



Mineral exhaustion and its livelihood implications for artisanal and small-scale miners

Anna Frohn Pedersen^{a,*}, Jonas Østergaard Nielsen^a, Cecilie Friis^{a,b}, Jesper Bosse Jønsson^c

^a Humboldt-Universität zu Berlin, IRI THESys and The Department of Geography, Unter den Linden 6, D-10099, Berlin, Germany

^b University of Copenhagen, Department of Geosciences & Natural Resource Management, Øster Voldgade 10, 1350, Copenhagen, Denmark

^c RSK Environment (East Africa) Limited, Plot 52, Minazini Road, P. O. Box 3519, Dar es Salaam, Tanzania

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ABSTRACT

Artisanal and small-scale mining (ASM) is a vital livelihood practice around the world, especially in the Global South. In Tanzania, millions of people depend on artisanal and small-scale gold mining and many of these people are in Geita, the main gold mining region of Tanzania. Based on qualitative research conducted in this region, this paper engages the artisanal and small-scale miners' experiences of gold mining. It highlights how extracting gold is experienced as increasingly difficult and how miners worry that gold reserves will be exhausted in the near future. Academic attention and policy making have focused on formalization and sustainable management of ASM, addressing current practices and their social and environmental impacts. However, a knowledge gap remains in the understanding of livelihood implications that emerge when mineral sources are nearing exhaustion and they become harder to extract. In Geita, this has led miners to diversify their investments and consider alternative livelihood strategies. With a focus on the Sustainable Development Goals (SDGs), this paper calls for a broader sustainability discussion on ASM, as well as a better integration of ASM into the SDG agenda. This integration should consider exit strategies for miners as their livelihoods depend upon non-renewable resources.

1. Introduction

Artisanal and small-scale mining (ASM) is a vital livelihood practice and one of the main non-farm rural activities in the Global South (Hilson, 2016; Maconachie and Conteh, 2021). ASM is often defined as the extraction and processing of minerals through intensive labor, rudimentary techniques, and low levels of technology (Hilson and Maconachie, 2017; Veiga et al., 2015). Estimates of the number of people engaged in ASM vary significantly, due to the informality of the sector (World Bank, 2019). In the Global South, approximately 40 million people work with ASM, and 150 million indirectly depend on it (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, 2018). Health and safety risks, exploitation, pollution, chemical contamination, land degradation, and deforestation are widely associated with the sector (Fisher, 2007; Smith et al., 2016; Veiga and Hinton, 2002; Odumo et al., 2018; Peterson and Heemskerk, 2001; Hilson, 2003). Accordingly, scholars, donors and policy makers have been concerned with the sustainable development of ASM (MacDonald,

2006; Zvarivadza, 2018; Maia et al., 2019; Ofosu et al., 2020; Hiron, 2020; Maconachie and Conteh, 2021).

Sustainability is defined as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs.' (World Commission on Environment and Development, 1987, pp 41; Janoušková et al., 2018). Drawing on this definition (Spangenberg, 2017), the Sustainable Development Goals (SDGs) were introduced in 2015 by the United Nations as a way to safeguard a peaceful and prosperous future (Morton et al. 2019). Engaging the three pillars of economic, social and environmental sustainability (Schmidt-Traub et al., 2017), many of the SDGs directly pertain to mining (Hilson and Maconachie, 2020a; Hiron, 2020). Sustainable mining, although an oxymoron, refers to mining practices that balance and promote such economic, environmental and social dimensions (Rajaram and Parameswaran, 2005). In 2016, the United Nations Development Programme launched a roadmap for incorporating mining into the SDGs that focused on large-scale mining (Hilson and Maconachie, 2020a; United Nations Development Program, 2016). However, little attention has been paid to

* Corresponding author.

E-mail addresses: anna.frohn.pedersen@hu-berlin.de (A.F. Pedersen), ostergaj@hu-berlin.de (J.Ø. Nielsen), cefr@ign.ku.dk (C. Friis), JJonsson@rsk.co.uk (J.B. Jønsson).

