Application of systems thinking in the management of a mineral resource active region.

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Abstract

Most mineral active regions with stocks of mineral and energy resources have undergone decades of extraction, 'fueling' economic development. Although some countries have benefited greatly from mineral extraction and have pursued policies to translate mineral wealth to human and fixed capital, others have failed to capitalize on these, whilst often left with the environmental damage of extractive activities and trade-offs on social and economic variables. Inequity in distribution of resource benefits and cost predispose these regions to conflicts, whilst flows of interaction amongst economic, environmental, and social variables that evolve over time underpin the complex structure that exists in resource systems. These interactions make mineral active regions complex to manage and obscure efforts toward sustainability. Several of the models that evolved to manage subsoil mineral resources lack holistic and multi-disciplinary perspective and fail to address the complexity of the issues. The potential of systems thinking to address these limitations and deliver holistic solutions that are not simply based on competition but collective system benefits has been investigated here in the context of a case study. Findings demonstrate the potential of employing systems tools in understanding and communicating the complexity of these regions, with a conceptual framework for how resources and stakeholders are 'connected' within a 'texture of interdependencies' proposed as an integrated and holistic way to improve management of these regions.

Keywords: Mineral active region. Systems thinking. Sustainability. Environment. Socio-economic.

1. Introduction

The natural environment is an emporium of resources, renewable and non-renewable (Asafu-Adjaye 2005); viewed as a complex of biodiversity and geodiversity. These resources make up our natural capital which includes; sub-soil assets, abiotic flows, and ecosystem capital. Sub-soil extraction has fueled economic development in the modern world and would continue within the conceivable future as long as there are mineral and energy resources to extract while states have sovereign right over the exploitation of their natural resources[1] to meet economic needs. Historically, economic exploitation of minerals and energy resources have inflicted environmental and social consequences in locations of extraction. However, it is a paradox that many regions in the world that are privileged with a plethora of mineral stocks have failed to capitalize on it to set in motion a virtuous cycle of socio-economic change but have suffered instead of benefiting from such resources. This is particularly the case in the developing world where extractive industry operations leave landmarks on communities and regions of mineral wealth as the 'organs' of nature is wrested and stripped away with a disproportionate human and ecosystem impact in mineral rich regions. Based on a previous attempt by (Franks *et al*. 2013), the term mineral active region (MAR) describes a region with stocks of subsoil resources of intrinsic economic interest that can be used beyond the scope and or need of the local people and consequently has characteristically undergone decades of extraction. These regions have commercially extractable deposits of resources with historical production, proven reserves, and on-going extractive activities. For example; minerals, oil, and natural gas. Various factors account for the economic viability of mineral deposits and these include; ore grade and type, mineral quality, and engineering processes available to extract the resource (Franks *et al*. 2013). Mineral extraction is often associated with windfall profits while simultaneously coupled with significant environmental and human health impacts in regions where they take place (Voulvoulis *et al*. 2013) and have been associated with socio-cultural impacts (Kitula 2006), climate impacts, ecosystem and biodiversity destruction as well as human health effects (Azapagic 2004). However, problems associated with mineral resource cannot be attributed to the latent subsoil asset but the complexity and configuration of interest that develop around its exploitation and management. Complexity is a constraint to resource and environmental management and obscures efforts to sustainable development. Complexity is not limited to the amount of knowledge we have because it is an inherent characteristic of environmental and resource systems, however, it is based upon the interdependences and interactions of the components of the system. Studies concerning resource extraction has been advocated at regional level. Finer *et al*. (2008) argues that it provides

[1] Principle 2 of the 1992 Rio Declaration on Environment and Development

avenues for proper delineation and for resource extraction to be coupled to other systemic impacts including proper characterization of exploring regions. Building on from that, (Solomon *et al*. 2008) opined that it improves governance structures and analysis while engendering sustainable development in regions of mineral extraction. Although this study is focused at regional scale, interactions and emergent features that characterise such complex regions could exceed regional level. Examples of mineral active regions include the Cabinda and Soyo regions of Angola (Reed 2009); sub tidal environments of Michilla and Chapaco of Chile (Vásquez *et al*. 1999), the Chaco region of Bolivia (Bebbington 2013), the Orinoco Delta Amacuro of Venezuela (Mantovani 2017), and the Niger Delta Nigeria (Osuji *et al*. 2010). These examples are not exhaustive but illustrate regions where resource extraction has been a challenge for communities, corporates, policy makers and regulators. Mineral active region is a complex system such as those of water catchment. They are dynamic, difficult to understand and confounded by spatial and temporal factors. According to (Arnold & Wade 2015), three paradigms establishes a system, namely; purpose, elements, and interconnections. For a MAR, the purpose is to ensure provision and sustainable use of natural resources and ecosystem services derived while maintaining the structure, functioning, productivity, and diversity of the region. There are inherent ecological and social interactions in a MAR that is usually difficult to understand and contributes to the complexity. It is noteworthy that environment and resource management policies are drawn from wide-ranging sources including the scientific domain and aims to create optimal policies. Feedbacks and emergent features that characterise interactions in mineral active regions have inspired development of management models to enable sustainable mineral extraction regime. These includes but not limited to the integrated resource management (IRM) and the ecosystem approach (EA) that has gained prominence and was bolstered by the (Millennium Ecosystem Assessment 2005). Ecosystems are intrinsically complex and dynamic and the approach has been employed in the management of resource problems in both terrestrial and marine systems. Although the ecosystem approach is a broad and robust way to understand how minerals or energy resource extraction interact with ecological processes and the implications of these interactions for ecosystem function and health, its application in complex systems studies has been limited. However, systems thinking is an important cross-sectoral tool for understanding interactions, complexities and systems behaviour, and has been applied in different domains such as public health, supply chain management, environmntal and sustainability studies. It is therefore worthy to investigate the potential of systems thinking in the mangement of a MAR region. Resource problems are simultaneously viewed as environmental problems and Ludwig *et al*. (1993) argue that natural resource management involves the management of people instead of being exclusively reduced as a resource issue, hence it should be approached from a base level since environmental policy is inherently cross-sectoral and multidisciplinary. The systems approach involves thinking, data collection and communication. Therefore, robust environment and resource policy decisions should base on holistic principles that systems approach provides.

