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Methodological and Ideological Options

Setting the limits to extraction: A biophysical approach to mining activities

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ABSTRACT

While the mining industry is steadfastly committed to the goal of increasing extraction of minerals, the failure to recognize the existence of biophysical constraints to extraction results in massive degradation to socio-ecological systems. In this paper, we propose an innovative approach for analyzing mineral extraction which links the use and management of natural resources by means of the Stock-Flow/Fund-Service model developed by Georgescu-Roegen. Mining is a productive process that not only depletes minerals ores but also affects other natural resources that are needed to maintain life-supporting processes over time. The central claim is the need of recognizing the existence of biophysical limits to extraction in order to manage natural resources as irreplaceable providers of ecosystem services. By providing a new conceptualization for operationalizing the ecosystem services approach based on the Stock-Flow/Fund-Service model, we intend to challenge the current extractivist narrative that assumes unregulated practices, monetary indicators, technological advancements and substitutable resources. We argue that limits to mining activities should depend on a biophysical evaluation of the effects of these activities on the environment. Furthermore, social deliberation is required to determine whether extraction should occur and to what extent it is socially acceptable while still maintaining the integrity of socio-ecological systems.

1. Introduction

The extraction of mineral resources is considered critical for the economic development of many countries. Increasing demand on these resources has led to the expansion of new mining projects in ecologically sensitive areas which are also inhabited by people (Martinez-Alier et al., 2010). Thus, the growing scale of the extraction generates large environmental and social impacts. For instance, hard-rock mining is the biggest source of toxic waste within the economic sector (EPA, 2009). Despite environmental and social concerns about this economic activity, the frontier of mining extraction continues to expand (Bebbington et al., 2008). The Environmental Justice Organizations, Liabilities and Trade Atlas has reported 250 active environmental conflicts around the world related to mineral extraction, concentrated mainly in Latin America (EJATLAS, 2014). Since mining extraction is expected to increase, analyses of the scale of its impacts should be a priority for decision-makers in order to develop regulations that limit environmental degradation and uncontrolled waste generation.

This paper emphasizes the importance of social identification of biophysical limits to mining. Mineral extraction not only decreases the quantity and quality of underground ores, but critically erodes the quantity and quality of other resources associated with this extraction (Mudd, 2007a). This article stresses that mineral extraction is a productive process that should no longer depend solely on economic indicators to control rates of extraction. Our main argument is that mining requires regulation which considers the existence of biophysical limits to extraction. For this to occur, the discussion ought to be directed towards the effects of mining on the structure and functions of the environment and societal relations in the long run.

Several models have been applied to the analysis of mining activities and their effects upon people and the environment. While some studies evaluate the monetary loss of ecosystem services (Li et al., 2011); others analyze the mechanisms for ecological restoration to recuperate ecosystem services (Wassenaar et al., 2013). Other studies develop multiple-compensation frameworks for addressing the alteration of water-related ecosystem services (Bai et al., 2011), or discuss the importance of post-mining landscape

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planning (Larondelle and Haase, 2012). However, little research has yet focused on understanding the limits to mineral extraction required for the maintenance of socio-ecological systems over time.

In this article, we use the analytical framework of the Stock-Flow/ Fund-Service model developed by ecological economist Nicholas Georgescu-Roegen (1971). This model has been previously used for the analysis of mineral extraction in the context of ecological distribution conflicts (Silva-Macher and Farrell, 2014). We expand on Georgescu-Roegen's foundations to emphasize the biophysical limits to extractive processes. We also highlight the need to develop deliberative mechanisms for defining social boundaries, taking into consideration the tradeoffs between economic production and the overall maintenance of ecosystem services. The article starts with a review of the biophysical realities of mining activities. It then applies Georgescu-Roegen's model for the mining process. The model is followed by an analysis of mining impacts on socio-ecological systems. Later, we discuss the implications of using the Stock-Flow/Fund-Services approach for managing ecosystem services. We put particular emphasis on social deliberation processes for identifying limits to mineral extraction and finally, we provide a conclusion.

2. The Mining Productive Process and its Biophysical Realities

Extractive activities rely on biophysical realities. These activities constitute economic productive processes determined by a unidirectional flow of energy and material that irreversibly transforms resources coming from the environment into waste (Cleveland and Ruth, 1997). This process inexorably increases entropy in a system and reduces the availability of energy and materials for human use[2] (Georgescu-Roegen, 1979). Ruth (1995) argues that biophysical limits to resource extraction are imposed by the finite availability of material and energy during the extractive process. In addition, he highlights the lack of research related to limitations of extraction by assessing environmental damages. By similar logic, we argue that biophysical limits to mining activities need to consider the critical capacity of the entire socio-ecological system[3] to maintain its structure and functions over time. Denying the existence of these limits ignores the dependence of humans upon natural resources, as well as the limited capacity of ecosystem to provide services.

