Resources Policy 50 (2016) 234–243

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Spatial assessment of open cut coal mining progressive rehabilitation to support the monitoring of rehabilitation liabilities

Alex Mark Lechner[a,*], Owen Kassulke[b], Corinne Unger[b]

[a] Regional Water and Land Resources, Sustainable Minerals Institute, The University of Queensland, St Lucia, Brisbane, Queensland 4072, Australia
[b] Centre for Mined Land Rehabilitation, Sustainable Minerals Institute, The University of Queensland, St Lucia, Brisbane, Queensland 4072, Australia

ARTICLE INFO

Keywords:
Mine rehabilitation
Performance measures
Mine regulation policy
Rehabilitation liabilities
Coal mining

ABSTRACT

Worldwide coal mining has expanded over the past few decades, though growth has recently slowed due to reduced demand, partly due to concerns around CO_2 emissions and climate change impacts. Coal mining is also a significant driver of land disturbance in regions where economic coal seams and coal mining methods are applied, in particular open cut extraction. To address these impacts, mined landscapes are rehabilitated with the aim of making them safe, stable, non-polluting and self-sustainable to an agreed post-mining land use such as agriculture or conservation. Progressive rehabilitation is often conducted to keep the footprint of disturbance to a minimum and to ensure that ecological and/or agricultural land use production is restored as soon as possible in preference to waiting until after mine closure. Environmental regulators require methods for tracking the performance of mining companies engaging in progressive rehabilitation to evaluate the success or otherwise of their regulatory frameworks and to ensure companies meet the requirements of their environmental authorities or mining licenses.

In this study, we describe a spatial method for assessing mine disturbance and rehabilitation regionally and analyse our results in terms of rehabilitation liability. We first developed a land cover classification framework for mapping mining impacts and rehabilitation that categorises land cover using a mining land cover disturbance typology. We then used the Fitzroy Basin in Australia as a case study, utilising the land cover classification scheme to map 37 open cut-coal mines, using manual interpretation of remote sensing data. By comparing the percentage area of rehabilitation with the total mine area we assessed the variability in progressive rehabilitation for the 37 mines. For example, older mines which have a history of progressive rehabilitation should have large areas and a high proportion of area rehabilitated. Finally, we calculated a range of regional rehabilitation liabilities by applying two publically available rehabilitation cost-calculators to the land cover data. We calculated the rehabilitation liability as ranging from $2.7 to $5.5 billion Australian dollars. The lower and upper bounds of the estimate reflect the uncertainty associated with the range of land use types and potential rehabilitation methods, from simple to more complex rehabilitation methods. We conclude by discussing how the methods could be used to support effective decision making by government agencies regulating and monitoring mining activities.

1. Introduction

Coal mining has expanded globally over the past few decades and is a key driver of significant land disturbance in regions where economic coal seams are found and open cut coal mining methods are applied. Coal mining regions are located in developed nations such as Australia, the United States, and the United Kingdom as well as emerging economies such as Mongolia, India and China. The impact of coal mining is of particular concern for countries such as Australia and Mongolia, which have seen a significant expansion in mining in response to the increase in global demand for energy in recent years (Battogtokh et al., 2012; Measham et al., 2013; Petkova et al., 2009). Recently, global demand for coal has slowed down, and for the first time since the 1990s, growth ceased in 2014 and it is estimated that the share of total primary energy from coal will fall from 29% to 27% between 2014 and 2020 (International Energy Agency, 2015a).

While coal mining makes an important contribution to economies, in many countries there are significant conflicts between mining operations, local communities and existing land uses such as agriculture and biodiversity conservation as a result of environmental impacts

* Corresponding author.
E-mail address: a.lechner@uq.edu.au (A.M. Lechner).

http://dx.doi.org/10.1016/j.resourpol.2016.10.009
Received 3 March 2016; Received in revised form 15 October 2016; Accepted 17 October 2016
0301-4207/

on natural resources. This is the case, for example, in Australia (Lechner et al., 2014; Petkova et al., 2009; Windle and Rolfe, 2014), China (Hu et al., 1997; Hu and Gu, 1995; Li et al., 2011), the United States of America (Darmody, 2000; Langkamp, 1985), India (Martha et al., 2010) and Mongolia (Cane et al., 2015). Of even greater environmental concern are the associated impacts to global climate change resulting from the contribution to greenhouse emissions from coal-fired power stations (Department of Climate Change and Energy Efficiency, 2012; International Energy Agency, 2015b). The medium-term coal market report by the International Energy Agency identified climate policy and low CO_2 emissions reduction targets as a major driver for a reduction in demand (International Energy Agency, 2015a). Climate change impacts aside, long term environmental impacts associated with coal mining extraction are often addressed through mine rehabilitation.