2. Methods

Data on subsoil resources was explored including the World Bank metadata which provides information and data of total wealth estimates and per capita wealth estimates of countries whilst subsoil assets are calculated as sum of oil, natural gas, coal and minerals. For many countries and regions enriched with subsoil asset that have witnessed decades of extractive activities, the explored data suggest that the sustainability of these regions are premised on reserves and quantity of extractable stocks going by World Bank's approach of mineral depletion and exhaustion time. However, systems thinking was applied in a case study to investigate the interactions in a mineral active region as a test of sustainability and to enable improvement in environmental and resource management of the region. Group model building (GMB) activity involving a broad range of stakeholders, interviews and field observations were key to eliciting information that informed the research. Group model building process relied on mental models to elicit variables on resource-environment-economy dynamics of a mineral active region. The process allowed groups to relate variables and to identify feedbacks. Leveraging the capabilities of mental models, patterns and viewpoints were identified for potential systems understanding that could improve decision making processes for policy consideration. This process helped to decompose the complex mineral active system by creating a collective representation and integration of different perspectives as to improve overall understanding of the system based on stakeholder holder inputs.

3. Findings

In a world of increasing complexity and unstructured problems, problem solving needs to be holistic and multidisciplinary. To understand a complex problem as to guide solution design, it is important to have a conceptual representation that envisions the process architecture of interacting components at different spatial and temporal scales. For the MAR, the system components (natural capital, environmental quality, biodiversity and ecosystems, geotechnical features, geopolitical condition, local and regional economy, socio-cultural features, human health effects) are subsumed in the environmental, economic, social, and institutional sustainability tetrapod. It is noteworthy that epochal shifts have seen corporates, non-corporates and government either working toward or being pressured to aspire for a sustainable business orientation. This development occasions the need to reappraise economic and business viewpoints of extractive companies to ensure sustainable business climate. Remarkably, there is increasing recognition that business policies and economic gains are intricately connected (Eweje 2006), thus the need to understand relationship and trade-offs involving extractive industries, the environment and host communities. The literature demonstrates that complexity is an inherent characteristic of environmental and resource systems and a common occurrence across mineral active regions. In this study, a behaviour over time graph of the case study region; the Niger-Delta (ND) Nigeria, was explored and shows a consistent and unmitigated environmental degradation and consequent ecosystem capital loss occasioned by mineral extraction activities and associated externalities. Data demonstrates