Accordingly, biophysical limits to mining activities are not only related to the non-renewability of minerals. They are also related to the highly exploitative metabolism (i.e. high material and energy throughput) that affects the integrity and resilience of the socio-ecological system. This includes resources being used and consumed in the mining process (e.g. water, energy and chemical consumption) and the degradation of other resources directly and indirectly affected by pollutant emissions or land use change (e.g. soil, air and biodiversity) (Mudd, 2007a).

A predicted worldwide increase in open pit mining and the resultant generation of waste would go hand in hand with an increase in the extractive metabolism associated with the decline in ore grade (Mudd, 2007b; Müezzinoğlu, 2003). This is an important concern since empirical evidence shows that uncontrolled mining has large, long lasting impacts on the environment and people (Eisler, 2004; Golow et al., 1996). Although the mining industry strives for efficient technological advancements and innovation in mining techniques (Huber, 2000), the actual contribution of these techniques to the prevention of environmental and social impacts must also be questioned. Current goals of the mining industry are to reduce the intensity of use of resources and generation of waste through the employment of more efficient technology. However, in optimizing production, inputs are used more efficiently only to the extent to which such efficiency improvements maximize production and increase profits, resulting in more impacts overall (McLellan et al., 2009; McElroy et al., 2008; Cleveland and Ruth, 1998). For example, the reduction of water consumed per ton of ore does not guarantee the reduction of total amount of water consumed if the amount of ore extracted increases. Thus, it is argued that pushing for more efficient solutions will lead to rebound effects. This is evidenced by the expansion of large-scale mineral extraction to locations previously deemed inaccessible or undesirable due to low mineral content. Although improving the efficiency of the productive process might reduce environmental impacts per unit of output (van Berkel, 2007), it does not question whether the constant increase in production can continue infinitely without irreversibly affecting socio-ecological systems (Ruth, 1995). For instance, as ore quality declines, environmental impacts per unit of output might go up even as efficiency per unit of ore processed increases (Bridge, 2004).

Market solutions have also been developed to advance optimal resource extraction. Several studies suggest that optimal extraction levels ought to be based on an evaluation of the price effects on resources (Hall et al., 2001; Dasgupta and Heal, 1974). Solow (1974), for example, develops a theory of optimal extraction of nonrenewable resources which stresses that depletion and waste are not a problem as long as prices reflect scarcity.[4] Likewise, classical theorist Harold Hotelling (1931) emphasized that resources are not finite but that the cost of extraction increases with the extraction itself. Accordingly, production and demand for resources will both decrease over time due to increasing costs. However, price changes do not necessarily reflect the state of the environment. This is particularly relevant given that monetary indicators only include the provision of inputs in relation to the generation of outputs and do not take into account the influence of the whole economic process in the whole socio-ecological system (Norgaard, 1990). Mining extraction cannot be based solely on economic indicators since the enormity of biophysical deterioration extends beyond conceptualizing nature purely in terms of market value or by creating compensatory measures for social and environmental degradation.

Technological efficiency and monetary models alone have not been able to address socio-ecological challenges to resource extraction since they are not attuned with biophysical realities (Gowdy and O'Hara, 1997). They assume an infinite source of resources that can be transformed to obtain a final output while effectively pretending that natural resources can be extracted in perpetuity. From this viewpoint, the maintenance of natural resources and ecosystem services is less valued than their capacity to foster any productive process. Instead, O'Hara (2015) argues the importance of accounting for a context-dependent productive system, which is inextricably nested within a biophysical and socio-cultural reality and depends of it to sustain itself. Accordingly, the work of Georgescu-Roegen in analyzing productive processes is valuable in terms of assessing the performance of mining extraction and understanding how natural resource degradation can irreversibly alter the provision of ecosystem services over time.

[2] While low entropy energy can only be used once on any productive transformation, many metals can be reused several times. Gold or cooper for example, become more available for human use once they have been extracted but the material throughput for processing metals reduces the availability of materials for other uses within the system overall.

[3] This term refers to systems defined by spatial, temporal and organizational scales consisting of bio-geophysical components interacting with social actors within a set of institutions that govern society (Gunderson and Holling, 2002).

[4] Yet, there is virtually no evidence that prices reflect scarcity of the resource in the ground. Price seems to more accurately reflect above ground scarcity, which increases inversely to in-ground scarcity (Reynolds, 1999).