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SHIFTING FROM LAND-USE CAPABILITY TO LAND-USE SUITABILITY IN THE OUR LAND & WATER NATIONAL SCIENCE CHALLENGE

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Abstract

The need for simultaneous improvements in primary sector productivity and in environmental performance are driving changes in land and water policy and management in New Zealand. The intent of these changes is sustainable productivity within the limits of land and water resources. Implementing these changes will require a shift from the traditional focus on land-use capability for production, to a broader view that accounts for effects of land use on environmental, social, cultural and economic values at multiple spatial and temporal scales. We call this broader view 'land-use suitability' (LUS). Our premise is that incorporating LUS in managing the effects of land use and land evaluation can reduce the degradation of values and maintain productivity. The LUS programme in the Our Land & Water National Science Challenge will develop tools needed to incorporate LUS in land management (e.g., through mechanisms in regional water plans) and land evaluation. These tools will have three properties that ensure their utility: 1) spatially explicit links between source areas of land-use pressures and receiving environments (surface water, groundwater, soil) where responses to those pressures occur; 2) consideration of the resilience of receiving environments; and 3) consideration of interventions that increase resilience, and risks incurred by interventions. In the first phase of the LUS programme, we will develop a classification-based tool called LUS Spatial Explorer that uses national environmental datasets and pressure-response models to categorise relationships between source areas and receiving environments.

Key words: Our Land & Water, land-use suitability, receiving environments, classification, resilience, interventions, land and water plans.

Introduction

Land and water management in New Zealand has recently entered an era in which 'managing within limits' is both a guiding principle and a legislative requirement (Rouse et al. 2016). Managing within limits refers to managing resource use without exceeding limits such as water takes and contaminant discharges (McDowell 2015, Scarsbrook and Melland 2015). Limits on resource use are intended to ensure that objectives set for receiving environments are achieved. One of the drivers for managing within limits is the National Policy Statement for Freshwater Management 2014 (NPSFM; New Zealand Government 2014). The NPSFM requires regional councils to set objectives for freshwater receiving environments and to define in plans the resource-use limits needed to achieve those objectives. Several councils are using community collaborative processes to define objectives (Arunachalam 2016, Harmsworth et al. 2016). Widely recognised freshwater objectives include appropriate trophic state (e.g., low periphyton and phytoplankton concentrations), soil fertility, sustainable freshwater fisheries, 'swimmability' (i.e., low risk of infection by faecal pathogens in recreational waters), and sustainable populations targeted for customary harvest.

In the NPSFM, freshwater objectives refer to intended environmental outcomes regarding values in freshwater management units. Compulsory national values are included that relate to ecosystem health and to human health for recreation, and there is provision for inclusion of other national values and values that regional councils consider appropriate (which may be identified through community consultation). In this essay, we define values more broadly as economic, environmental, social and cultural (EESC) properties and processes that are highly valued by New Zealand communities. We also consider a wider range of receiving environments that includes coastal waters, aquifers and soils as well as rivers and lakes (MacDiarmid et al. 2013, Thrush et al. 2013, Schiel and Howard-Williams 2016, Ministry for Primary Industries 2015).

Developing and applying limits and managing within them pose major challenges for the science, government and primary sectors. Substantial advances in catchment science and planning are needed to formulate limits for achieving different objectives in different receiving environments (Snelder et al. 2014, Rouse and Norton 2016). For the primary sector, limits on resource use are likely to influence land-management choices, the value of assets and the desirability of investments. For example, in catchments where contaminant load limits have been set, the range of profitable land uses for a given parcel may be limited by the risk of exceeding limits; this risk may be an impediment to gaining consents and a disincentive for investment (Daigneault et al. 2012, McDowell et al. 2016). The NPSFM addresses two general types of limits, limits to abstraction (e.g., surface water and groundwater abstraction for irrigation), and limits to contaminant losses and loads (e.g., nitrogen, phosphorus, sediment and bacterial loads). In this essay, we focus on contaminant losses and assume that limits are specified by loads. In this context, managing within limits means ensuring that land-derived contaminant loads do not exceed acceptable loads.

One of the fundamental changes required to manage within limits is a shift in land management and land evaluation from the traditional focus on land capability for sustained production to a broader view that accounts for both land capability and effects of land use on EESC values. We term this broader perspective 'land-use suitability' (LUS) to distinguish it from the narrower perspective of 'land-use capability' (LUC) (McDowell et al. 2015). Here we set out the case for a new, LUS-based system to facilitate managing within limits. Our premise is that incorporating LUS in resource management plans and land evaluation can help reduce adverse effects of land use pressures on rivers, soils and other receiving environments.

The LUS system

The LUS system is intended to contribute to two important functions in the government and primary sectors, land-use effects management and land evaluation. These functions have different purposes and characteristic spatial scales, and are generally undertaken by different stakeholders. Land-use effects management is a regional council responsibility that is implemented through policies and rules in regional and catchment plans. Predicting and managing contaminant generation and loss are increasingly important components of regional and catchment plans (Rouse et al. 2016), and plans increasingly contain limits in addition to policies (e.g., Waikato Regional Plan Variation 5, Horizons One Plan) for managing the effects of specific land-based contaminants (e.g., nitrate) and to achieve specific objectives (e.g., lake trophic state, periphyton abundance).

