains a Selected Land Use Register (Pitt 2018) similar to MfE's Hazardous Activities or Industries List (HAIL) database.

Environment Canterbury monitors irrigated land area as an indicator to gauge progress against targets for increasing the area of irrigated land in the region (ECan 2019b). Mapping results (e.g. Brown 2016) are included in MfE's irrigation footprint layer that is already used for national reporting (section 6). ECan also monitors soil quality (350 sites) and soil quantity (25 paddocks) approximately once every decade (ECan 2019a).

SoE reporting and the maintenance of environmental indicators by regional authorities appears to be less prevalent than it was two decades ago (although monitoring of freshwater state indicators has advanced significantly). We did not, as such, identify any potentially outstanding LUI indicators that were new to us, although we acknowledge this is a small review. There is opportunity for LUI indicators that could be built from council consents (effluent, discharges, land use, etc.) and the land-use data sets being collected by some councils for soil conservation and freshwater management purposes (e.g. environmental farm plans, Overseer files and reports). However, there is often considerable variation in what councils monitor, how it is recorded, and how readily it can be shared and standardised for national reporting (e.g. see Manderson 2018).

6.1.3 Land-use intensity indicators from territorial authorities

We include a snapshot of environmental indicators from city and district councils (Table 4) because they offer insight into the type of indicators used in urban areas. As a broad statement, many of the council web pages and SoE reports we examined included LUI indicators for land cover, land use, population, and livestock. In most cases these indicators were constructed using publicly available Stats NZ, MWLR, and industry data (e.g. LIC, DairyNZ, Zespri). Similarly, environmental monitoring and reporting by territorial authorities is highly variable, ranging from no reporting through to indicator frameworks comparable to or better than those of many regional councils (e.g. Rotorua, Matamata–Piako, and Manawatū District Councils).

We were somewhat surprised by an apparent reliance on data from national data sets for a large proportion of SoE indicators. However, strong potential for indicator development is evident for infrastructure and services indicative of changes in (urban) land-use intensity, especially with subdivision (actual and planned change or expansion in residential, industrial, commercial, recreational, etc.), wastewater management, storm water management, contaminant risks, and solid waste management.

Table 4. A snapshot of potential pressure indicators from territorial authorities (including current, past, and proposed indicators)

Indicator(s)	Reference
Spatial land use & development. Proposed. Includes urban (residential, commercial, industrial), rural and coastal (agriculture, forestry, mining, etc.), conservation and recreation (parks and reserves), airports.	FNDC 2008
Development trends. Proposed. Includes number of development consents.	FNDC 2008
Solid waste per capita generated. From landfill data. Proposed.	FNDC 2008
The number, classification and distribution of known contaminated sites. Proposed	FNDC 2008
Types and amounts of hazardous substances in use in the district. Proposed.	FNDC 2008
Quantities of hazardous wastes collected and disposed of. Proposed.	FNDC 2008
Point discharges to freshwater. From consents for discharges from dairy farms, industry, sewage, septic tanks.	FNDC 2008
The number of dry weather sewage overflows from Council's sewerage system, expressed per 1,000 sewerage connections to that sewerage system.	KDC 2019

Indicator(s)	Reference
The number of abatement notices, infringement notices, enforcement orders and convictions received by Council in relation to its resource consents for discharge from its sewerage systems.	KDC 2019
Total amount of recycling (diverted from landfill) as a percentage of total waste collected.	KDC 2019
Rural area development. Applications received/granted to subdivide class I, II and III soils (into lots of less than 8 ha; number of building consents applied for/ granted to build dwellings on class I, II and III soils; area of class I, II and III soils designated for non-productive land uses; & number of applications applied for/granted for non-productive activities on class I, II and III soils	MPDC 2020
Residential growth. Number of residential lots created as a result of subdivision; number of resource consents applied for/granted for dispensation of development controls (max. height, yards, site coverage etc.); number of notable trees or areas of indigenous vegetation removed as a result of residential development; & number of building consents applied for/granted for new dwellings	MPDC 2020
Solid waste. Total quantity of waste disposed to landfill from residential and business sources; composition of waste disposed at landfills; total quantity of hazardous waste disposed to landfill and sewer; & number of incidents and spills involving hazardous waste.	MPDC 2020
Waste generation. kg/capita/yr to landfill. Monitored by council.	BECA 2017
Land cover. Permeable/impervious and indigenous/exotic land cover area (ha).	BECA 2017
Stormwater contaminant load. Heavy metals. Council site/consent monitoring.	BECA 2017
Wastewater N & P removal rate. Tonnes and % of nutrient removed and remaining in wastewater.	RDC 2019
Household units with access to wastewater reticulation services (balance of households is a proxy for septic systems, etc.).	RDC 2019
Urban subdivision. Number of subdivision resource consents granted in residential zones; number of new lots created in residential zones (with RMA section 224 approval); number of potential lots in residential zones (pending RMA section224 approval).	RDC 2019
Residential development. Number of resource consents granted in residential zones; types of resource consents granted in residential zones.	RDC 2019
Rural subdivision. Number of subdivision resource consents granted in rural zones; number of new lots created in rural zones (with RMA section 224 approval); number of potential lots in rural zones (pending RMA section224 approval).	RDC 2019
Rural development. Number of resource consents granted in rural zones; types of resource consents granted in rural zones.	RDC 2019
Waste to landfill. Kg of waste to landfill per person, per week.	RDC 2019
Urban stormwater quality. Heavy metals.	GDC 2015
Area of consented forestry harvest. Sediment generation risk.	GDC 2015
Length of consented forestry roads and tracks. Sediment generation risk.	GDC 2015
Fragmentation of rural land. Number & distribution of subdivisions. Lot sizes.	HCC 2020
Demand on land (residential and commercial). Subdivisions, building consents.	HCC 2020
Demand on infrastructure and services. Number & location of connections (water supply, stormwater, wastewater).	HCC 2020
Volume of water consumed per capita.	KCDC 1999
Dwellings on reticulated water supply (number & %).	KCDC 1999
Dwellings on reticulated sewage (number & %).	KCDC 1999

Indicator(s)	Reference
Sewage overflows. Number of wet weather sewer system overflows.	KCDC 1999
Quantity and type of waste disposed to landfill.	KCDC 1999
Number of incidents and spills involving hazardous substances.	KCDC 1999
Number of contaminated sites in the district.	KCDC 1999
Number of building consents granted.	KCDC 1999
Number of subdivision consents applied for and granted.	KCDC 1999
Density of buildings on residentially zoned land.	KCDC 1999
Change in land zoning (planning).	KCDC 1999
Population. Current, projected, distribution.	MDC 2007
Number of new urban dwelling building consents.	MDC 2007
Number of new rural dwelling building consents.	MDC 2007
Amount of rural land converted to rural subdivision.	MDC 2007
Average size of new subdivision lots for each zone in the district.	MDC 2007
Number of home occupations in the residential zone.	MDC 2007
Number of discharges to water consents issued by Horizons Regional Council for discharges in the Manawatū District.	MDC 2007
Number and location of discharge to water consents held by Manawatū District Council.	MDC 2007
Water demand. Industrial and domestic consumption m^3 per day.	MDC 2007
Tonnage of waste to each transfer station.	MDC 2007
Number of fly-tipping incidents.	MDC 2007
Number of known or potentially known contaminated sites.	MDC 2007

As with regional councils, we have reservations about how accurately and consistently territorial authorities could contribute to the collective development of national LUI indicators. We expect high variability in standards, data recording, and the ability to extract data easily. Further, based on previous projects, it can be a challenging process to find the correct channels for obtaining data-use permissions and good technical data explanations (metadata, lineage, methodologies, etc.).

6.1.4 Environmental Monitoring and Reporting (EMaR) initiative

The Environmental Monitoring and Reporting (EMaR) initiative represents a partnership between MfE and regional councils working towards achieving more consistent and integrated regional and national environmental data collection and reporting. In 2015 EMaR convened a land domain workshop (Weeks & Collins 2015). The report concluded that intensification is a key indicator, but lamented that no comprehensive national or regional land-use database was yet available to adequately measure and monitor intensification (e.g. fertiliser application, irrigation, stocking intensities) or other types of land-use change (e.g. urbanisation, forestry to dairy). They went on to recognise that many potentially relevant land-use data sets exist, but access is generally difficult and costly, and data requires further processing to be useful.

6.2 Currently feasible indicators

MfE has expressed a preference for indicators that can be represented in map form. Examples of national environmental indicators expressed this way include *land cover*, *livestock numbers*, *irrigated land area*, and *geographical pattern of agricultural nitrate leaching* (MfE & Stats NZ 2019). The New Zealand Sustainability Dashboard Project also reports national maps for *agricultural land use* (APS data presented at the region level) and *wine industry land use* (NZSD 2020).

6.2.1 Statistic indicators by Territorial Authority

Conceivably any Census or APS data with location (e.g. address) can be linked and presented by geographical units (regions, territorial authority units, or possibly meshblocks in some cases). Likewise, several industries provide multi-year statistics by geographical unit (e.g. Figure 4).

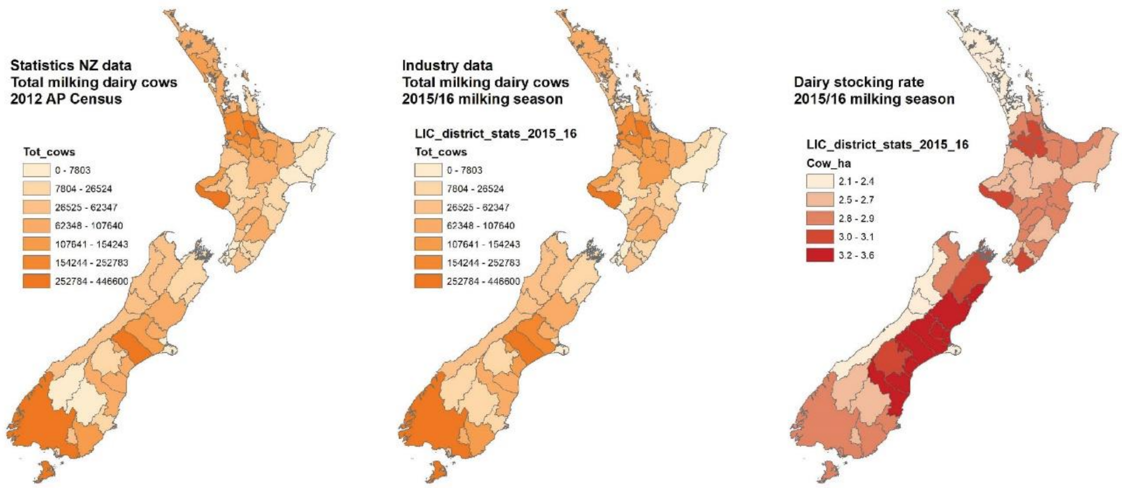

Figure 4. Examples of statistics from LIC & DairyNZ (2016) and Statistics NZ agricultural census data linked to LINZ 2015 Census territorial authority unit boundaries.