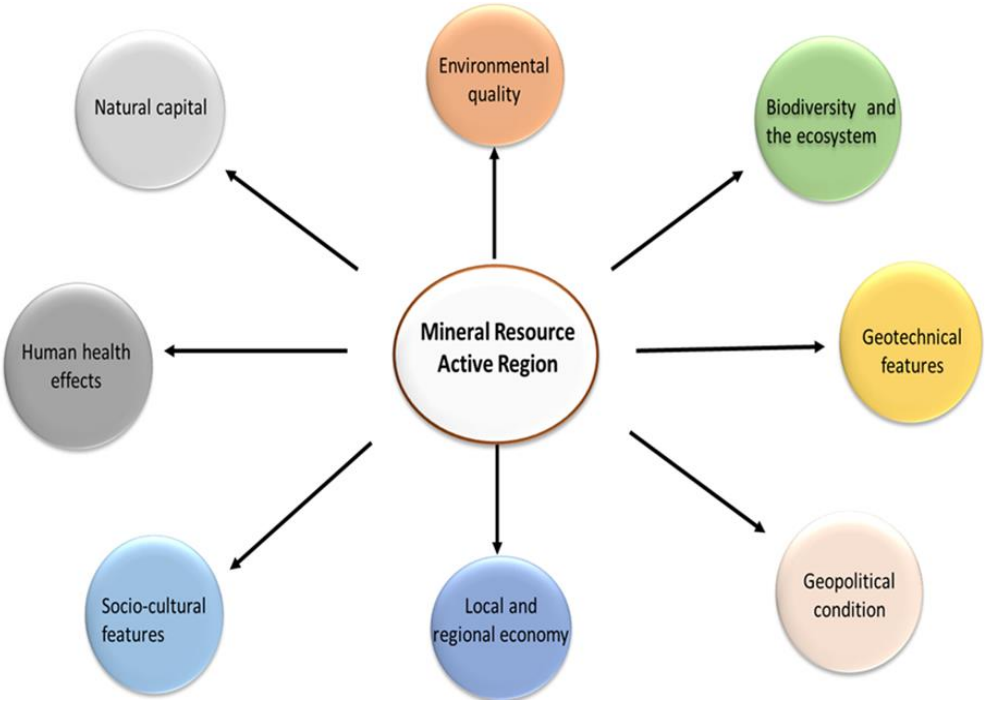

Figure 1. A conceptual representation of the components of a mineral active region.

that sabotage, equipment failure and corrosion were mainly responsible for the irresolvability oil spill 'myth' that plague the region whilst gas flaring; an existential threat to the economy, human and ecosystem health has been attributed to obsolete policies, weak enforcement, lack of local infrastructure, market etcetera. For oil spill, a decline in equipment failure was observed while sabotage increased with time, indicative of a latent socio-economic problem that has evolved over time. The findings set a precedence for the fieldwork that had focus on participatory model building process that would lead to design of robust regional policy based on stakeholders' views. The study reveal that a complex combination of environmental, economic, social, and political factors is responsible for the problem of the ND region. The aspiration of the research was to draw on contemporary knowledge of stakeholders to understand the factors responsible for the complexity observed in mineral active regions to improve their management. A significant finding was a coordinate relationship between environmental damage, land productivity, health, ecosystems services, livelihood destruction, and conflicts in communities. The cumulative environmental and socio-economic impact of oil and gas extraction in communities in the region, coupled with the asymmetric geo-political relations, hinders communities from capturing wealth and employment that could influence regional futures sustainably. This relationship has instigated the emergence of illicit oil economy with non-state actors prevailing over the oil wealth; a prerogative of the state de jure. The non-state actor phenomena have become self-reinforcing by filling the prevailing economic gap in communities that were bioeconomically driven and sustainable. Additional or 'second order' drivers in the system includes: regional futures and development, demand for cheap crude abroad and refined products locally; which is usually in short supply and unaffordable for most communities in the Niger delta, especially those who live in the periphery of cash economy. In addition, lack of capacity to conduct regulatory functions, overlap in regulatory and oversight functions among institutions, absence of political will, obsolete policies and top-down policy formulating approaches were identified to be among problems that beset the region based on the mental models elicited from stakeholders.

4. Discussion

The study shows that resource and environmental problems are inherently complex and characterised by several viewpoints and competing interests. Complexity occasion surprises and policy resistance that can be avoided if problem conceptualisation and solution design are holistic, taking account of interactions and stakeholders' view (Awerbuch *et al*. 2009). By undertaking a participatory approach, different viewpoints were secured to understand the dynamics of human-nature interaction relating to mineral extraction. It is a bottom-up process and allows for representation of the system at base-level processes. The complexity and cumulative impacts of resource extraction is a challenge to institutions, communities, and corporates whilst traditional approaches have been ineffective at management. Therefore, systems thinking based on participatory model building leads to a holistic understanding of complex problems. The use of mental model constructs to understand complex and unstructured problems could be a suitable means for examining and decomposing environmental and resource problems. As a learning process, it creates potential for optimal policy formulation and intervention. This study explored the validity of systems thinking through participatory approaches and affirms its robustness as a choice approach to investigating a complex and unstructured problem. It is

noteworthy that mineral active regions such as the Niger delta Nigeria have an environmentally linked economy; therefore, emergent features and feedbacks from the systems interaction could be a draw-back to the sustainability of communities in these regions. The complexity of mineral active regions and debates surrounding its management and future raises the need to build governance regimes and capacity to effectively optimize benefits and downscale harm attendant with mineral extraction.

5. Conclusion

To manage activities that impact the environment and socio-economic subsystems of the natural world, there is a need to understand the interaction and relationship of the systems components based on an interdisciplinary and holistic approach. Systems thinking techniques can improve our perception of complex situations that lead to policy resistance and therefore a useful tool in policy making. As a tool with exploratory potential for real world complex problems, this approach is valuable to understand the resource-environment-economy complex of a mineral active region and promotes synergy in learning and supporting decision-making and implementation instead of relying on overly optimistic expert or technical knowledge. This article aspires to draw up conceptual constructs while highlighting critical gaps that undermine efforts to sustainable resource extraction and environmental management of MARs. This is a research-in-progress that would deliver a MAR management framework coupled with policy recommendations.

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