In contrast to council-led land use effects management, land evaluation is undertaken by a range of stakeholders with interests in the profitability and use of land parcels, including land owners, investors, banks, and rural professionals. Land evaluation refers to assessments of land parcels in terms of their potential for specific land uses (Dominati et al. 2016). Conventional land evaluation does not consider the impact of land use beyond the land parcel boundary. In New Zealand, a national-scale LUC classification system is well established tool for land evaluation (Lynn et al. 2009). Land evaluation and farm planning tools have evolved rapidly in the last 10 years, as indicated by the recent appearance of several farm-scale simulation models (Doole and Romera 2015, McDowell et al. 2015). These models are designed to identify land-use configurations and/or mitigation measures that maintain or optimise profitability while minimising contaminant loss or water use.

As noted above, one of the primary goals for council-led land-use effects management is to restrict contaminant loss. Regulations set out in regional water plans are justified by demonstrating that they are needed to achieve objectives in downstream receiving environments. A distinguishing characteristic of the proposed LUS system is feedback from receiving environments to upstream land parcels. This feedback accounts for the character and physical conditions in the receiving environments (e.g., lake and estuary residence times and circulation, river flow regimes, soil texture and organic content), the contaminants to which those receiving environments are vulnerable, and the environmental objectives that are set to support EESC values. Collectively, the intrinsic characteristics of receiving environments determine their resilience (Thrush et al. 2008, Shallenberg et al. 2011, Corstanje et al. 2015).

In this essay, resilience refers to the capacity of receiving environments to resist or recover from perturbations to their state caused by land use pressures. Natural resilience can be enhanced by human interventions that reduce the concentration or exposure of land use pressures in receiving environments (e.g., lake flushing, sediment capping, phytoremediation; Kassam et al. 2009, Park et al. 2011) or reduce the magnitude of adverse responses (e.g., stream shading, biomanipulation, flushing flows; Burrell et al. 2014, Burns et al. 2014). Note that we distinguish here between interventions that are implemented within receiving environments, and mitigation systems that are used to reduce the generation or load of land use pressures, usually on-farm, before they reach receiving environments (McDowell and Nash 2012).

The LUS system will advance land use effects management and evaluation and facilitate managing within limits by combining information about the three processes described above: 1) contaminant losses from land-use; 2) responses of receiving environments to contaminant loading; and 3) increases in the resilience of EESC values to contaminant loading through intervention measures.

LUS assessment tools

In view of recent land use change and agricultural intensification in New Zealand (Anastasiadis and Kerr 2013), stakeholders in land and water management should benefit from the widespread use of LUS tools. However, a quantitative, customised LUS assessment to underpin every land-use decision would be prohibitively expensive. Instead, highly transferable tools are needed that can use national- and regional scale spatial information to evaluate LUS in any catchment. Most geospatial datasets in New Zealand contain information about static properties (e.g., land-cover, soils, river networks, land-use capability, denitrification potential; Snelder et al. 2005, Lynn et al. 2009, Landcare Research 2011, Lilburne et al. 2012, Pairman 2014). National- and regional-scale information about the dynamics of land-use pressures and about pressure-response relationships are more limited. Due to those information shortages, LUS assessments in most New Zealand catchments will be based on existing national-scale datasets of static properties and interpolation of pressure-response relationships to receiving environments that lack them. Environmental classifications provide a means of making those interpolations, in a non-quantitative way (Leathwick et al. 2003, Olden et al. 2012).

In the development of classification systems, quantitative data is converted to categorical or ordinal data (e.g., land cover proportions are used to assign catchments to land cover classes). As a result, interpolations based on classifications are also categorical or ordinal. Categorical and ordinal predictions are much lower in precision than quantitative predictions. Therefore, a primary use of the LUS classification would be as a screening tool. For example, the LUS classification could be used to identify receiving environments that are highly sensitive to a particular contaminant, and are connected to source areas where the risk of loss of that contaminant is high, and the connections between source areas and receiving environments have low attenuation potential. In these situations, the LUS class could indicate that a more detailed study is warranted.

The LUS classification system will be based on concatenation of three categories: land-use potential, contribution to catchment contaminant delivery, and pressure in receiving environments (Fig. 1). The rationale for this approach is that every unique pair of a land parcel and a receiving environment can be represented by a categorical description of the land parcel, the receiving environment, and the inherent potential for that land parcel to contribute to the pressures in the receiving environment. Collectively, the three categories comprise a LUS class. Although they are complex, some LUS classes will recur at multiple locations. To our knowledge, no previous land use classifications incorporate receiving environments, connectivity and economic potential of land.