Tagging existing statistics to existing geographical units would represent a simple solution for generating national maps for a range of LUI indicators. However, this approach would probably lack the granularity desired for reporting at catchment scales.

6.2.2 Statistic indictors by catchment

Reporting APS statistics by catchment is achievable, as demonstrated by MWLR and Stats NZ as part of the Rangitikei Resource Accounting project (Figure 5). These are special catchments, which each represent a unique aggregation of River Environments Classification (REC) (Snelder & Biggs 2002) lower-order catchments according to land-use intensity and land-use type, aggregated in a way to offset the risk of triggering Stats NZ confidentiality rules.

The purpose of the catchment statistics was to validate inputs for spatial Overseer modelling sourced from less reliable sources. As an indicator, we would recommend at least a primary overlay with land cover to produce finer granularity with improved context (e.g. urea use as tonnes per year per hectare of grassland).

If statistics by catchment is considered a method of interest, we would further recommend standardising how APS records are tagged into a given catchment. We expect this is done using an address point location. If so, this assumes the entire farm is located within the catchment, which is not always the case (i.e. the point location often represents the main entrance to a farm). Further, we would recommend developing optimisation routines for classifying catchments, as considerable work would be involved to create these specialist catchments for all of NZ. In principle, however, once the optimisation routine is coded, the catchment units can be generated on demand to accommodate changes in data (e.g. like meshblocks).

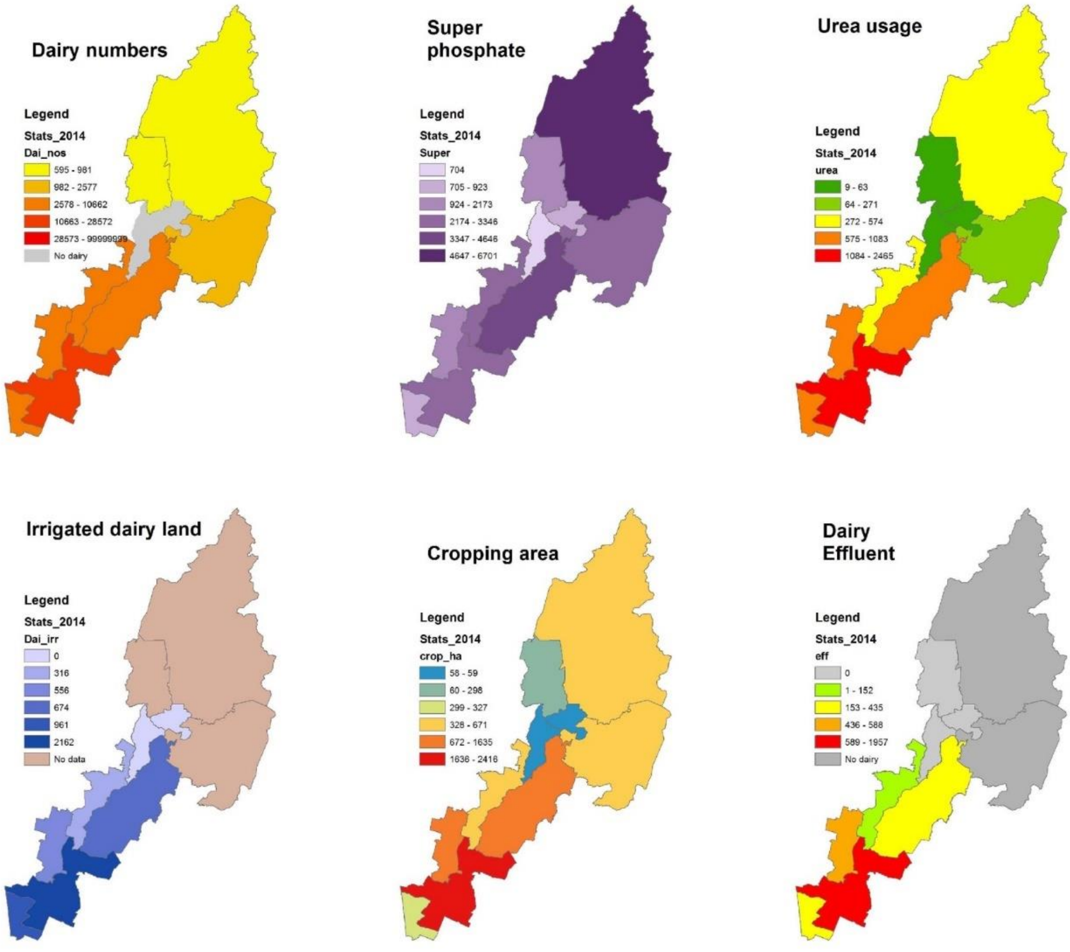

Figure 5. Example of APS statistics by special sub-catchments, developed by MWLR for the Rangitikei Resource Accounting Project (Singh et al. 2017). Statistics populated by Stats NZ. Total catchment area = 4,000 km^2.

6.2.3 Statutory protected land

The rate of land coming under statutory protection is an inverse indicator of land-use intensification, but it is mentioned here because it is already available as an indicator in the form of the recently updated Protected Area Network of New Zealand (PAN-NZ) spatial layer (originally developed by Rutledge et al. 2009), now embedded in MfE's LUCAS Land Use Map (see Manderson et al. 2019). The updated PAN-NZ recognises land protected under the Reserves Act 1977, Conservation Act 1987, Reserves Act 1977, QEII National Trust Act 1977, National Parks Act 1980, Waitangi Endowment Act 1932–33, Te Ture Whenua Maori Act 1993, Historic Places Act 1993, Wildlife Act 1953, and Resource Management Act 1991.

6.2.4 Enhanced land use data set

NZ data sets with a land-use classification – such as the AgriBase, Farms Online, and valuation data – all record land use spatially at the parcel or property level, as derived from digital cadastral units maintained by LINZ. A parcel or property can contain more than one area of land use or land cover. For example, a parcel classed as 'school' often contains buildings, sports fields, trees, and large areas of impervious surfaces such as car parks or sports courts (Figure 6). Simple overlay of land cover with land-use parcels can be used to produce new data with higher utility and accuracy for indicator development.

This is a common undertaking, especially for spatial modelling and land-use classification (e.g. Motu 2010; Manderson et al. 2018). For example, Manderson et al. (2019) combined valuation data land-use classification with LCDB covers to identify the change in area of dairy-grazed grassland (and change in other livestock-grazed land) for multiple years as part of MfE's 2016 LUCAS Land Use Map update (Newsome et al. 2018).

Figure 6. 'School' land-use parcels assigned using valuation data and LINZ property parcels, overlaid on aerial photography to demonstrate that simple parcel classifications can include a diversity of land uses and covers.

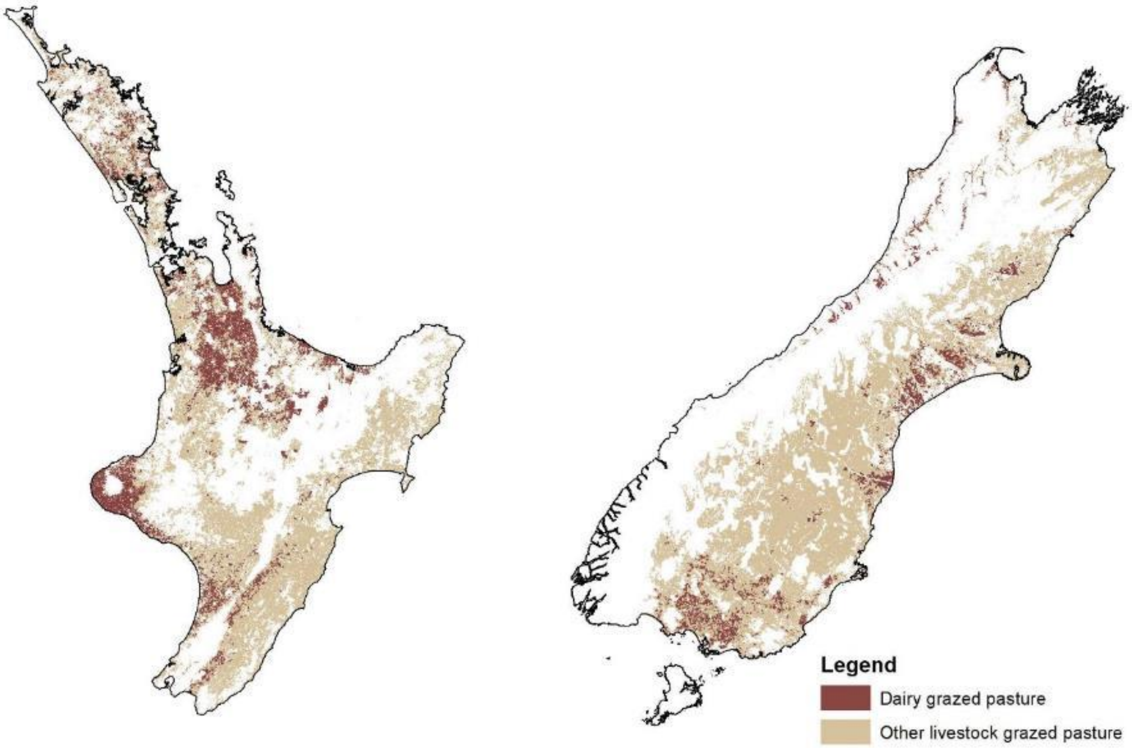

Figure 7. Example of producing more detailed land-intensity data by combining data sets. In this case the potential indicator would be *change in area of dairy grazed grassland* (from Manderson et al. 2019 for MfE's LUCAS LUM). Many other combinations are possible. Note that considerable post-processing was undertaken to minimise confidentiality risks of identifying individual property boundaries within this data set.

6.2.5 The extent of artificially drained land in NZ

Artificial drainage is the modification of natural pathways of water flow to improve the removal of excess water from otherwise wet land (Manderson & Belliss 2016). Such modifications are increasingly recognised as important pathways for the transport of contaminants from land to freshwater (Stenger et al. 2016; Monaghan et al. 2016).

The extent of artificially drained land has been estimated for NZ (Figure 8) using a combination of detailed drainage data sourced from regional and territorial authorities, and a contemporary agricultural intensity map, combined with other inputs through a fuzzy logic inference model (Manderson 2018). The result was validated against 8,000 observation points.

Like irrigation, artificial drainage is a land development that results in conditions more suitable for sustaining intensive land use, so artificial drainage has potential as a national LUI indicator. At this stage of development we consider it as a case study or as supporting information, although some of the underlying data are of high quality and could perhaps be used as a stand-alone indicator.

