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Challenges of integrated modelling in mining regions to address social, environmental and economic impacts

Alex M. Lechner [a, b, *], Neil McIntyre [a], Katherine Witt [c], Christopher M. Raymond [d], Sven Arnold [a], Margaretha Scott [e], Will Rifkin [c, f, g]

[a] Regional Water and Land Program, Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD, 4072, Australia
[b] School of Environmental and Geographical Sciences, University of Nottingham Malaysia Campus, Semenyih, 43500, Malaysia
[c] Centre for Coal Seam Gas, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD, 4072, Australia
[d] Department of Landscape Architecture, Planning and Management, Swedish University of Agricultural Sciences (SLU), Alnarp, S-230 53, Sweden
[e] WH Bryan Mining & Geology Research Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD, 4072, Australia
[f] Centre for Social Responsibility in Mining, The University of Queensland, Sustainable Minerals Institute, St Lucia, Brisbane, Queensland 4072, Australia
[g] Hunter Research Foundation Centre, Faculty of Business and Law, University of Newcastle, Callaghan, NSW 2308, Australia

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ABSTRACT

Planning in mining regions needs to accommodate the extraction of minerals/energy resources in co-existence with established land uses, such as agriculture and ecological conservation. Here, we first identify six critical aspects of planning in mining regions: i) the temporal nature of mining operations; ii) spatial dimensions of mining operations; iii) irreversible changes that create post-mining landscapes; iv) social dimensions of mining impacts and corporate responsibility; v) cumulative dimensions of impacts; and vi) a need to integrate methods from a range of disciplines. We then illustrate the potential to address these challenges using integrative modelling nested within a participatory approach to allow for clear, transparent, and stakeholder-inclusive decision-making. We describe a 5-step framework that supports a broadening of strategic assessments and offers mining companies forewarning about potential environmental and social conflicts. Case studies are needed to assess and refine the proposed framework and develop guidance for its use.

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1. Introduction

Regional planning approaches have so far failed to foster a vision of development in regions that are rich in mineral/energy resources that is common across various sectors and stakeholder groups (Lechner et al., 2015; Hilson, 2002). A common vision is needed to enable co-existence between minerals/energy extraction and established land uses, such as agriculture, forestry and ecological conservation. Achieving a common vision of mining development would follow from an objective, multi-lateral, planning approach, where existing and potential land use values/preferences are estimated, reported and reviewed in a manner that is clear, transparent and stakeholder-inclusive. We seek to progress thought and practice in this domain with particular attention to applications related to resource development in regions that are rich in extractable resources.

Mining is an inherently interdisciplinary pursuit, although it is commonly regarded as the domain of geologists and engineers. Increasingly, mining activities must consider the effects on surrounding hydrology, biodiversity and communities as well as traditional concerns of resource supply and extraction efficiency (Franks et al., 2010a; Kiesecker et al., 2010; Lechner et al., 2016; Mudd, 2010; Petkova et al., 2009; Saenz et al., 2013). Mining development is spatially constrained by a resource's geology (such as the location of a coal seam), which can result in a concentration of mines in a single region at various stages of their operational lifecycles. Therefore, the impacts of mining, both positive and negative, from a single mine or multiple mines need to be understood both spatially and temporally across a region.

* Corresponding author. Regional Water and Land Program, Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland, Brisbane, QLD, 4072, Australia.
E-mail address: alex.lechner@nottingham.edu.my (A.M. Lechner).

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Of key importance for regional planning in resource rich locations is assessing the cumulative dimensions of impacts. Cumulative impacts result from successive, incremental and combined impacts (positive and negative) on the environment, society and economy (Franks et al., 2013). Fig. 1 illustrates how the impacts from a single mine may be insignificant regionally, but the impacts of successive and additional mine developments over time can result in changes to important natural and cultural resources. Cumulative impacts in resource rich regions can also arise through the interaction and aggregation of impacts from different activities, such as coal seam gas development and agriculture (Evans and Kiesecker, 2014; Franks et al., 2010b; Moran and Brereton, 2013). Importantly, cumulative impacts reflect effects of activity occurring in different economic sectors and drawing on different forms of capitals or regional assets - natural, social, human, financial and manufactured (Moran et al., 2013). However, conflicts can arise in any shared use of resources among different stakeholders, whether those resources are land, labour, water, infrastructure, or amenity (Filova et al., 2014; Franks et al., 2010a; Hilson, 2002; Kemp, 2009; Kemp et al., 2011; Prno and Slocombe, 2013). Understanding interactions between impacts can assist in the identification of trade-offs between competing land uses, particularly where development in one sector affects others.

