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Original article

Bread from stones: Post-mining land use change from phosphate mining to farmland

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ABSTRACT

Modern mining jurisdictions commonly require a mine-site to be restored to its original land-use when mining is completed. However, the conversion of disused mine sites for agricultural purposes (rather than restoration to an original condition) is an innovative strategy as food security in many regions becomes critical. Selected mine-sites on Christmas Island were converted to an agricultural land use as the mining company withdrew from mineral extraction in the aim to achieve employment, economic, and socio-economic benefits for the isolated island population (pop. ~2000). The Australian Government co-funded this research with a mining company (Phosphate Resources Limited) to assess the science required to introduce commercial agriculture to the island. This paper describes land-use change methods and results, including pre-commercial trials of selected broadacre crops, rotational cropping using legumes, high value crops, and a microbial prospecting program to determine capability of indigenous bacteria. This research demonstrates a range of successful methods have enabled a new post-mining land-use to productive farmland from an apatite (phosphate) minesite. We have outlined where productive use of post-mining lands is both desirable and has proven to be particularly challenging, but which can lead to a productive and commercially viable opportunity in both advanced and emerging economies.

1. Introduction

There is a well-established international expectation by industry, financiers, and practitioners that post-mining land use consideration should be an intrinsic element of the entire life cycle of mining from initial project design (e.g. (International Council on Mining and Metals (ICMM), 2008; International Finance Corporation, 2007; Mining Minerals and Sustainable Development (MMSD), 2002; Sweeting and Clark 2000). The Environmental Law Alliance Worldwide (2010) state that planning for post-mining land uses . . . "must include a guide to deactivate, stabilize, and perform long-term surveillance of waste management units or facilities" (p96), and advocate that specific information is provided in a mine closure plan to enable an independent appraisal. It is increasingly expected that after mining activities cease, a stable and productive land use is available to a community (Davies et al., 2012; Otto, 1997; Stacey et al., 2010), and that during the development of the mine the community should be engaged in terms of what post-mining legacy they will ultimately inherit (Morrison-Saunders et al., 2014). Therefore, the community will need to be actively engaged to define their own post-mining environmental, socio-economic, socio-political, and development preferences (International Council on Mining and Metals (ICMM), 2008; Sassoon, 2009; Stacey et al., 2010). The MSSD further discuss that planning for post mining land use is even more important than mine closure itself, and that this process should "ensure that the land and structures can be restored for alternative uses after the mine closes" (Mining Minerals and Sustainable Development [MSSD], 2002 p27). In Western Australia both the *Mining Act* 1978 and Environmental Impact Assessment (EIA) under the *Environmental Protection Act* 1986 allow for mine closure planning to be addressed during initial assessment, mine approval, and with

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periodic review, with joint guidelines issued by the Department of Minerals and Petroleum (DMP) and Environmental Protection Authority (EPA) (Morrison-Saunders et al., 2016). In the Western Australian example, key stakeholders are defined as "post-mining land owners/managers and relevant regulators" (Department of Mines and Petroleum and Environmental Protection Authority, 2011 p21). These stakeholders are to be consulted by proponents during the mine closure plan process, and "post-mining land uses should be identified and agreed upon through consultation before approval of new projects" (Department of Mines and Petroleum and Environmental Protection Authority, 2011 p14).

Mine closure planning is less well established and much more challenging in less developed regions (Morrison-Saunders et al., 2016). For example, the Economic Commission for Africa and Southern African Development Community (2004) state that . . . "[m]odern mine developments should have economic, social and environmental evaluations, all of which should contemplate and anticipate mine closure and its consequences" (2004) p153. An important consequence for ex-mine sites in emerging economies is that it can attract a large number of informal artisanal and small-scale miners (ASM), making closure in practice very difficult (Morrison-Saunders et al., 2015). The African Union (2009) reported that some 3.7 million people were engaged in the ASM sector on the continent, with around 30 million indirectly dependent upon it, with the numbers expected to grow significantly over time. The 2009 report recognised that ASM provides more employment than large-scale mining, but is beset with problems of sustainability, serious safety concerns, and legal and regulatory failures. Therefore, mine operations anticipating ASM activities may contemplate alternative productive land use that also provides significant employment and community benefits. It is common where ASM is a major informal industry, that mining and agriculture share the same or adjacent landscapes, face common challenges (i.e. worker education and health, political governance and instability, etc.), and sometimes also compete for resources (natural and human) (McHenry and Persley, 2015). Traditionally, the mining sector has not actively sought to fund activities that link them with the broader economy as a purposeful catalyst to broader regional development (Campbell, 2012). With respect to financial aspects, the Southern African Development Community (2004), p36, indicated that "Countries within the region are changing their regulatory frameworks to ensure that sufficient funds will be available at mine closure to rehabilitate the environment and monitor the post-mining environment". When seeking to link with broader economic developments in emerging economies, agriculture is the 'other' dominant industry and source of local employment and livelihood, and is a practical means for inter-sectoral collaboration (McHenry and Persley, 2015).