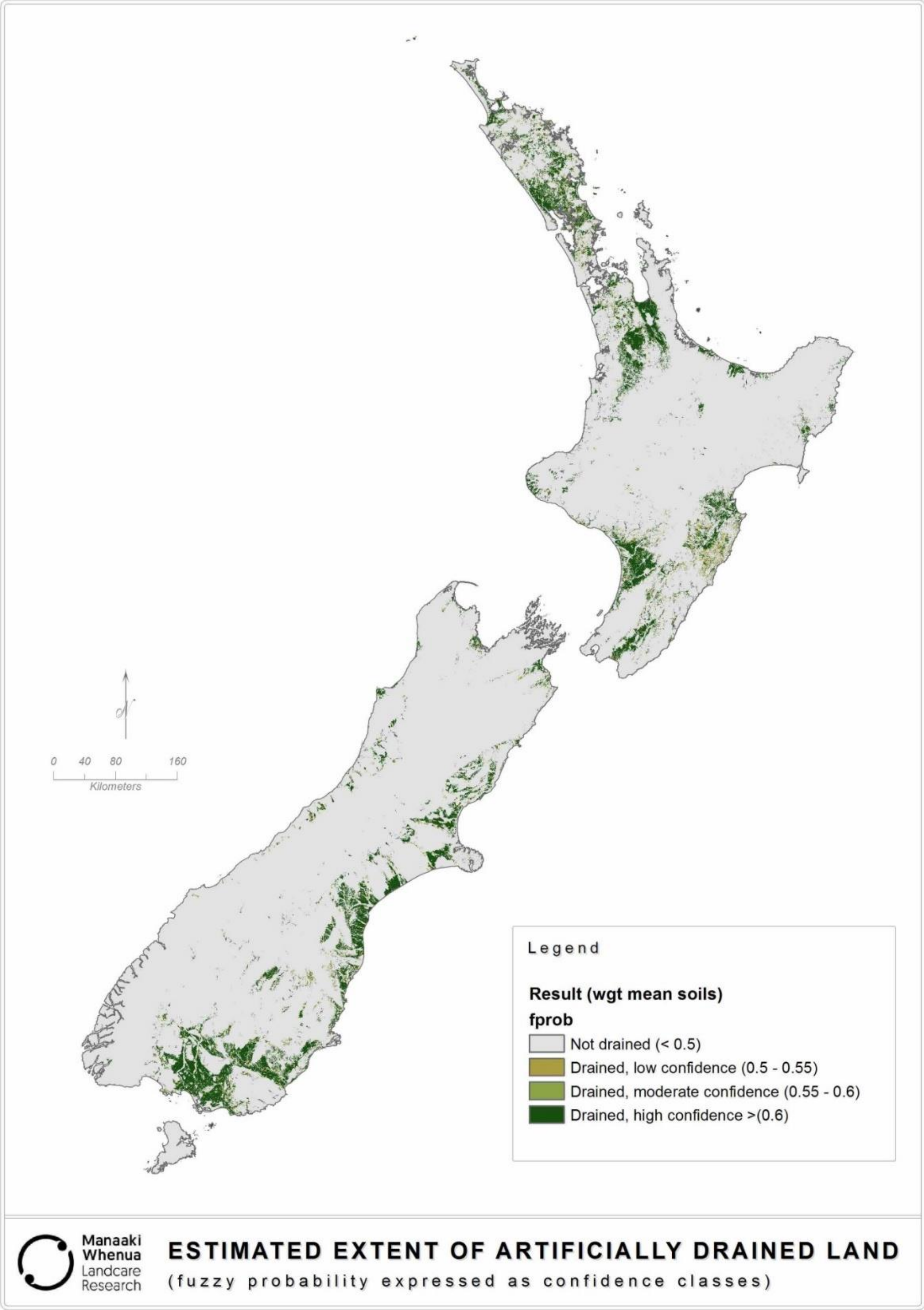

Figure 8. The extent of artificially drained land via fuzzy set theory (Manderson 2018).

6.3 Proposed new indicators

6.3.1 New indicators from enhanced land cover

There is considerable opportunity to use remotely sensed data to determine changes in land cover. This is reflected in the ongoing use and updating of the LCDB, and current research initiatives that may create new opportunities for LUI indicators when published. For example, current MWLR research in the Advanced Remote Sensing of Aotearoa programme is investigating time-series imagery for spectral activity as a key element of estimating pasture productivity from around the country.

Information more detailed than the LCDB is also being extracted for paddock-scale mapping (North et al. 2014) and mapping impervious surfaces within built-up areas (e.g. Figure 9). Similar techniques are currently being developed to more precisely delineate riparian areas, bush remnants, wetlands, and space-planted soil conservation trees.

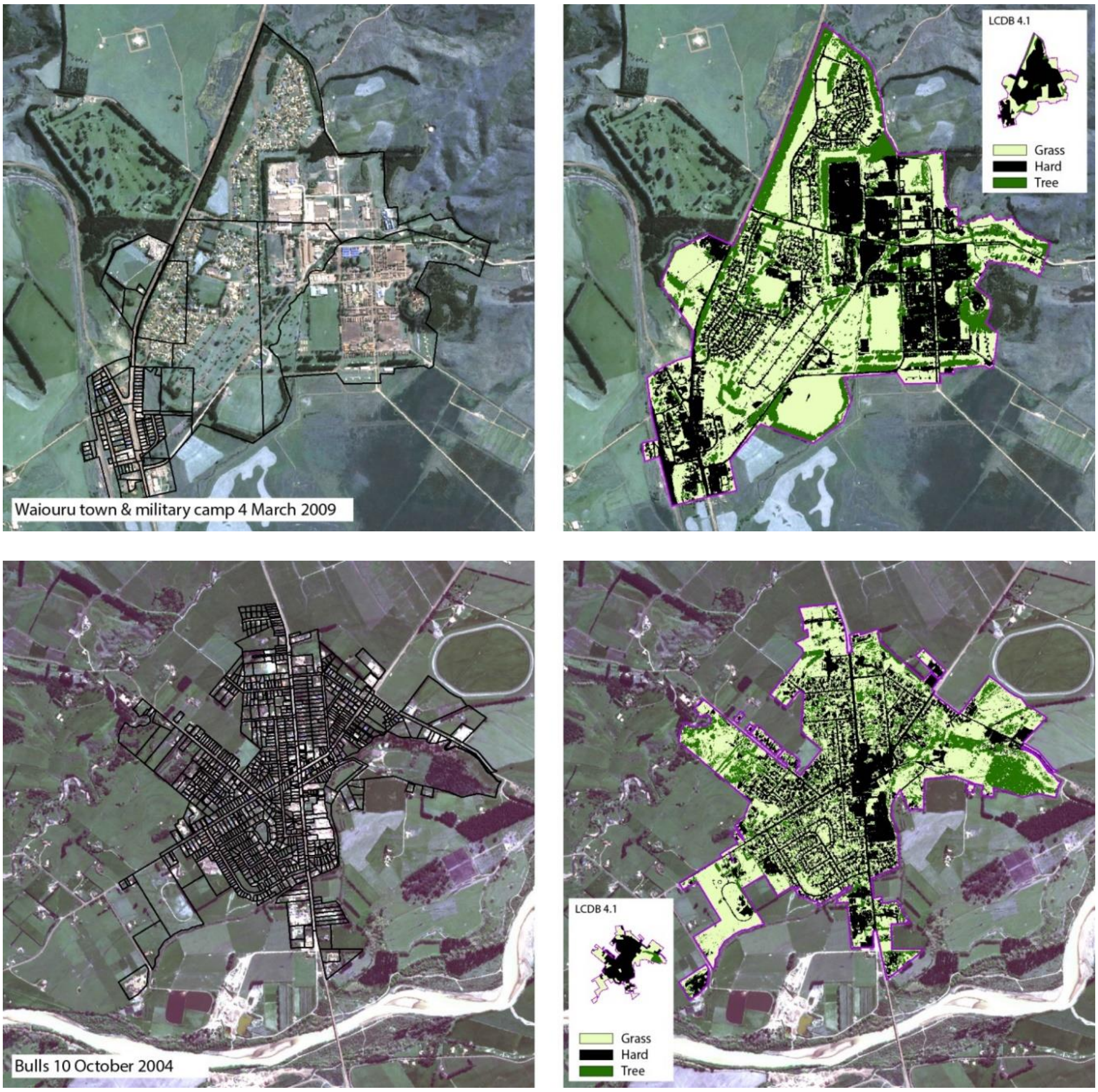

Figure 9. Mapping pervious vs. impervious land cover from high-resolution satellite imagery for Waiouru (top) and Bulls (bottom). Insets are LCDB 4.1 covers for comparison.

6.3.2 New indicators from enhanced land-use data sets

We do not have sufficient data-use permissions as part of this project to demonstrate the full scope of possible LUI indicators that can be constructed using the enhanced land-use technique. We have provided lists of common land-use and cover classifications as Appendix 2 for the reader to explore and consider. Some of the more topical LUI indicators that may be possible include:

- change in grassland area under agriculture, urban and amenity, and/or statutory protected land
- change in grassland area under dairy
- change in native vegetation area within agricultural land use
- change in the area of wetlands within agricultural land use
- fragmentation and connectivity of native vegetation within agricultural land use
- broad changes in pervious vs impervious surfaces under urban uses.

6.3.3 National N-leaching loss indicator

We believe *national N-leaching loss* is an important LUI indicator for agriculture and although this is being reported (Table 1) through the Dymond et al (2012) framework, we offer two potential pathways of indicator improvement (alongside improvements in data – see section 7):

- A shift to using stratified Fracleach: Fracleach is used in NZ's GHG inventory, and the *trends in N leaching from agriculture indicator* could be used for the *geographical pattern of agricultural nitrate leaching indicator*. Unlike Overseer it offers a transparent and widely published method but suffers in that it is a singular cofactor multiplied against 'N-inputs to soil from livestock and fertiliser'. As a single value it does not account for the many other variables that influence N-leaching rates (e.g. soils, climate, best practice). NZ uses a Fracleach value of 0.07, but it is recognised that Fracleach has a potential range from 0.1 to 0.8 (IPCC 2000), and that some countries have developed their own stratified Fracleach systems for GHG reporting (e.g. Environment Canada 2010). MWLR has developed a method for a national Fracleach layer (Figure 10) as part of follow-up investigations for MfE regarding the development of a national freshwater reporting model (Manderson et al. 2015).
- Overseer Nutrient Budget modelling undertaken using APS and Census data in Statistics NZ's data labs, and subsequent aggregation of N-loss (and P-loss) results into catchments for export and use outside the labs. We have used two pathways for similar investigations: (i) either batch processing of multiple Overseer simulations (e.g. we recently processed 915 farms, involving 2,750 management blocks, through Overseer) to produce catchment statistics including distributions (Figure 11); or (ii) typology modelling similar to that performed by MWLR using B+LNZ Economic Survey data for all NZ sheep and beef farms for the years 1995 and 2015 (Monaghan et al. in prep.).