Mine rehabilitation is a process which aims to make landscapes safe, stable, non-polluting and self-sustainable to an agreed post-mining land use such as pasture (for agriculture) or conservation (Arnold et al., 2012; Cooke, 2006; Doley and Audet, 2013). Design of pit-lakes and management of voids are also important rehabilitation issues (Kumar et al., 2009). Coal mining landscapes comprise open cut pits (remaining as water filled voids or backfilled), subsided areas over underground mining, waste rock dumps, tailings or washery wastes, water management structures and other areas associated with infrastructure and access. Our case study focuses on open cut mines as surface impacts are significantly greater than from underground mining (although still of concern, especially in prime agricultural land (Lechner et al., 2014)) and they can be readily mapped with remote sensing. Leading practice mine rehabilitation requires mining companies to progressively rehabilitate mined land once it is no longer required for operational purposes. This keeps the footprint of disturbance to a minimum and ensures that ecological and/or agricultural land use production is restored before mine closure. Depending upon climate and proximity to communities and employees there are also human health benefits from progressive rehabilitation from reduced dust and fire control (Franks et al., 2010a; Hendryx and Ahern, 2008; Martha et al., 2010). Successful progressive rehabilitation is also an indicator that the operational aspects of mining are aligned with regulatory and community expectations for closure and post-mining land use objectives and reduce the risk of increasing the inventory of abandoned and unrehabilitated former mine sites (Lamb et al., 2015; Unger et al., 2015).

However, even when progressive rehabilitation is undertaken, radical changes to almost every component of the landscape such as topography, soil, and surface and groundwater hydrological systems, as well as persistent non-natural landcover features (e.g., waste rock dumps and spoil storage facilities) represent considerable obstacles to restoration (Doley and Audet, 2013). The inability to achieve intended rehabilitation goals can result from the radical and potentially irreversible differences between the physico-chemical starting points of the post-disturbance environment compared to post-rehabilitation land use targets (Cooke, 2006; Doley et al., 2012; Hobbs et al., 2009). Furthermore, difficulties associated with rehabilitating post-mining landscapes can be exacerbated by unfavourable climatic conditions, such as irregular, unpredictable and intense rainfalls, especially in tropical locations (Arnold et al., 2013; Audet et al., 2013; Halwatura et al., 2015).

Environmental regulators require mechanisms to track performance of mining companies engaging in progressive rehabilitation against the requirements of their environmental authorities or mining licenses in order to evaluate the success or otherwise of their regulatory frameworks. This information is usually provided on a site-specific basis, through reporting and audits, however, governments are also required to assess the industry as a whole in order to evaluate regional or national trends in sustainability or for the purposes of regional planning (e.g. Eco Logical Australia, 2012; Franks et al., 2008; Mineral Council of Australia, 2015; NSW Department of Planning, 2005). For example, reporting at the jurisdictional level needs to be conducted, though less frequently, to address State of Environment reporting requirements (e.g. Australian Government, 2011). State of Environment reporting is used world-wide to provide relevant and useful information on environmental issues for the public and decision-makers for awareness raising and to support effective evidence-based policy and decision making that ensures sustainable outcomes (Australian Government, 2011; Comolet, 1992).

In Australia there is a lack of detailed reporting of mine disturbance and progressive rehabilitation at regional, jurisdictional and national scales making it difficult to draw a comparison with the benefits of the industry which are more readily assessed in economic terms (e.g. employment and revenue) to long-term impacts on the natural environment. The latest 2011 Queensland (DEHP, 2012) and Australian (Australian Government, 2011) State of Environment reports only quantified the total footprint of mining - at 0.09% and < 0.1% respectively. Impacts assessed only on the basis of mining footprint disregard the heterogeneity of mining landscapes and the associated range of rehabilitation costs. The mine foot print area also does not account for opportunity cost where mining occurs on good quality agricultural land. For example, a recent study (Lechner et al., 2014) found approximately 4·49 million hectares (61%) of good quality strategic cropping land in Queensland coincides with coal mining exploration permits. The lack of reporting not only impacts on effective planning, but also affects the public debate on the negative impacts and benefits of mining. For example, the Queensland Resources Council suggests that the "mining and gas industries accounts for a tiny fraction of the state's land mass" (Queensland Resources Council, 2013), while, environment and farmer advocacy groups suggest that land currently being mined is a poor indicator of the spatial impact of mining and claim the magnitude would be much greater if the intensity of the disturbance, potential for rehabilitation and cumulative impacts were assessed (e.g. Friends of Felton, 2011).

In this study, we conducted a spatial assessment of mine disturbance and rehabilitation of open cut coal mining and analyse our results in terms of mining land cover type and associated rehabilitation liability. The methods outlined in this study can assist in the planning, regulating and monitoring of progressive rehabilitation in mining regions. We first develop a land cover classification framework for mapping mining impacts and rehabilitation that categorises land cover using a hierarchical mining process land cover typology. Then, using a case study of a coal mining region, the Fitzroy Basin in Queensland, Australia, we utilised the land cover classification scheme for mapping the disturbed area of open cut coal mining using remote sensing data. We assessed the disturbance regionally by comparing the rehabilitation percentage area versus total mining footprint between mines. Finally, we assess rehabilitation liabilities by applying two publically available rehabilitation cost-calculators to the land cover maps to determine total rehabilitation liability in the region. The analysis was based on the best available data for 2012 to coincide with the reports by the Queensland Audit Office (Queensland Audit Office, 2014, 2011) which noted that the state of Queensland has poor data and inadequate systems which hinder planning and risk assessments. We conclude by discussing the results of the quantitative analysis in terms of how these data can be used to support effective policy, plans and programs by decision makers in government agencies regulating mining activities. In particular, we focus on how these data can be used to more effectively calculate rehabilitation costs by providing a regional snapshot of the area of mine related disturbance.

2. Methods

2.1. Study area

The Fitzroy Basin is Australia's second largest river basin and is