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how ASM can be incorporated in, contribute to, and benefit from the SDGs. Yet, improving the sector can significantly contribute to reduce poverty (SDG 1), improve food availability (SDG 2), promote gender equality (SDG 5), and create better work environments and economic growth (SDG 8) (Hilson and Maconachie, 2020a).

The importance of ASM for poverty alleviation in the Global South is well established (Ofosu et al., 2020; Cartier and Bürge, 2011; Hilson and Garforth, 2012; Maconachie, 2011). ASM is an important livelihood diversification strategy particularly in times of agricultural hardship (Hilson et al., 2021; Ofosu et al., 2020) as it provides income for people who struggle to find work elsewhere (Hilson et al., 2021; Hiron, 2020). One major challenge, however, is that ASM, like mining in general, relies on non-renewable resources. Hence, a livelihood based on ASM will inevitably fail to ‘maintain or enhance its capabilities and assets, while not undermining the natural resource base’ (Scoones, 1998, pp. 2). Consequently, ASM becomes precarious as a sustainable livelihood practice over time (Cartier and Bürge, 2011; Ofosu et al., 2020). Livelihood diversification research focused on the ASM sector has highlighted how many miners simultaneously engage in other income generating activities (Cartier and Bürge, 2011; Hilson et al., 2021; Ofosu et al., 2020). However, these often depend upon income generated through mining (Cartier and Bürge, 2011; Hilson, 2016). Declining mineral deposits and less labor absorbent extraction methods represent in this light some of the largest sustainability threats related to ASM, impacting those who are directly and indirectly depending on the sector (Maconachie and Conteh, 2021). Facilitating a diversification out of the sector has particular implications for the possibility of reducing poverty (SDG 1) and the securing of resilient and sustainable communities (SDG 11). This discussion is not only relevant for ASM in the Global South, but for many sectors that rely on depleting resources or resources being phased out.

As our point of reference, we consider Geita, the main gold mining region in Tanzania. In Tanzania, ASM is one of the most important non-farm livelihood strategies (Bryceson and Geenen 2016) and it is estimated that between 450,000 and 1.5 million people engage in ASM, while up to 9 million depend on the sector (Mutagwaba et al., 2018). The importance of ASM is increasingly being acknowledged and promoted by policy makers in Tanzania (Pedersen et al., 2019). Although ASM is an important livelihood for thousands of Tanzanians, it is becoming increasingly difficult to practice. Based on 6 months of ethnographic fieldwork in Geita and other settings across Tanzania, we describe how miners experience increasing difficulty in extracting gold due to diminishing deposits. This experience has led many to consider alternative livelihood strategies.

This paper begins with a review of the existing literature on ASM and argues that there is a knowledge gap concerning the livelihood implications of mineral depletion. We proceed to describe ASM in Tanzania by focusing on Geita. This is followed by a presentation of methods. In the results section, we first describe how miners in Geita experience gold depletion and increasing difficulty in extracting it before showing how this situation pushes some miners to consider alternative livelihood strategies. Subsequently, we discuss how our findings contribute to the discussion on the ASM sector and SDGs. We highlight the importance of a broad discourse of sustainability, including the finite nature of the minerals in the sector. We conclude that SDG agendas pertaining to ASM must consider the importance of livelihood diversification and exit strategies.

2. ASM as a livelihood strategy and the challenges for sustainability

Much has been written on the practices and importance of ASM for rural livelihoods in the Global South. This literature explores why people engage in ASM (Jönsson and Fold, 2009; Fisher et al., 2019; Bryceson and Jönsson, 2010; Bryceson et al., 2014), how ASM practices are organized (Jönsson and Fold, 2009, 2011; Bryceson and Geenen, 2016;

Verbrugge, 2015; Chipangura, 2019), the impact of ASM on the natural environment (Hilson, 2002; Kitula, 2006), and how ASM contributes to poverty alleviation (Siegel and Veiga, 2010; Hilson, 2010; Banchirigah and Hilson, 2010; Fisher et al., 2009).