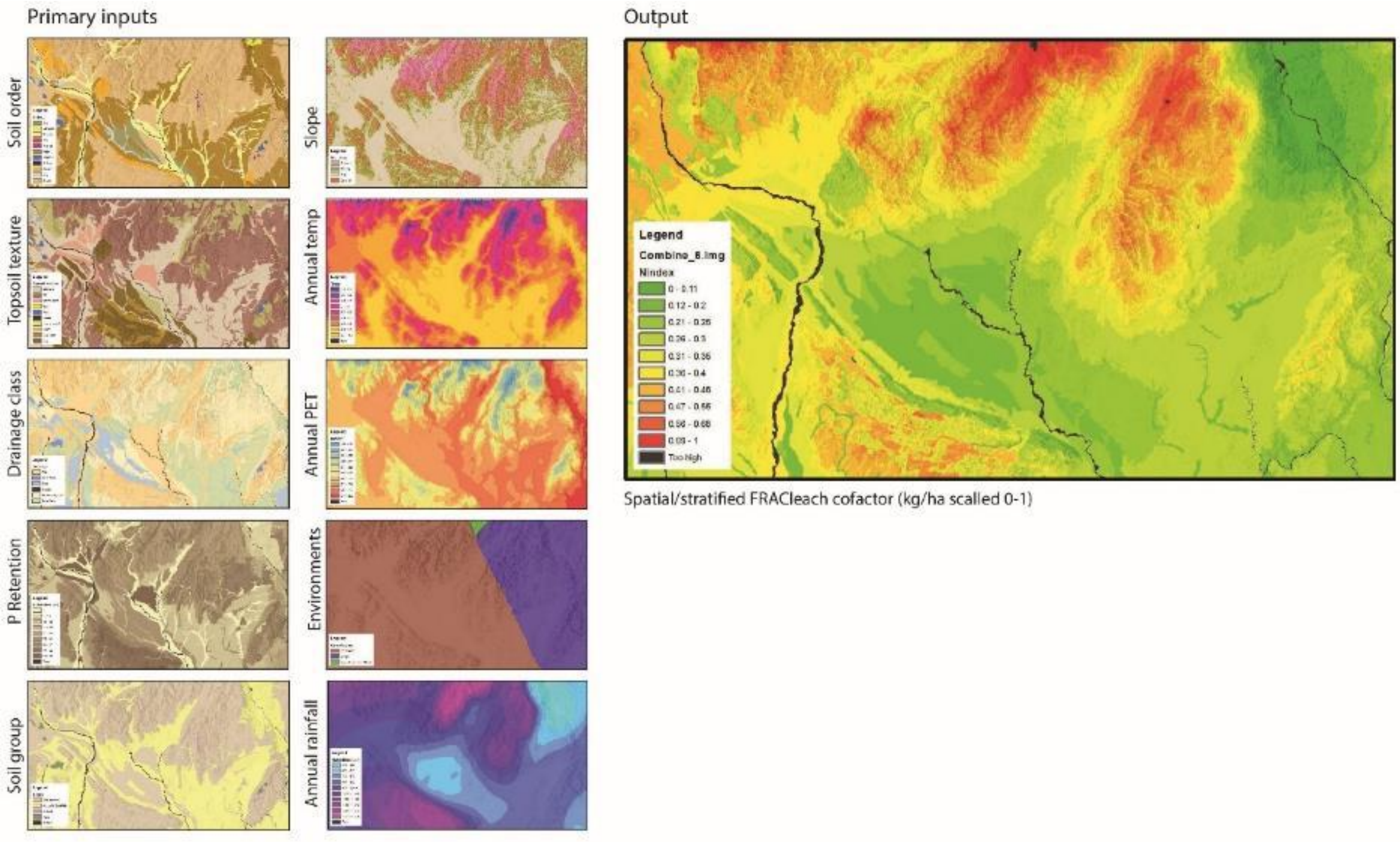

Figure 10. Snapshot of a national stratified $Frac_{leach}$ layer with relevance for improved calculation of national N-leaching indicators. Based on Overseer principles.

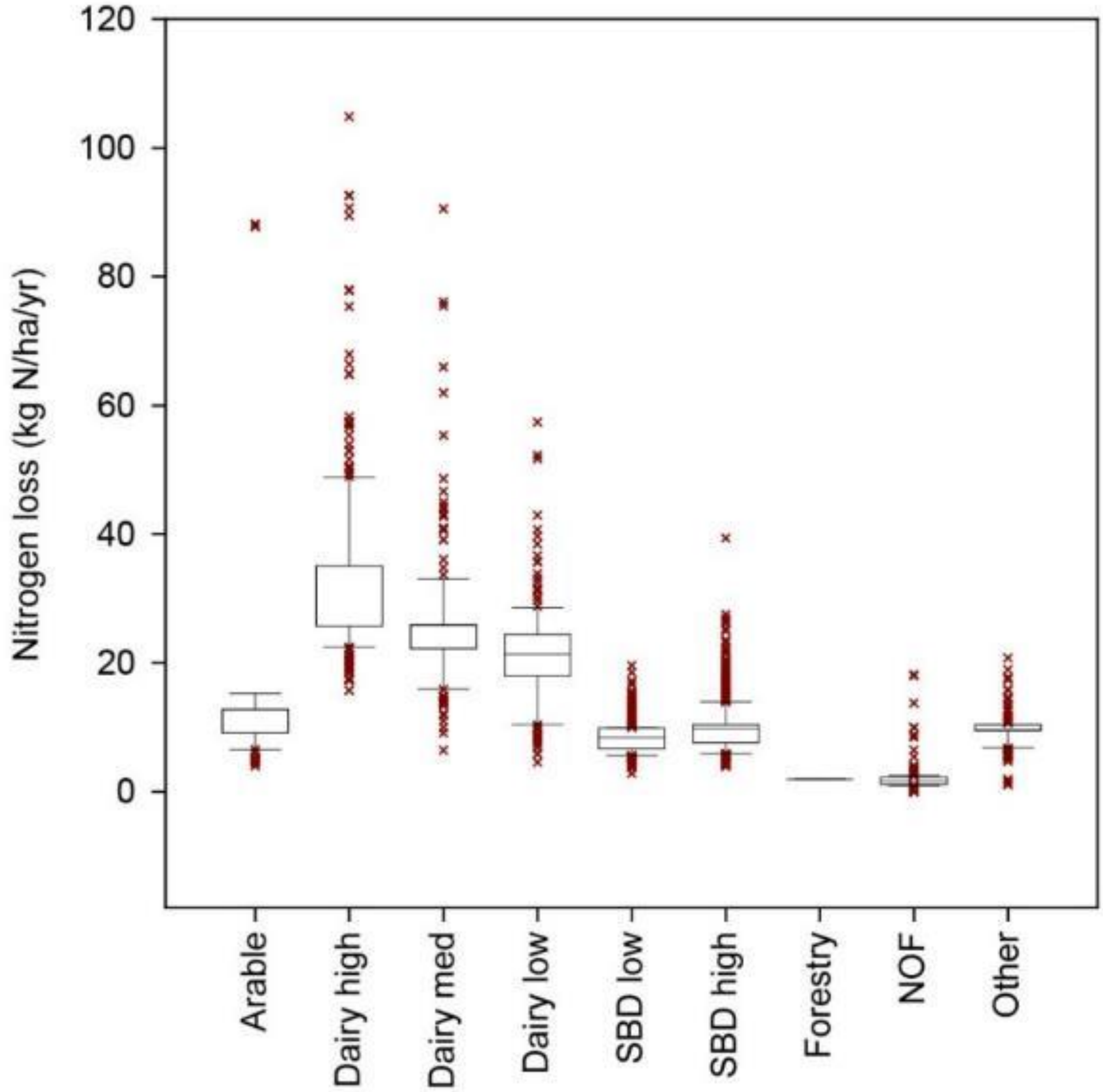

Figure 11. N-loss statistics by land-use intensities as a catchment indicator, calculated by batching 43 farm typologies across 915 farms and 2,750 nutrient management blocks and parametrised using spatial data, for the Rangitikei Resource Accounting project (Singh et al. 2017).

6.3.4 N-loss from on-site wastewater treatment systems

Private septic systems, particularly those that are poorly managed, are a recognised source of freshwater contamination (MfE 2008). While the potential nutrient contribution from single systems is generally regarded as low in a whole-of-catchment sense, they do contribute to the total nutrient loads, especially where population densities are high. Further, individual sites can exhibit high levels of local nutrient impact (e.g. sensitive enclosed water bodies), and even small levels of septic leachate can contain elevated pathogen concentrations and thus have elevated public health risks (Leonard & Gilpin 2006).

Nitrogen losses from septic systems have been estimated for the Rangitikei Catchment using a population density approach (Figure 12), following the proposition that N mass loading rates from on-site wastewater treatment systems are proportional to population densities (Leslie 2015). Data inputs include district council services data (urban and peri-urban parcels linked to municipal wastewater treatment systems), recent consents for onsite treatment systems, and Census dwelling statistics by meshblock (number of households, people per household). Overseer Nutrient Budgets were used to model potential losses by different types of septic system.

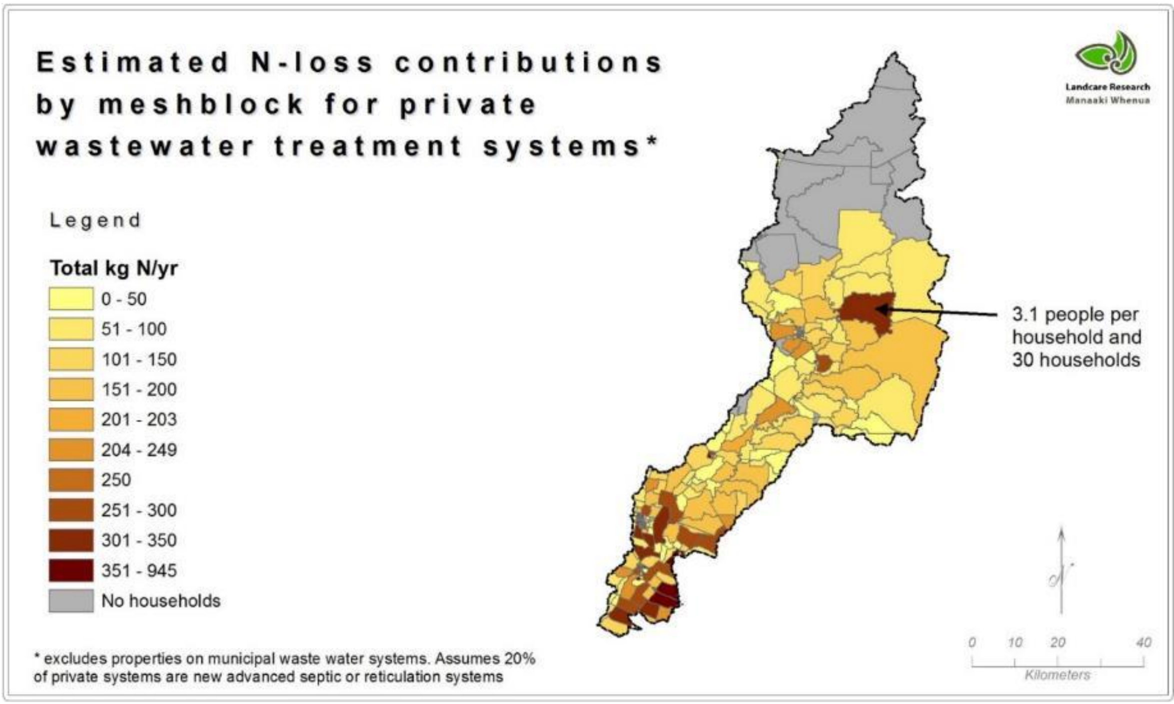

Figure 12. Example of estimated N-loss from on-site wastewater systems, by meshblock, for the Rangitikei Catchment.