There is growing interest in the significant opportunity for the two major primary industries, mining and agriculture, to collaborate to de-risk and diversify commercial and national interests for accelerated development in emerging economies (McHenry and Persley, 2015). With a greater level of economic linkages between sustained mining operations, there are many development benefits possible for the immediate precinct, to regional service towns, and to major economic hubs (Robbins, 2013). Mining and agricultural sectors are both important contributors to economic development in many countries, and there are synergies at the local geographical level for mining and agricultural/forestry investments, including similarities between labour demand, partnering, and infrastructure (McHenry and Persley, 2015). The conversion to an agricultural final land use explored in this research is a prospective means to achieve employment, economic, and socio-economic benefits in remote Western Australia, and may be appropriate for emerging economies.

In emerging economies there is a need for small-scale subsistence farming to be intensified and commercialised (Opara, 2011). The primary barrier to commercial-scale agriculture is poor infrastructure, and upgrades stimulate the creation of an agricultural value-chain, making the delivery of inputs practical and commercially viable and the parallel creation of markets for products (Dupasquier and Osakwe, 2005; McHenry and Persley, 2015; Meeuws, 2004; Robbins, 2013; Robbins and Perkins, 2012). As mining projects tend to have core infrastructure (transport, energy, water, etc.) components, it may provide and stimulate co-use and additional investment in infrastructure in rural regions (Robbins and Perkins, 2012). As extractive industrial development is often occurring in traditional agricultural regions and corridors, it has the potential to increase farmer access to transport and markets (Weng et al., 2013). Indeed rural populations tend to grow near crucial physical and economic infrastructure (Jayne et al., 2010; Meeuws, 2004; Speielman et al., 2010; Woodhouse, 2009). It is well known that a strategic alignment of rural road investments with agricultural developments are likely to have the largest influence on agricultural productivity and market access (Gwillam et al., 2009). Farmers near sealed roads are more likely to access improved technologies, and also more able to sell and purchase surplus production despite weather conditions (Counguara and Moder, 2011). However, without active partnering the presence of mining is usually not sufficient to catalyse commercial agriculture, and is why the development of commercial agricultural enterprises are not a usual outcome of mining activity in a rural region with little development (McHenry and Persley, 2015).

The Australian Government Department of Infrastructure and Regional Development, through a grant under the Indian Ocean Territories Community Development Program and Phosphate Resources Limited co-funded research by Murdoch University to undertake a scientific assessment of requirements to introduce agricultural production on their inactive sites on Christmas Island (CI); MINTOPE (Mining to Plant Enterprise). The strategic dimension of MINTOPE is to ultimately reduce the CI economic dependence on imported food products using on-island resources whilst increasing post-mining economic development and export opportunities where possible. As there are many guidelines for 'mine closure' available for most major mining jurisdictions in additional too much international 'best practice' literature and documentation, this paper seeks to provide an example of the practical elements of land conversion from mining to agriculture; this is in contrast to a focus on meeting regulatory requirements of 'mine closure' that generally include site decommissioning, rehabilitation, and often (but not always) tenement relinquishment. The selected components of the MINTOPE project we discuss in this research are the development of the following on the disused minesites:

1. Pre-commercial trials of selected broadacre crops;
2. Rotational crop trials using legumes and specific nitrogen fixing bacteria;
3. High value crops, and;
4. A microbial prospecting program to determine nitrogen-fixing capability of indigenous bacteria

1.1. Materials and Methods

1.1.1. Study site

The geological, socio-economic, and regulatory background of the mining on CI is complex, and through agriculture MINTOPE aims to prevent economic decline on CI when mining by the company Christmas Island Phosphates (CIP) ceases sometime in the next two decades (King and Snowdon, 2013). CI has been

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