Poverty alleviation is considered a key attribute of the sector and ASM is often framed as a poverty driven activity, meaning that people mainly engage in ASM to escape poverty (Hilson and Osei, 2014; Barry, 1996). ASM provides an income opportunity, a hope to strike it rich, and a chance to diversify and secure a livelihood (Hilson and Osei, 2014; Hilson and Potter, 2003; Fisher et al., 2009; Mwaipopo et al., 2004; Geenen, 2018). Indeed, ASM is often observed as complementing other livelihood strategies, primarily small-scale agriculture and pastoralism, as well as enabling new business ventures (Banchirigah and Hilson, 2010; Hilson, 2016). ASM and small-scale agriculture, for example, are closely linked because many farmers work in mines during agricultural off-seasons (Banchirigah and Hilson, 2010; Hilson, 2016) and income from ASM is often invested in agricultural inputs such as fertilizers (Chachage, 1995; Hilson, 2016). In fact, ASM is estimated to be the most important rural non-farm activity in sub-Saharan Africa (Hilson and Maconachie, 2020a; Maconachie and Conteh, 2021). In other places, including Tanzania, it is increasingly becoming a career path for younger generations in particular because it presents better income opportunities than farming (Bryceson and Jönsson, 2010; Hilson 2010).

Despite these positive aspects of ASM, the sector is rife with environmental, social and economic challenges. The financial cost of engaging in mining is a challenge as the majority of miners have minimal ability to attract capital and often end up in debt (Hilson, 2012; Fisher, 2008). The latter is closely related to the uncertainty and risk inherent in ASM (Hilson, 2012), along with the informal loan systems, in which brokers pre-finance miners (Perks, 2011). Literature has also shown that women are particularly likely to encounter challenges when engaging in ASM. Women’s lack of empowerment and participation in decision-making processes, and their struggle to benefit sufficiently from the sector have been discussed (Lawson, 2018; Jenkins, 2014; Mwakumanya et al., 2016; Hinton et al., 2003).

Moreover, much attention has been paid to the negative environmental impacts of ASM, particularly the issue of mercury use (Hilson, 2002; Taylor et al., 2005; Telmer et al., 2009). Studies have shown that ASM practices lead to land degradation (Bansah et al., 2018; Odumo et al., 2018; Hilson, 2002) and deforestation (Swenson et al., 2011; Peterson and Heemskerk, 2001), and negatively impact groundwater and soil quality (Gyamfi et al., 2019; Veiga and Hinton, 2002). Pollution and mercury contamination (Gibb and O’Leary, 2014; Camacho et al., 2016), along with poor and unsafe work conditions in many ASM operations (Elenge and Brouwer, 2011; Logrosa et al., 2018), have a negative impact on the health of both miners and adjacent communities (Smith et al., 2016; Gibb and O’Leary, 2014; Basu et al., 2015; Bose-O’Reilly et al., 2010).

Consequently, a large body of literature on ASM is concerned with how to improve the sector (Kitula, 2006; Hilson, 2002; Zvarivadza, 2018; Zolnikov, 2012). Better governance (Nyame, 2010; Hilson et al., 2018; Clifford, 2014) education and information (Marshall et al., 2017; Veiga et al., 2015), more environmental management (Burke, 2006), participatory decision-making (Mutagwaba, 2006; Tschakert, 2009), and more transparent and just supply chain management (Veiga et al., 2006; Childs, 2014; Engwicht, 2018) have all been put forward as solutions. Generally, all these solutions are closely associated with formalization or how to incorporate the sector into the formal economy and legal framework (Geenen, 2012; Hilson et al., 2017; Hilson et al., 2019a). The need for formalization, as well as the barriers and challenges to it, have also been a central point of scientific discussion (Siegel et al., 2009; Fold et al., 2014; Hilson, 2020a, 2020b). A key barrier identified is that policy makers and donors promoting formalization rarely account for the livelihood challenges of miners, internal power structures and complex labor and trade systems in ASM (Fold et al., 2014; Geenen, 2012; Maconachie and Hilson, 2011; Verbrugge and

Besmanos, 2016).