Further work, including peer review, is required before this approach is suitable for consideration as a spatial LUI indicator. A standardised method would allow this indicator to be readily calculated and compared as new Census data become available.

6.3.5 Farm stocking rate

Stocking rate is a true LUI indicator for NZ agriculture as it expresses a density per unit area per unit time (usually annual). Further, it attempts to standardise differences between livestock type, age, breed, fecundity, and feed demand. It is therefore regarded as a key indicator of the intensity of land use (HRC 2019), and stocking rate is reported as having a good correlation with freshwater impacts (Julian et al. 2017; Larned et al. 2019).

Two methods are used to estimate stocking rate for livestock:

1 the standard stock unit (SU) approach, where 1 standard SU requires 550 kg dry matter (DM) annual intake, which is equivalent to a 55 kg ewe at mating and weaning 1 lamb

2 the revised stock unit (RSU) approach, whereby 1 RSU is equivalent to the consumption of 6,000 MJ of metabolisable energy (ME), broadly equivalent to 545 kg dry matter at an average quality of 11 MJ ME/kg dry matter.

Stocking rate is readily calculated when and where good land-use data are available. At a minimum, livestock type and number are sufficient to provide a broad estimate for modelling purposes using the standard stock unit approach (Figure 13). More robust estimates using the RSU approach require an estimate of feed intake.

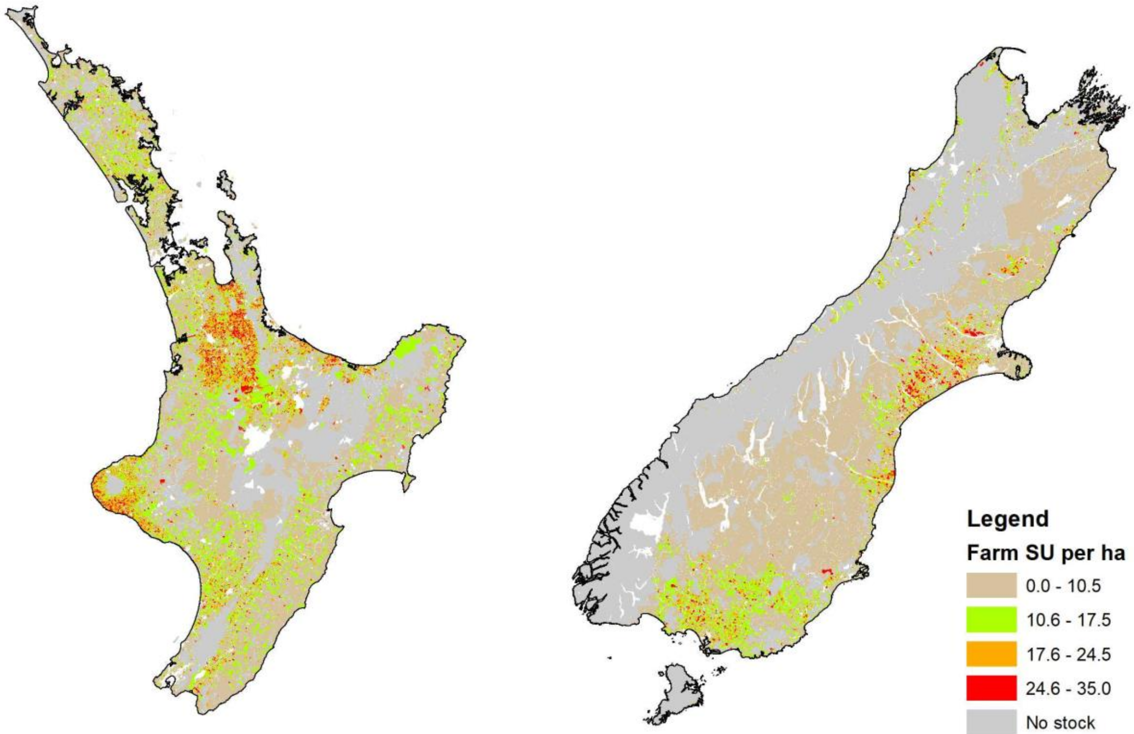

Figure 13. National farm stocking rate (livestock) calculated using the AgriBase, LCDB, and computed stock type ratios by territorial authority, using Agricultural Production Census data (developed for Ausseil & Manderson 2018).

6.3.6 Value of improvements

Value of improvements is described by Quotable Value as the difference between the capital value (the likely price a property in its entirety would sell for) and the land value (the value of the bare land component). Value of improvements is regularly 'assessed' every 3 years and is available for all ownership parcels in NZ as part of valuation data sets.

Examples of improvements for rural land uses include dwellings, decks, garages, carports, sleepouts, gardens, power supply, water reticulation, sheds, barns, stables, yards, fences, silos, greenhouses, tracks, shelter, and orchards (LINZ 2011).

The validity of value of improvements as an LUI indicator needs testing. While it is fair to propose a relationship between dollars invested in a property and the intensity of land use, there are scenarios where this does not hold. For example, land leased for market gardening or cropping can be used intensively but may have no improvements other than a boundary fence. There are also questions regarding the subjectivity of the data, as ratings valuations are often made remotely, based on estimates rather than onsite assessment. Despite this, we consider this indicator has potential and is thus worth investigating further, although we should point out that determining if there is an actual relationship between value of improvements and land-use intensity or environmental impact would require a separate research study.

6.3.7 Subdivision rate (actual and planned)

Planned (zoned) and actual subdivision rate provides a strong LUI indictor for urban environments that can be presented in map form. This is a relatively simply indicator and data are readily available and updated as LINZ primary parcels. However, while this indicator can be displayed spatially, it is not suitable for display as a national map because of scale considerations. We suggest a more appropriate use of the indicator is for selecting windows of urban change for monitoring purposes.

6.3.8 Terrestrial biodiversity indicators for regional councils

In 2016 MWLR produced a recommendation for terrestrial biodiversity indicators for use by regional councils (Bellingham et al. 2016), partly based on early work by Lee and Allen (2011). Understandably, most indicators were designed for monitoring the state and trend of biodiversity rather than freshwater quality. However, *change in area under intensive land use* is one indicator with LUI potential, described as changes in cover classes that can be defined as intensive (i.e. any cover class that is not considered terrestrial native biodiversity). The intent was to use 'cover classes' from the LCDB, but the specific classes were not offered. Further, it was proposed that measures of 'disturbance intensity' need to be developed to tag against each cover class, and a method was presented.

6.4 Conclusions

We did not identify any singular indicator of LUI pressures that could be used across all land-use types and domains. An exception may be global indicators such as carbon emissions and energy use, but these are highly generalised and convey little understanding of the nature of the pressure without additional contextual information.

At least 13 LUI pressure indicators are already promoted as national LUI indicators (drawn from the freshwater and land domains). Those with a spatial dimension could be improved with refinements in method, and through improvements in better access to land-use data.

SoE reporting and indicator development by regional and territorial authorities does not appear to be as prevalent as it was two decades ago. For regional councils, the more significant opportunities may be for developing indicators from resource consents (effluent to land, discharges to water, land-use consents, etc.), and from the unique land-use data sets that some councils hold and maintain.

For territorial authorities, strong potential for LUI indicator development exists for urban land use, especially regarding subdivision (actual and planned change in urban use type), wastewater and stormwater management, contaminant risks, and solid waste management. However, the types of data and the way they are recorded can be highly variable between councils, creating issues for the ease and validity of data collation for national reporting purposes.

Only a small number of LUI indicators with a high potential for immediate reporting were identified. A wider variety of potential LUI indicators could be developed, but specifics about method and quality could not be gauged because of limited access to data sets.

6.5 Recommendations

Consideration should be given to affording greater prominence to existing national indicators that already qualify as LUI indicators. Thirteen existing national indicators were identified. Suggestions have been made for indicator refinement.

Land-use data and indicators associated with regional and territorial authorities could offer new opportunities for national LUI indicator development. We were unable to fully investigate this potential within the scope of this project, and thus recommend further investigation to more clearly document existing indicators, land-use and related data sets, and the potential for collective council reporting for a national LUI purpose.

Land-use intensity indicators considered suitable for immediate or near-immediate reporting are few, largely owing to data access restrictions. Potential options include:

- reporting Agriculture Production Survey statistics by special catchment aggregations, where the degree of aggregation is optimised by Stats NZ confidentiality rules
- reporting the extent of artificially drained land – drainage of wet soils and wetlands allows land to be used more intensively for agricultural and recreational purposes, and the extent of artificially drained land has been estimated by MWLR for 2018 and may qualify as a case study or as supporting information
- developing new LUI indicators by generating enhanced land-use layers to improve reporting accuracy and detail.

Options for developing new LUI indicators are greater, but our ability to fully explore the potential is again constrained by having limited data access, especially to those relating to urban environments. Following are the key options with a strong spatial dimension.

- *Value of improvements* (investment in infrastructure, etc.) should be considered as a potential LUI indicator because it can be readily calculated from valuation data and expressed in map form at the parcel ownership scale. This indicator has been proposed through the workshop, but further work may be required to more fully explore the link with freshwater quality.
- Enhanced land cover indicators developed from advances in remote sensing, for more detailed monitoring around changes in riparian, soil conservation, bush fragments, and within-paddock covers, and for the development of new intensity indicators such as pasture productivity. This is an active research area and we expect new types of indicators to emerge in the next 2−3 years.
- *National farm stocking rate (livestock)* is a key indicator. While easy to calculate, significant data quality concerns currently limit further development as a national indicator. This may be resolvable using a multi-data cross-validation framework, that brings together and validates livestock data from commercial interests (e.g. Agribase), government (e.g. Farms Online and NAIT), and the livestock industry.