Assessing cumulative impacts requires a cross-disciplinary understanding of social, economic, and environmental impacts as well as understanding of the interactions and aggregations among these impacts across time and space. This process can be characterised by a systems-thinking, integrated approach to planning and modelling (Ban et al., 2013; Hamilton et al., 2015; Jakeman and Letcher, 2003; Lein, 2003). Systems approaches emphasise the importance of viewing "problems" as parts of an overall system, rather than viewing specific parts in isolation. "Integrated assessment" is a process that combines multiple and diverse components of a system across its social, organizational and conceptual boundaries (Hamilton et al., 2015; Jakeman and Letcher, 2003). Research in this field is necessarily integrative and interdisciplinary, and incorporates the knowledge of both scientists and local community stakeholders. Furthermore, integrative modelling provides the platform for exploring social-ecological interactions to assist decision-makers in developing policies that provide acceptable environmental and socioeconomic outcomes (Argent, 2004; Hamilton et al., 2015; Maier et al., 2008). However, the complexity of the studied systems and the need to integrate knowledge, theories, and approaches from a range of different disciplines - as required in planning for mining development - pose a considerable challenge.

In this article, we consider the unique characteristics of mining and propose how these characteristics should be considered when constructing and applying quantitative modelling frameworks to support regional planning. We first provide a background to the unique aspects of mining developments associated with the: i) temporal nature of mining operations; ii) spatial dimensions of mining operations; iii) irreversible changes in post-mining landscapes; iv) social dimensions of mining impacts and corporate responsibility; v) cumulative dimensions of impacts; and vi) integrating methods from a range of disciplines. We then describe a 5-step modelling framework for regional planning, a model that builds on established frameworks, and we outline the key mining-specific challenges and how they may be addressed within the framework. We conclude by discussing how integrative modelling approaches may be operationalized by mining companies and governments. We expect that the proposed approach would be used in the context of a strategic environmental assessment (SEA) (Azcarate and Balfors, 2009; Noble, 2009; Tetlow and Hanusch, 2012), which represents a commonly accepted legislative and government approach to regional planning. This article is written for environmental modellers who may be familiar with existing integrative modelling approaches but who are unfamiliar with the unique challenges associated with using these approaches in the mining context.

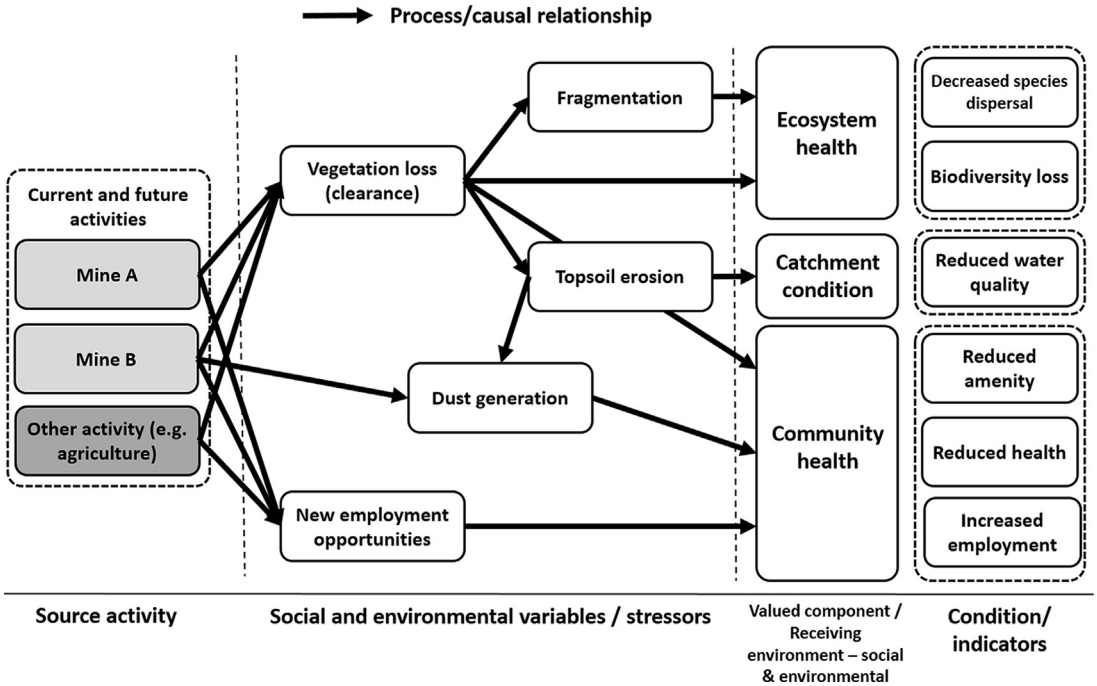

Fig. 1. A simplified example of cumulative impacts describing a subset of the multiple source activities and impact pathways (*i.e.*, direct versus linked) on receiving environments/ receptors.

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