Recently, scholars have turned their focus towards the Sustainable Development Goals (SDGs) and how ASM can contribute and adhere to these (Hilson and Maconachie, 2020a; Mensah et al., 2020; Sturman et al., 2020; Hiron, 2020; Laing and Moonsammy, 2021; Ofofu et al., 2020; Maconachie and Conteh, 2021; Niesenbaum, 2020). This focus is partly motivated by the absence of ASM in reports and roadmaps of the SDGs (Hilson and Maconachie, 2020a; Hiron, 2020). This is surprising, since the ASM sector provides employment for millions of people and plays a central role in reducing poverty (SDG 1) and ensuring economic growth (SDG 8) (Hilson and Maconachie, 2020a). Focus is again on formalization as this is assumed to improve working conditions, enable environmental regulation, enhance transparency and advance mechanization (Hilson and Maconachie, 2020a). Within this literature, reliance on finite resources, and the sustainability challenges that come with this, has received less attention. As such, our understanding of the nexus of sustainability and livelihood implications of depending on non-renewable resources, such as gold, remains incomplete (Strambo et al., 2019; Andrews-Speed et al., 2005). Yet, mineral depletion due to ASM is becoming a challenge (Maconachie, 2011; Walsh, 2012; Cartier and Bürge, 2011; Maconachie and Conteh, 2021). Studies from Sierra Leone show how ASM activities declined due to overworked and depleted mining sites (Maconachie, 2011) and how key deposits are becoming increasingly exhausted (Maconachie and Conteh, 2021). Likewise, in the Amazon, mining sites were abandoned because of mineral depletion (Veiga and Hinton, 2002). Mineral busts have also occurred in Tanzania (Bryceson et al., 2012, 2020) and it has been described how artisanal and small-scale miners in Tanzania have to abandon mining sites due to an increased depth of the remaining deposits (Chimhete, 2020). Traditionally, the mobile lifestyle of artisanal and small-scale miners have alleviated this as miners move elsewhere to mine (Bryceson et al., 2020). However, moving to a new site is economically risky and dependent upon the continuous discovery of new mineral sites (Jönsson and Bryceson, 2009). Livelihood diversification is an important strategy in coping with mineral exhaustion (Maconachie, 2011; Cartier and Bürge, 2011). Yet, it often requires access to capital, equipment and land (Perks, 2011), which can be difficult to obtain for the less resourceful ASM workers, who barely earn enough to sustain daily life (Hilson, 2012; Fisher, 2008). Moreover, the capital needed for livelihood diversification is often generated by ASM (Hilson and Garforth, 2012; Cartier and Bürge, 2011). It has been shown, for example, how new businesses and agricultural improvements in many sites across the Global South depend upon income from ASM (Jönsson and Bryceson, 2017; Cartier and Bürge, 2011). The availability of minerals is therefore important for reinvesting in more sustainable livelihood practices (Cartier and Bürge, 2011). Consequently, mineral depletion and its livelihood implications must be incorporated in the sustainability agendas of ASM. We address this issue by turning towards the artisanal and small-scale gold mining sector in Tanzania.