7 National data sets for developing land-use intensity indicators

7.1 Introduction

Our project brief required a pre-workshop identification of NZ land-use data sets. The purpose was to ensure we could provide an introduction to NZ land-use data sets that the workshop participants could build upon (see Theme 2 of the Workbook, section 4.3). In this section we expand on the pre-workshop identification to more fully describe potential data sets. Both data access and quality are of paramount importance to any indicator development project.

The method used draws heavily on studies and investigations that MWLR have undertaken for past projects. In particular, the Agricultural Production Census property matching project (Ausseil et al. 2015; Stats NZ 2015), the development of the NZ Land Use Classifier (Manderson et al. 2018), the Geospatial Land-use Classification for NZ (Rutledge et al. 2009), a GIS-based land-use map for Southland (Rutledge et al. 2016), and the grassland improvement mapping using innovative data analysis (IDA) techniques (Manderson et al. 2019). The reader is referred to these reports for a more technical considerations of the lineage, accessibility, and quality of various national data sets. Context varies from modelling for freshwater impact indicators through to data standardisation via land-use classification.

7.2 Results

7.2.1 The Land Cover Database (LCDB 1-5)

The New Zealand Land Cover Database (LCDB) is a digital map of the land cover of New Zealand created using satellite imagery. It contains detailed information on 33 classes of land cover and their boundaries, and is a record of land cover changes over time. Four versions have been released (1996, 2001, 2008, 2012), and MWLR have just released LCDB-5 (2018).

The LCDB is a national data set, which is quantitative and publicly available, achieves high accuracy (Dunningham et al. 2000), is regularly updated, and readily achieves indicator selection criteria. However, the breadth of classifications is limited, and the data set contains minimal land-use information and no land-use activity data (e.g. livestock numbers). Positives far outweigh the limitations, such that the LCDB is already used as a stand-alone national *land cover* indicator, and features as a critical input into the development of other indicators (e.g. *indigenous cover and protection in land environments*). Additional derivative indicators – such as the ratio of high- to low-producing grassland – are also increasingly possible through improvements in satellite imagery data and image-processing techniques (John Dymond, MWLR, pers. comm.).

7.2.2 LUCAS Land Use Map

The Land Use Map (LUM) is a component of the Land Use and Carbon Analysis System (LUCAS), which is being implemented by MfE to meet New Zealand's reporting requirements under the Kyoto Protocol. LUM is a national spatial database, mapped using LCDB methods but with 12 'land use' classes tailored to carbon accounting and Kyoto requirements. LUM has been mapped for 1990, 2008, 2012 and 2016.

The LUM has relevance similar to that of the LCDB but carries the additional limitation of having fewer classes. However, unlike the LCDB, the LUM has expanded to include land use and an alternative accounting of high- and low-producing grasslands (Manderson et al. 2019).

7.2.3 AgriBase™

The AgriBase is a national spatial farms database that contains data representing approximately 135,000 farms and rural blocks. Each record has a 'farm type' classification (34 classes), and enterprise data such as farm size, animal numbers by stock class, and planted/cropped areas. These data are commercially available under licence for most uses according to the principles of the Privacy Act 1993. (See Ausseil et al. 2015 for further detail.)

The key advantage is that AgriBase represents the only readily accessible national spatial farm data set for NZ (under a commercial licence). However, it has a low to modest level of farm activity data (e.g. no fertiliser record), the enterprise data within a farm are not spatially distributed (e.g. crops), and records span many years (not a snapshot in time). For these reasons we suspect that any LUI indicator developed from AgriBase would be unlikely to achieve national indicator quality standards.

7.2.4 Farms Online and NAIT

Farms Online (FOL) is a spatial database of NZ livestock farms and lifestyle blocks. It is managed by the MPI's Biosecurity New Zealand as an emergency response tool. The database records address and ownership details, land-use type (ratings classifications), crop, and stock types. FOL farm IDs can be linked with livestock records from the National Animal Identification and Tracing (NAIT) programme. Collectively, both represent a national data collection of farms and livestock movements, but both are also restricted data sets with an unknown quality and reliability for indicator development.

However, despite having restricted access, these data sets in the past have been made available to researchers for research purposes. We understand that director-general approval is required. MWLR's attempts to gain access for research purposes have to date been unsuccessful. Feedback from other interests suggests FOL may have value as an alternative farm database (i.e. has farm delineations and a land-use type classification), but is unlikely to be vastly different from the AgriBase or CoreLogic data sets. Access to NAIT, in principle, offers a potentially rich source of high-quality livestock data (possibly the best that can be accessed in terms of quality and currency in a national sense), but considerable processing would be expected to make it applicable to indicator development.

7.2.5 Council data sets (regional and territorial)

Regional and territorial authorities maintain their own data sets for land-use and related data (e.g. resource consents). We are not fully clear on what specific data types may be available, as different councils have different capabilities, resourcing, and issues (i.e. each tends to meet their ends in different ways). Resource consents are one potential source of detailed land-use information. Another is 'farm plan' data sets constructed under both voluntary and regulatory programmes. These can be a rich source of farm management data. Voluntary examples include Horizons Sustainable Land Management Initiative (SLUI), Greater Wellington's WRECI programme, and Taranaki's STRESS programme. Examples of regulatory programmes include Horizons 'intensive farms' farm plans, ECan's Farm Environmental Plans (FEPs), and Waikato Regional Council's FEPs under Plan Change 1 (WRC are establishing a 'farm plan' database).

The opportunities regarding council data sets are still unclear, as much of the data is collected under public licence and funding, but there is a conflict around sharing data that could be considered commercially or environmentally sensitive. Further, coverage is likely to be sporadic, and currently we expect a sizeable effort would be required to obtain, collate and standardise much of these data. However, we also foresee that the collection of these data will continue to grow and the related council data management systems will continue to improve.

7.2.6 Industry and industry-good data sets

Private industry and industry-good organisations maintain their own national data sets. Examples include:

- Beef+Lamb NZ Farm Survey: an annual survey of approximately 500 sheep and beef farms (the key advantage is that consistent annual data are available for an extended period)
- Foundation of Arable Research (FAR) ProductionWise: rich cropping and arable data in a spatial database (contribution is voluntary)
- Fonterra farm data: Fonterra maintains milk production records and whole-farm nutrient budgets for all its suppliers
- DairyBase and other DairyNZ data: DairyBase holds detailed farm data for approximately 2,500 dairy farm businesses –(contribution is voluntary)
- Livestock Improvement Corporation (LIC) data: LIC maintains a national dairy cow breeding programme and regularly collects data from NZ dairy farms
- fertiliser companies, including Ballance AgriNutrients and Ravensdown (both hold client data on soil tests [soil fertility levels] and fertiliser sales)
- the Fertiliser Manufacturers Research Association.

Industry data sets have the potential to contain high-quality land-use and land management information. We feel that it is generally unlikely that access would be universally granted for national reporting purposes unless the data were provided in an aggregate form.

7.2.7 Nationwide valuation data sets

Territorial authorities are responsible for producing the District Valuation Role (DVR). Most councils manage their DVR through private providers such as Quotable Value or Opteon. LINZ are responsible for auditing DVRs, while Corelogic has a data-standardising and filtering role. Corelogic also make available the collective DVR for all of NZ as a single data set (for commercial purchase). Among other things, the Corelogic data set contains a land-use classification, and valuation data that have relevance to some economic indicators.

Valuation data are nationally consistent, updated regularly, and accessible for a fee. Data are provided in table form that can be linked to LINZ cadastral data via parcel IDs. The land-use classification developed for valuation purposes covers all land uses (unlike rural databases). Unfortunately, valuations made every 3 years may not involve a visit and site re-evaluation of land use, which means the land-use classification may in many cases be out of date. Further, spatial parcel matching is a difficult process because of one-to-many relationships. Despite these challenges, we believe the valuation data set has a strong potential for future LUI indicators provided greater monitoring surety can be provided around the land-use classification.

7.2.8 Government censuses and national surveys

Data on every NZ household collected through the national census may have value for urban indicators. Data collected as part of the Agricultural Production Survey (APS) has value for the development of rural land-use indicators. Both represent nationally consistent data from large populations (i.e. all households, and all farm businesses listed in the Statistics NZ Business Framework).

For spatial applications, data are usually only available at an aggregate level (e.g. meshblocks) to protect confidentiality. Access to individual records is strongly restricted. Matching APS records to parcels or farms has been attempted (Stats NZ 2015) but with only partial success. Addresses used by agents (e.g. solicitors) or absentee owners can produce erroneous parcel matching and aggregate results. We rate this data source as having a high potential for LUI indicator development.

7.3 Conclusions

- There is no single authoritative land-use data set available for NZ. Hence, data accessibility for developing LUI indicators is a significant issue. Data sets do exist, but access is limited in terms of commercial licensing, confidentiality, and in some cases limited standardisation across agencies. There are also uncertainties relating to data types, completeness, and quality. Some industries are prepared to discuss data sharing, but only as data shared in aggregate form.

7.4 Recommendations

- Consider developing a collaborative exploration initiative with industry, councils, and other ministries of 'what might be possible' if data from multiple sources were made available for LUI indicator development under strict usage agreements similar to those used by Stats NZ with data lab access. This would allow a deeper dive into what might be possible.
- We predict that the volume and quality of land-use data collected and managed by councils will only increase. We recommend proposing a cross-council integrated project that seeks to design and test a broader data-commonality framework expressly for national reporting.

8 Conclusions and way forward

The development of LUI indicators should continue, but the approach and time frame need to be reappraised. The workshop demonstrated that land-use intensity and related indicator development is a large and complex area, and despite our best efforts we have only touched the surface. We echo a view from the workshop that it should be regarded as a first but important step, but further work is required in a staged way towards a cumulative, high-quality goal.

8.1.1 Clarifying the land use intensity definition

Based on the literature review and workshop findings, we recommend defining land-use intensity as a **measure of human activity concentrated per unit area and time**. Human activity can be measured as inputs (e.g. amount of fertiliser), outputs (e.g. yields), emissions (e.g. nitrogen, phosphorus, *Escherichia coli*, air emissions), efficiencies, frequencies (e.g. cultivation), or densities (e.g. housing density).

8.1.2 Proposing new or improved LUI indicators

We recommend investing in improving existing national indicators that already qualify as LUI indicators. Suggestions are made to improve 13 current and recent national indicators from both the freshwater and land domains.

