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Original Articles

The land use suitability concept: Introduction and an application of the concept to inform sustainable productivity within environmental constraints

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ABSTRACT

The Land Use Suitability (LUS) concept informs decision-making by providing stakeholders with integrated information about the economic, environmental, social and cultural consequences of land use choices. This paper addresses an application of the LUS concept: evaluating the suitability of land for sustained productivity subject to environmental constraints, as defined by water quality objectives. We refer to this application of the LUS concept as 'Productivity within Environmental Constraints' (PEC). A PEC assessment uses three indicators to evaluate land-water systems: 1) productive potential, describing the inherent productive and economic potential of land parcels; 2) relative contribution, describing the potential for a land parcel to contribute contaminants (relative to other land parcels) to downstream receiving environments; and 3) pressure, describing the contaminant load delivered to a receiving environment compared to the load that ensures that environmental objectives are met. The three indicators can be expressed categorically, mapped at catchment to national scales, and used to support strategic land assessments and plan land development and investment.

1. Introduction

Intensification of primary production to meet growing demand for food and economic well-being has the potential to degrade land, water, biodiversity and climate from farm to global scales (Foley et al., 2011; Meyfroidt, 2017). It is also increasingly recognised that land use decisions have economic, environmental, social and cultural impacts beyond the farm (Goldstein et al., 2012; Liebig et al., 2017; Renting et al., 2009). In order to address the pressures on ecosystems and society, stakeholders need information that assists in understanding the implications of land uses for the full range of desired outcomes.

There are many examples of assessments of land suitability or land evaluation assessments that have built on the USDA (Klingebiel and Montgomery, 1961) and Food and Agriculture Organization (Food and Agriculture Organization, 1976) classification frameworks (Van Diepen et al., 1991). The principles behind these frameworks include assessing the capability of the physical environment, such as climate, relief, soils, hydrology and vegetation, to support a given land use. Subsequent land evaluation systems described the biophysical constraints that limit sustained productivity and quantified production in that context (Lynn et al., 2009; Mueller et al., 2010). Production constraints include soil properties (e.g., depth, water holding capacity, erodibility), climatic conditions (e.g., rainfall, growing degree days) and risks posed by climate change. We use the term land suitability to generically refer to frameworks used to assess the capacity of land to support primary production.

As pressure to increase food production, economic prosperity and environmental sustainability grows, land suitability assessments will need to move beyond a narrow focus on agricultural productivity, and involve a broader range of factors (Foley et al., 2005). Attention has recently turned to the ways in which concepts such as ecosystem services, including contaminant assimilation, transformation and removal,

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can encourage a broader view of land suitability when considering sustained primary productivity (Doody et al., 2016; Liebig et al., 2017; Renting et al., 2009). While there are examples of systems that assess the potential of land parcels to contribute contaminants to receiving environments (McDowell et al., 2015), these have not been combined with assessments of productive potential, nor have they considered impacts on receiving environments. If sustainable productivity and environmental objectives are to be achieved, a suitability assessment system needs to provide information on all of these aspects.

We define the Land Use Suitability concept (LUS) as a framework for assessing the suitability of land for primary production that acknowledges and accounts for the connections between land use and economic, environmental, social and cultural impacts. LUS is distinct from land suitability assessment frameworks that focus only on the farm scale, and it recognises that land use impacts accumulate in space and can occur far away from individual farms. LUS seeks to promote sustainable land use by providing stakeholders with information that highlights the interconnected and cumulative nature of land use impacts. The broad scope of the LUS concept means that its practical applications need to be specific to particular contexts, scales and problems. Consequently, the selection of relevant indicators of suitability, and the way they are assessed and combined is likely to vary with each application of the LUS concept. In this paper, we discuss an application of the LUS concept to the issue of land use and its impacts on water quality in New Zealand.

In our application of the LUS concept, we use three indicators to collectively describe the suitability of land for primary production that takes into account water quality objectives in downstream receiving environments (e.g., streams, rivers, estuaries, groundwater). We refer to this application of the LUS concept as sustained Productivity within Environmental Constraints (PEC). One PEC indicator assesses productivity of land parcels, and the other two assess the impacts in downstream receiving environments. The impact indicators are based on the premise that, all other considerations aside, productive land located in catchments with lower environmental constraints is more suitable land for intensive production. Similarly, within a catchment, land that has a lower potential to cause environmental impacts is more suitable for intensive production than land with higher potential to cause environmental impacts.