3. ASM in Tanzania and Geita region

Gold was discovered in Tanzania in 1894. In 1922, ASM activities emerged in south-west Tanzania (Kinyondo and Huggins, 2019). The high price of gold during the 1930s led to an acceleration of both large-scale and artisanal gold mining and, in 1939, the overall production was 4 tonnes per year. In the 1940s and 1950s, production declined drastically due to a labor and supply shortage (Kinyondo and Huggins, 2019), rising mining costs (Chimhete, 2020) and low gold prices (Chachage, 1995). New deposits were however discovered but after Tanzania's independence in 1961, President Julius Nyerere was hesitant to initiate new mining activities. According to his government, new mining activities should wait until the country had acquired the technical and financial means to mine without the assistance of foreigners (Kinyondo and Huggins, 2019). This challenged the sector and ASM remained difficult until 1979 when Tanzania introduced its first Mining

Act, allowing Tanzanian citizens to apply for prospecting licenses (Kinyondo and Huggins, 2020). In the wake of this act, new gold fields were discovered (Bryceson et al., 2020). In the 1980s and 1990s, mining became an important non-farm livelihood activity (Bryceson et al., 2020) and there was an estimated 500,000–900,000 artisanal and small-scale miners active in Tanzania by the mid-1990s (Kinyondo and Huggins, 2019).

In 1997, a new Mineral Policy was introduced in order to attract foreign direct investment (Kinyondo and Huggins, 2019). This policy also introduced the Primary Mining License (PML) for small-scale miners, which enabled them to operate within a legal framework and obtain mining rights (Mutagwaba et al., 2018). In 2009, another Mineral Policy further integrated the ASM sector into the national economy. It focused primarily on the slow development of the sector, weak governance, and its minimal contribution to Tanzania's GDP. These issues are likewise addressed in the policies of the current government (Pedersen et al., 2019). By promoting the ASM sector, the policy aims to formalize the sector and enhance revenue collection (Kinyondo and Huggins, 2020). One way in which this policy has manifested is through the newly established state-governed mineral markets. The first market was the gold market in Geita, where over 500 kg of gold is traded on a monthly basis.

Geita is the primary gold mining region in the country and is home to approximately 24% of Tanzania's artisanal and small-scale gold miners (Mutagwaba et al., 2018). Located within the Lake Victoria Zone in Northern Tanzania, it hosts the largest gold mine in Tanzania, Geita Gold Mine. Around this mine, many ASM sites have emerged, ranging from very artisanal endeavors to more developed mining sites. In the Geita region there were in 2019, 1408 licensed ASM areas that averaged 7.5 ha in size. ASM operations in Geita, as elsewhere, are often organized through informal partnerships and comprised of multiple actors, including the claim holder, pit owner, workers and the brokers and dealers who sponsor ASM activities and trade the minerals (Jönsson and Fold, 2009; Fisher, 2007). Because of the interdependent relationships between stakeholders, only a minimum of the profit goes to the workers at the ASM sites and large internal hierarchies exist between actors engaged in the sector (Fold et al., 2014).

After gold mining, the main income sources of the region is agriculture and animal husbandry. During the last two decades, the region has developed immensely, and Geita Town is one of the fastest growing urban areas in East Africa (Bryceson et al., 2020; Lange, 2006). In the past five years, the infrastructure of the town has improved and tarmac roads, tap water and electricity have all been introduced. In addition, new gold-mining technologies have entered the region, such as VAT leaching plants. These plants enable the most resourceful ASM actors to use cyanide to process tailings. Consequently, larger amounts of gold are extracted. Much of this gold stems from the mining sites around Nyarugusu.

Nyarugusu ward consists of five villages and is a main hub for ASM in Tanzania (Bryceson et al., 2020). In Nyarugusu, 40% of the land area is currently being used for mining. Mining activities there date back to the colonial period, when industrial mining was carried out in the region (Jönsson and Bryceson, 2017). When these activities ended in the 1960s, workers turned to artisanal mining. Artisanal mining attracted migrants and more gold deposits were discovered. In the 1980s, mining activity peaked (Jönsson and Bryceson, 2017). By the early 1990s, the surface deposits in Nyarugusu were exhausted and mining activity decreased by a third by the end of the decade (Bryceson et al., 2020). Despite the exhaustion of surface deposits, Nyarugusu still attracts people from all over the country who want to mine or benefit from mining (Jönsson and Bryceson, 2017). As a result, the population of Nyarugusu ward rose from 33,129 in 2002 to 40,588 in 2012 (The United Republic of Tanzania, 2013, 2020).