There are very few LUI indicators that we consider suitable for immediate or near-immediate reporting to a national indicator standard. Among the options highlighted in section 6.2, we prioritise in particular:

- reporting *Agriculture Production Survey / Census statistics by special catchment aggregations*, where the degree of aggregation is optimised to remove the risk of tripping Statistics NZ confidentiality rules (the example in this report demonstrates catchment LUI indicators for dairy numbers, fertiliser use (super phosphate and urea), irrigated land, cropping area, and dairy effluent land application area)
- reporting *the extent of artificially drained land in NZ* – drainage of wet soils and wetlands allows land to be used more intensively for agricultural or recreational

purposes, and the extent of artificially drained land has been estimated and may qualify as a case study, or as supporting information

- generating *enhanced land-use layers*, to improve reporting accuracy and detail.

Options for developing new LUI indicators are far greater, but our ability to fully explore their potential is again constrained by having limited data set access, especially for those relating to urban environments. Key options from section 6.3 include:

- indicators from *enhanced land cover mapping* to capitalise on advances in remote sensing, for more detailed monitoring of changes in riparian, soil conservation, bush fragments, and within-paddock covers, and for the development of new intensity indicators such as pasture productivity – this is an active research area and we expect new types of indicators to emerge in the next 2–3 years
- *national farm stocking rate* (livestock) is a key indicator – while easy to calculate, significant data quality concerns currently limit further development as a national indicator, although this may be resolvable using a multi-data cross-validation framework that brings together and validates livestock data from commercial interests (e.g. Agribase), government (e.g. Farms Online and NAIT), and the livestock industry.
- *value of improvements* (investment in infrastructure, etc.) as a potential LUI indicator, as it can be readily calculated from valuation data and expressed in map form at the parcel ownership scale – this indicator has been proposed through the workshop, but further work may be required to more fully explore the link with freshwater quality

Land-use data and indicators that are specific to regional or territorial authorities could offer new opportunities for national LUI indicator development. We have begun identifying such opportunities, but recommend further investigation to more fully examine existing indicators, land-use data sets, and the potential for council reporting for a collective national LUI purpose.

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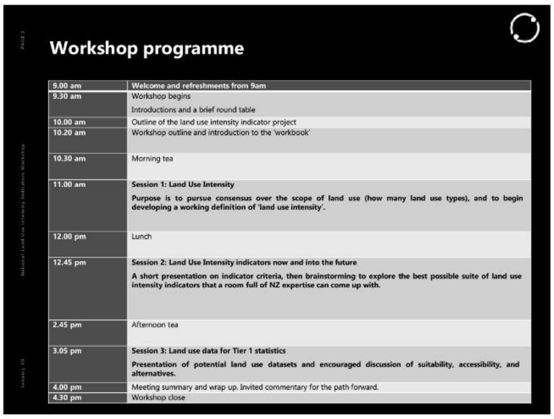
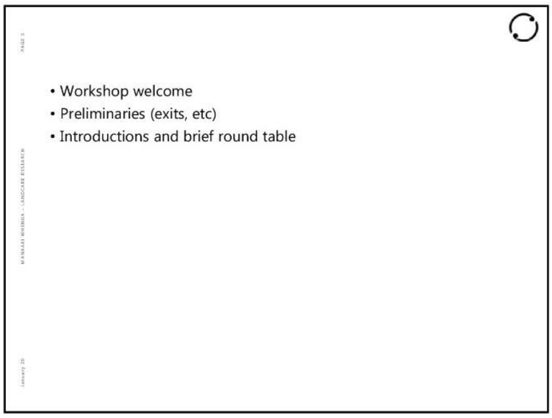
Appendix 1 – Workshop material

Presentation slides

1



2



3

4

5

6

Who's involved?

- Aiming to get expert advice and agreement on how to define urban and rural land use intensity that meets the needs of environmental reporting, but also resonates with stakeholders
- Data holders – understand where data currently exists, how it can be improved and where we can encourage new datasets to be created

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Outputs

- Report detailing:
  - Definition of land use intensity
  - Recommended indicator of land use intensity, including where data can be sourced, how the indicator should be analysed, limitations, caveats, etc
  - Recommendations for improving the indicator
  - Future state – what would be the ideal indicator? Where would we need to invest?

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Outline for the day

- We want your participation, contribution, your expertise and help
- Three key themes to address during the day:
  1. A definition for land use intensity
  2. Potential land-use intensity indicators (national, multi land use, what's possible now, what's needed in the future, freshwater pressure orientated)
  3. Land use data for constructing trustworthy indicators
- Workshop programme
- We aim to maximise your input
  - Structure. Each theme is reduced to fundamental questions that need to be addressed.
  - We use a combination of different workshop methods for each theme question
- Morning tea

9

mandersona@landcareresearch.co.nz

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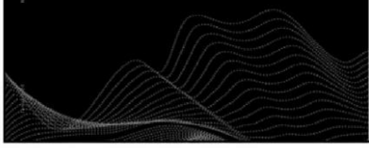
Session 1

Defining the scope of a national land use intensity indicator



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- Which land use types (scope)?
- Land use intensity definition
- Items for further investigation

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1.1 Land use types

- The current ambition is to include all land uses in a land use intensity indicator (grouped as agriculture, urban, and natural)
- But the intensity of different land use type(s) may be better described using different indicators. e.g.
  - Indicator(s) of dairy intensity vs. indicators of arable intensity
  - Indicator(s) of urban intensity vs. agricultural intensity
- Do we focus on developing:
  - One overarching intensity indicator for all uses?
  - A small but succinct set of intensity indicators to accommodate some differences between land use types?
  - Suites of intensity indicators by key land use types?
    (how do we identify key land use types – by dominance, by recognised intensity, by recognised impact on freshwater?)

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1.2 Land use intensity definition

- A selection of definitions…

"land-use intensity is the extent to which land is used. It is an indication of the amount and degree of development in an area, and a reflection of the effects generated by that development"

"agricultural intensity is defined as the ratio of inputs and outputs within an agricultural system, i.e., in terms of yield per land area and per input unit, or alternatively, as the sum of different categories of input costs and the total usable agricultural area of the farm"

"Land-use intensity (defined as the percentage of developed land per unit area)"

"land use intensity defined as the number of times the land has been cultivated"

"Although often defined as the degree of agricultural input or output per unit of area and time (Turner and Doolittle 1978), *land-use intensity can also be defined as the magnitude of impact of land-based production on biodiversity, water quality, or carbon* (Erb et al. 2013)."

"Land use intensity, defined here loosely as the degree to which humans interfere with the land"

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1.2 Land use intensity definition

- We need a definition for NZ
- Minimum criteria:
  - Sufficiently broad to apply to multiple land use types
  - Intensity ≠ environmental impact
  - Suggests scale, magnitude, or measurability
- Activity:
  - For the next 10 minutes, each group to come up with a definition of 'land use intensity'
  - Each definition will be presented on screen and discussed (15 minutes)
- What are the 3 big definition challenges we need to focus on?
- Lunch

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Land use intensity definitions

- Type here

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Session 2

Land use intensity indicators now and into the future

- What makes a good indicator?
- Our current criteria for a land use intensity indicator
- Ideas for a national land use intensity indicator

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What makes a good indicator?

- Bronwyn Newton, Statistics New Zealand
- What makes a good indicator
- Tier 1 standards

Statistics New Zealand
TATAURANGA AOTEAROA

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2.1 Criteria for a national land use intensity indicator

- The ideal scenario is a single indicator that covers all types of land use and land-use intensity
- The indicator(s) must provide insight into the pressure of land use intensity on freshwater state (and secondarily, insights into pressures on marine ecosystems, climate, and air quality)
- Any indicator(s) will need to meet standards outlined in the Principles and Protocols for Tier 1 statistics
- Ideally the indicator(s) can be expressed spatially (e.g. as a map) and aggregated for 'catchment level' reporting
- "what's possible now" but also "what's possible in the future"

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2.2 Ideas for a national indicator

- Activity
  - For the next 25 minutes, each group to come up with ideas for national land use intensity indicators
  - Each group will be asked to nominate their top selection of indicators
  - Results will be put on screen for discussion (15 minutes)
- Afternoon tea

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Potential indicators

- Type here

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Session 3

Land use data

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- Available datasets
- Potential datasets (open discussion)

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3.1 Available national datasets

- Land cover database (LCDB 1-5)
  - NZ land cover from remote sensing (33 classes)
  - Many pros but nil land use activity data
- LUCAS 'Land Use' Map
  - Similar method to LCDB but 12 classes applicable to Kyoto obligations
  - Many pros but nil land use activity data
  - But has ambitions?
- AgriBaseTM
  - Commercial, dated records, reliability considerations, basic land use activity data, agriculture only
  - Ok for modelling

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3.2 Potential datasets

- Science datasets?
- Farms Online & NAIT
  - Rich data on livestock that can be tagged to farms
  - Accessibility?
- Council land use data (regional and territorial)
  - What's out there?
  - Urban datasets?
  - New agricultural datasets (FEPs, Overseer, consents)?
  - Collation should not be underestimated

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3.2 Potential datasets

- Industry data
  - What's out there?
    - (B+LNZ production survey, FAR ProductionWise, Fonterra, DairyBase, fert companies, LIC...)
  - Under what conditions could access ever be gained?
- Valuation data
  - CoreLogic, QV, Opteon (Landmass Tech), TAs
  - Accessibility? Quality?
- Government land use and property data
  - Censuses and surveys
  - Spatializing the data (reliably) (data matching, property id)
  - Accessibility

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Workshop summary

- Summary questions (workbook)
- Invited feedback (if time permits)
- Workshop close

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- Big thanks to everyone here today
- Special thanks to co-presenters Lauren & Bronwyn
- Extra special thanks to Christine Harper and Kelsey Wood who invested a lot of background effort with the workshop organisation

- Please don't forget to hand back your (named) workbooks
- Travel safe

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Background notes

Background notes for The National Land Use Intensity Workshop

Introduction

These notes are provided as background reading for participants in the National Land Use Intensity Workshop to be held in Wellington on the 13th February 2018.

Scoping a national land use intensity indicator project

The Ministry for the Environment (MfE) and Statistics New Zealand (Stats NZ) are responsible for reporting on New Zealand's environment. Reporting is undertaken every 6 months for specific domains, and once every three years for the environment as a whole. Reporting is achieved largely through the use of pressure, state, and impact indicators within an environmental reporting framework.

MfE and Stats NZ have recently initiated a scoping project to investigate the development of a **national land use intensity indicator** according to the following initial criteria:

- The ideal solution is a **single indicator** that covers all types of land use and land-use intensity.
- The indicator must meet standards and guidelines for **Tier 1 statistics**.
- The indicator must provide insight into the **pressure of land use intensity on freshwater state** (and secondarily, insights into pressures on marine ecosystems, climate, and air quality).
- The indicator should be spatial in that it can be expressed as a national map, and the indicator can be aggregated to 'catchment level' for reporting.