The remainder of this paper focuses on the PEC assessment system. The first section sets out the conceptual basis for a PEC assessment and its three indicators. The second section describes the analytical steps involved in carrying out a PEC assessment. The third section identifies sources of data and existing models that can be used in PEC assessments. The fourth section discusses the potential range of applications, limitations and future developments for PEC assessments.

2. The conceptual basis of a PEC assessment

Our conceptualisation of a PEC assessment is based on three indicators that describe 1) the capacity of a land parcel for primary productivity; 2) the potential of a land parcel to contribute contaminants; and 3) the response of receiving environments to contaminants. In the following text, we give operational definitions for important terms, which are underlined when they first appear. We begin by defining each of the three indicators in order. First, the capacity for primary productivity is described by the productive potential indicator, which is based on the inherent potential of a land parcel for sustainable primary productivity. Second, the likelihood of land to contribute contaminants is described by an indicator that quantifies the relative contribution of each land parcel to the delivered load at any point in the catchment. Third, the response to contaminant loading in receiving environments is described by the pressure indicator. The pressure indicator recognises that receiving environments are subject to environmental objectives that define their assimilative capacity. The pressure indicator discriminates between land parcels in terms of the extent to which their productive potential may be constrained by the assimilative capacity of receiving environments.

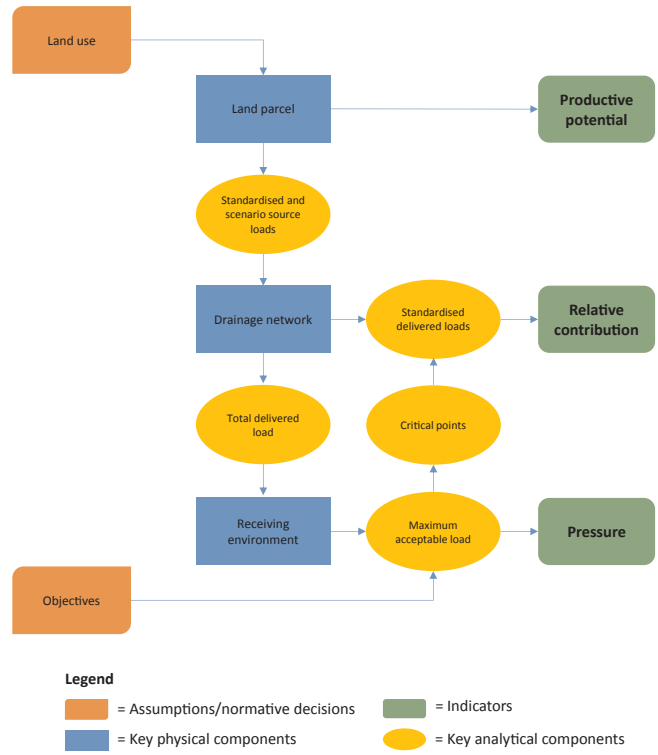

Fig. 1. Schematic diagram indicating the key physical components that comprise a land-water system and the analysis steps involved in deriving three indicators used in assessing sustainable productivity within environmental constraints within the land use suitability concept.

In a PEC assessment, a category is assigned to each of the three indicators for each land parcel in a land-water system (e.g., high productive potential, low relative contribution, high pressure). Evaluating the indicators for each land parcel requires an analysis of the land-water system (Fig. 1) and involves consideration of more than one spatial scale. The three indicators describe differences between land parcels in relative, not absolute, terms. Although the indicators are derived in a catchment-specific context, they are characterised in such a way as to enable comparison of the suitability of land parcels both within and across catchments.

The current conceptualisation of PEC only considers the assimilative capacity of receiving environments for four contaminants (nitrogen, phosphorus, sediment and the faecal indicator bacterium *Escherichia coli* [*E. coli*]), and the independent effects of each contaminant. We recognise that water quality effects will arise from interactions between contaminants and other off-site impacts of land use such as reduced river and groundwater flows and levels caused by the abstraction of water for irrigation. In addition, the current conceptualisation only considers aquatic receiving environments that are connected to a drainage network. In the future, a PEC assessment could be expanded to other receiving environments (e.g., soils, atmosphere), other contaminants (e.g., cadmium, pesticides) and non-contaminant stressors (e.g., water abstraction, soil compaction), and multiple-stressor effects.

Our current conceptualisation of PEC does not consider infrastructure, cultural or societal factors that may influence the suitability of a land parcel for a specific land use (e.g., distances to processing plants, ports and labour markets). Consideration of these factors is consistent with the broader LUS concept, but their assessment would require another specific application. An exception could be the contribution of contaminants from urban sewage works, which as a monitored point source could be accounted for in a PEC calculation. In addition, a PEC assessment does not consider how shares of the capacity