Multiple existing classifications will be modified to develop the three broad categorisations listed above. For example, the source classification will be based on the LUC system (Lynn et al. 2009) and existing physiographic data. Classifications that will be considered for classifying receiving environments include the River Environment Classification (Snelder and Biggs 2002), New Zealand estuary classification (Hume et al. 2007), New Zealand lake classification (Snelder et al. 2006), and S-Map-based soil classification (Hewitt 2010, Lilburne et al. 2012). New approaches will be developed in the programme (e.g., the contaminant contribution classification), and some existing classifications will be modified to incorporate resilience. Information for the contribution classification will be provided by the

Sources and Flows programme in the Our Land and Water Science Challenge, which is undertaking a national-scale assessment of contaminant loading and attenuation in rivers.

The first application of the LUS classification will be in a web-based, spatially-explicit mapping tool, the Land Use Suitability Spatial Explorer (LUSSE). The first version of LUSSE will integrate information at the land parcel and catchment scales to generate LUS classifications for individual parcels in a catchment. The architecture for LUSSE will follow the schematic diagram in Figure 1. LUSSE will be built using the R-shiny platform (Chang et al. 2016) and a series of pre-populated look up tables. It will allow users to manipulate environmental states and/or objectives and visualise the resulting changes in LUS classes. This feature could be particularly valuable for assessing the potential impacts of changes in management actions or regional policies.

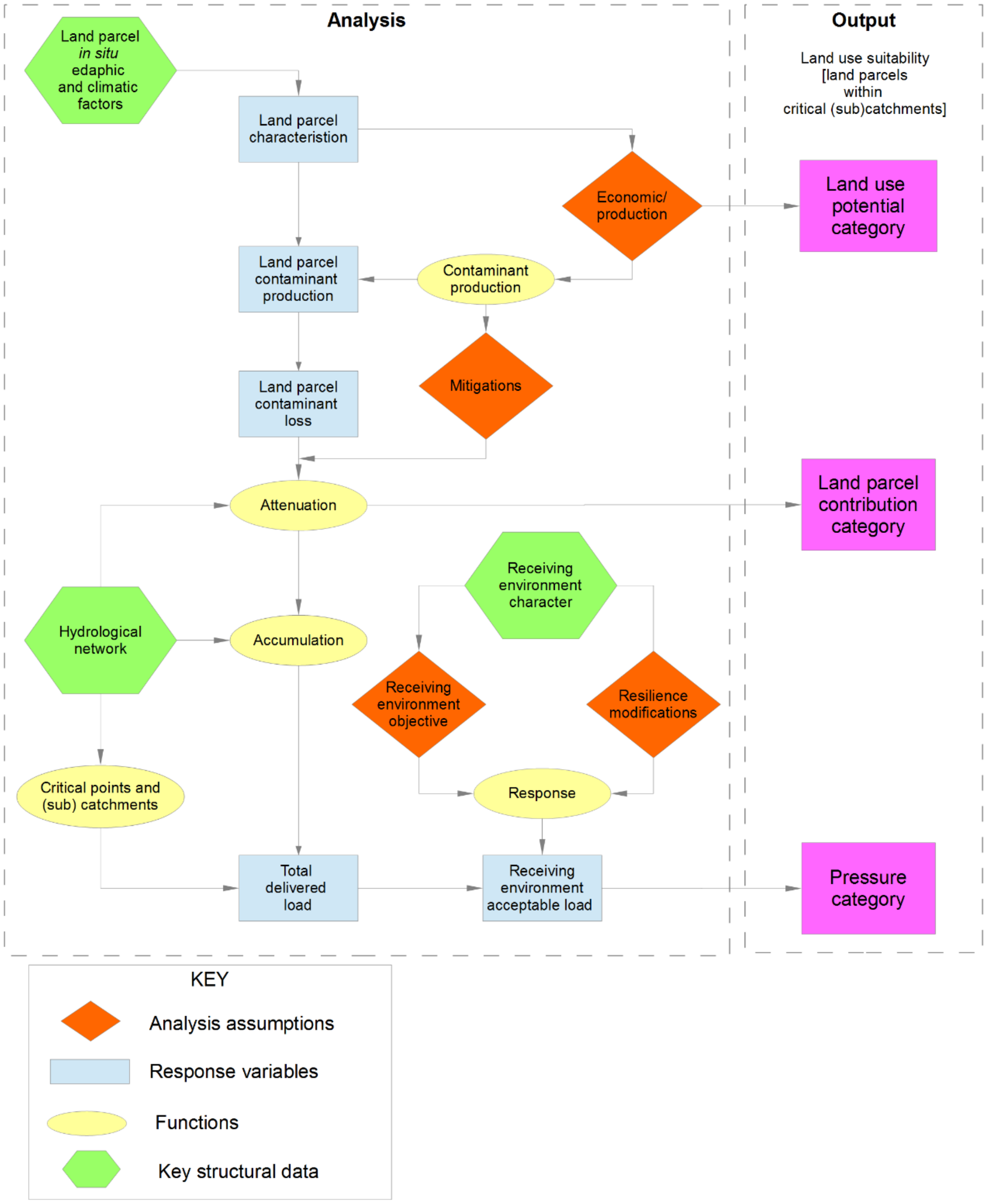

Figure 1. Schematic diagram of analysis components and outputs of the Land Use Suitability classification and the Land Use Suitability Spatial Explorer.

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