The National Land Use Intensity Workshop

A workshop has been organised to shape the development of any potential indicator. The purpose of the workshop is to explore:

- A definition for NZ land use intensity.
- Potential indicators of NZ land use intensity.
- Data resources to underpin the development of any potential indicator(s).

Results from the workshop will be used to guide and focus the preparation of a report with recommendations for the three themes listed above. Manaaki Whenua Landcare Research (MWLR) are contracted to run the workshop and lead preparation of the report. Neither MfE, Stats NZ, nor MWLR claim to have all the answers, so the expertise attending the workshop is critical to promote successful indicator development.

Workbook and agenda

Name: ______________________________

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National Land Use Intensity Indicator Workshop

Wellington, Tuesday 13th Feb 2018, 9.30am to 4.00pm

Terrace Conference Centre, 114 The Terrace, Wellington (Te Aro 1 room)

Workshop programme

9.00 am	Welcome and refreshments from 9am
9.30 am	Workshop begins
	Introductions and a brief round table
10.00 am	Outline of the land use intensity indicator project
10.20 am	Workshop outline and introduction to the 'workbook'
10.30 am	Morning tea
11.00 am	**Session 1: Land Use Intensity** Purpose is to pursue consensus over the scope of land use (how many land use types), and to begin developing a working definition of 'land use intensity'.
12.00 pm	Lunch
12.45 pm	**Session 2: Land Use Intensity indicators now and into the future** A short presentation on indicator criteria, then brainstorming to explore the best possible suite of land use intensity indicators that a room full of NZ expertise can come up with.
2.45 pm	Afternoon tea
3.05 pm	**Session 3: Land use data for Tier 1 statistics** Presentation of potential land use datasets and encouraged discussion of suitability, accessibility, and alternatives.
4.00 pm	Meeting summary and wrap up. Invited commentary for the path forward.
4.30 pm	Workshop close

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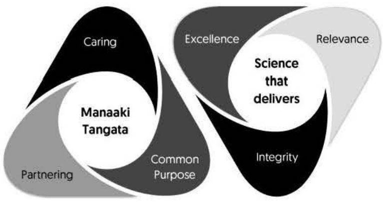

Workshop attendees

Adam Tipper (StatisticsNZ), Anne-Gaelle Ausseil (MWLR), Bronwyn Newton (StatisticsNZ), Christine Harper (MWLR), Corina Jordan (Beef+LambNZ), Dave Hodge (StatisticsNZ), Tom Stephens (DairyNZ), Deb Burgess (MfE), Evan Harrison (MfE), Ewan Kelsall (Fed Farmers), Fiona Curran-Cournane (Auck RC), *Gerald Rhys* (MPI), Haydon Jones (Waikato RC), James Barringer (MWLR), Kelsy Wood (MWLR), Lauren Long (MfE), Mike Scarsbrook (Fonterra), Nick Pyke (FAR), Richard McDowell (OLW & AgResearch), Robyn Simcock (MWLR), Stephen Groves (StatisticsNZ), Ton Snelder (OLW & NIWA), Andrew Manderson (MWLR), Baz Paker (MfE), Mike Judd (LINZ).

Workbook

The number of workshop participants (23-25) is at the higher end of what's considered optimal for running an effective workshop. Higher numbers may mean that some miss opportunities to fully express ideas and feedback within session time frames.

In the following pages we have provided a 'workbook' available to anyone who wishes to capture their thoughts and ideas on paper (particularly those ideas and thinking that doesn't make it into the discussions).

The 'workbook' is arranged by key themes expressed as questions, with space beneath to make notes.

The workbook is available as a Word document for those who may have a laptop.

We would like to collect these workbooks at the end of the workshop.

Workshop organisation

This workshop is organised and facilitated by Manaaki Whenua Landcare Research on behalf of the Ministry for the Environment and Statistics NZ.

Theme 1: Defining the scope of a national land use intensity indicator(s)

1. What are the key land use types that need to be included in a national land use intensity indicator for New Zealand? And why?

2. What is land use intensity? What are some examples? What might a workable definition for NZ 'land use intensity' look like? (Note: Should encompass rural and urban).

3. What are the 3 key challenges regarding a definition of NZ land use intensity that require further investigation?

Theme 2: Ideas for a national land use intensity indicator

4. Can you add to, or comment on, the criteria that have been proposed for a national land use intensity indicator?
   - The ideal scenario is a ***single indicator*** that covers all types of land use and land-use intensity
   - The indicator(s) must provide insight into ***the pressure of land use intensity on freshwater*** (and secondarily, insights into pressures on marine ecosystems, climate, and air quality)
   - Any indicator(s) will need to meet standards outlined in the Principles and Protocols for ***Tier 1 statistics***
   - Ideally the indicator(s) can be expressed spatially (e.g. as a map) and aggregated for 'catchment level' reporting

5. Please list (and describe if necessary) any ideas you may have for land use intensity indicators.

   Please consider both current and future indicators, along with multiple land use types (e.g. rural, urban, etc.)

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Theme 3: Land use data

Trustworthy national data are required for trustworthy national indicators.

6. For the following national data resources, please comment on their:
    a. Suitability for deriving a national land use intensity indicator
    b. Possible improvements to improve their future usability, including how to improve accessibility

The Land Cover Database (LCDB 1-5)

(contains nil land use activity data)

LUCAS 'Land Use' Map

(contains nil land use activity data)

AgriBase™

(commercial, dated records, reliability questions, basic land-use activity data)

Valuation datasets (Corelogic, Quotable Value, territorial authorities)

(commercial, subjective classes, dated records, limited land-use activity data, reliability questions)

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Farms Online and NAIT

(accessibility, transparency, specific land use activity data only)

Science datasets

What's available and what is possible?

Council data (regional and territorial)

What's available and what is possible?

Industry and industry-good data

What's available and what is possible?

Government censuses and national surveys

What's available and what is possible?

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7. Are there any national land use datasets we have not identified? Please list and briefly describe, including their usability and accessibility.

Summary questions

8. In your own opinion, which **indicator(s)** are most worthy of further investigation?

9. In your own opinion, which **data resources** are most worthy of further investigation?

10. Do you have any general comments to offer regarding the workshop?

Many thanks for your participation in today's workshop. Please return this workbook to help us define the next steps towards a national land use intensity indicator.

Appendix 2 – Common land-use and land-cover classes

Table A2.1 Agribase farm type and enterprise types

Farm type classes	
Code	**Description**
ALA	Alpaca and/or llama breeding
API	Beekeeping and hives
ARA	Arable cropping or seed production
BEF	Beef cattle farming
DAI	Dairy cattle farming
DEE	Deer farming
DOG	Dogs
DRY	Dairy dry stock
EMU	Emu bird farming
FIS	Fish, Marine fish farming, hatcheries
FLO	Flowers
FOR	Forestry
FRU	Fruit growing
GOA	Goat farming
GRA	Grazing other people's stock
HOR	Horse farming and breeding
LIF	Lifestyle block
NAT	Native Bush
NEW	Unconfirmed farm type
NOF	Not farmed
NUR	Plant Nurseries
OAN	Other livestock (not covered)
OPL	Other planted types (not covered)
OST	Ostrich bird farming
OTH	Not covered by other classifications
PIG	Pig farming
POU	Poultry farming
SHP	Sheep farming
SNB	Mixed Sheep and Beef farming
TOU	Tourism (i.e. camping ground, motel)
UNS	Unspecified (ie farmer did not say)
VEG	Vegetable growing
VIT	Viticulture, grape growing and wine
ZOO	Zoological gardens

Farm enterprise data	
Name	**Description**
AAA_HA	Land area devoted to livestock
ARA_HA	Arable Land
BEF_Nos	Beef cattle numbers
BERR_HA	Berry fruit
BISO_Nos	Bison numbers
CAM_Nos	Camelids (alpacas and llamas)
CITR_HA	Citrus fruit
DAI_Nos	Dairy Cattle numbers
DEE_Nos	Deer numbers
DOG_Nos	Dogs
DONK_Nos	Donkeys
DUCK_Nos	Ducks
EMU_Nos	Emus
FLOW_HA	Flowers
FODD_HA	Fodder
FOR_HA	Forestry
FRUU_HA	Undefined Fruit
GOAT_Nos	Goats farmed
GRAZ_HA	Grazing other people's stock
HERB_HA	Herbs/Medicinal Plants
HORS_Nos	Horse numbers
KIWF_HA	Kiwifruit Orchards
NAT_HA	Native Bush
NURS_HA	Nursery
NUTS_HA	Nuts
OANM_Nos	Other Animals
OFRU_HA	Other Fruit
OLAN_HA	Other Land Use
OSTR_Nos	Ostrich numbers
OTH_HA	Idle land or planned redevelopment
PIGS_Nos	Pig numbers
PIPF_HA	Pipfruit
POU_Nos	Poultry birds
SHP_Nos	Sheep numbers
STON_HA	Stone Fruit
VEG_HA	Vegetable Growing
VITI_HA	Viticulture

Table A2.2 LUCAS LUM classifications 2016

Class	Subclass
Cropland – Annual	Unknown
Cropland – Perennial	Unknown
Grassland – High producing	Grazed – dairy
	Grazed – non-dairy
	Ungrazed
	Unknown
Grassland – Low producing	Grazed – dairy
	Grazed – non-dairy
	Ungrazed
	Unknown
Grassland – With woody biomass	Unknown
Natural Forest	Unknown
	Wilding trees
Other	Unknown
Planted Forest – Pre-1990	Douglas fir
	Pinus radiata
	Unknown
	Unspecified exotic species
Post 1989 Forest	Douglas fir
	Pinus radiata
	Regenerated natural species
	Unspecified exotic species
	Wilding trees
Settlements	Unknown
Wetland – Open water	Human induced
	Naturally occurring
	Unknown
Wetland – Vegetated non forest	Peat mine
	Unknown

Table A2.3 Land Cover Database, 5 classes

Name_2018
Alpine Grass/Herbfield
Broadleaved Indigenous Hardwoods
Built-up Area (settlement)
Deciduous Hardwoods
Depleted Grassland
Estuarine Open Water
Exotic Forest
Fernland
Flaxland
Forest - Harvested
Gorse and/or Broom
Gravel or Rock
Herbaceous Freshwater Vegetation
Herbaceous Saline Vegetation
High Producing Exotic Grassland
Indigenous Forest
Lake or Pond
Landslide
Low Producing Grassland
Mangrove
Manuka and/or Kanuka
Matagouri or Grey Scrub
Mixed Exotic Shrubland
Not land
Orchard, Vineyard or Other Perennial Crop
Permanent Snow and Ice
River
Sand or Gravel
Short-rotation Cropland
Sub Alpine Shrubland
Surface Mine or Dump
Tall Tussock Grassland
Transport Infrastructure
Urban Parkland/Open Space