4. Methods

This paper is based on 6 months of ethnographic fieldwork in Tanzania that was conducted out over three visits by the first author between October 2018 and November 2019. Geita district and Nyarugusu ward were the main research sites, and research there was supplemented by fieldwork in Mwanza, the largest City of the Lake Victoria Gold Fields, Dar-es-Salaam, the commercial capital, and Dodoma, the political capital.

Semi-structured interviews (96 in total) were conducted with a representational range of ASM stakeholders, including ASM workers, claim holders, pit owners, sponsors, brokers and dealers, NGOs, local leaders, regional and national government officers and scholars (Table 1). Interviewees were selected based on their engagement in the ASM sector and identified through preliminary internet research and snowballing. The latter approach is particularly useful for accessing groups of people who operate in informal networks (McCarthy and Molina, 2015). Semi-structured interviews enable both focused discussions and the exploration of new topics and perspectives (DeWalt and DeWalt, 2001). Through the interviews, we engaged stakeholder perspectives on the ASM sector in Tanzania, particularly in relation to issues of local livelihoods, sustainability, transparency and governance. English was used in 49 interviews while 47 were conducted in Swahili. We employed an MSc student from the University of Dar-es-Salaam as a research assistant who helped conduct and translate the Swahili interviews. The vast majority of the interviews took approximately one hour, and were digitally recorded and transcribed.

Participant observation was employed in order to understand the living and working conditions of miners in Geita. Participant observation allows for an open exploration of what is at stake in the field (DeWalt and DeWalt, 2001). Moreover, it provides access to empirical dimensions that are non-verbal or rarely articulated, such as embodied experiences and everyday practices (DeWalt and DeWalt, 1998). The first author lived in Geita Region for a total of 12 weeks and visited various ASM sites. These included gold rush settlements, artisanal mining sites and the most established small-scale mining sites, covering the whole range of ASM activities in the region. Different leaching and elution sites as well as the newly established gold markets were visited on numerous occasions. Observing excavation and processing of gold, camp life at the sites, and daily life in Nyarugusu added further data and provided a deeper understanding of the challenges that miners encounter when seeking to profit from ASM. Moreover, we participated in local stakeholder meetings, workshops and national mining conventions across Tanzania in order to gain an understanding of power dynamics, representation and discourses around ASM – both locally and nationally. Information from participant observation was recorded as field notes and transcribed into Microsoft Word. All collected data were coded using MAXQDA. Data was coded inductively and codes were continuously developed in accordance with the empirical data.

Table 1
Overview of stakeholders interviewed.

Stakeholders	Location
ASM miners: <i>claim holders, pit owners, ASM workers, ASM managers and supervisors</i> (n55)	Geita Region: <i>Geita town, and Nyarugusu</i>
Brokers and dealers (n4)	Geita Region: <i>Geita town, and Nyarugusu</i>
Government officials (n12)	Geita Region: <i>Geita town, Dar-es-Salaam, Dodoma and Mwanza</i>
NGOs (n11)	Geita Region: <i>Geita town, Dar-es-Salaam and Mwanza</i>
Consultants (n9)	Geita Region: <i>Geita town, Dar-es-Salaam</i>
Scholars (n2)	Dar-es-Salaam
Chemical supplier (n1)	Geita Region: <i>Nyarugusu</i>
Journalists (n2)	Dodoma

5. Results

In the 1990s, alluvial mining was common in Nyarugusu. Inhabitants in their 50 s and 60 s recalled how they could pick up gold ‘from everywhere’ and how ‘everyone could mine’. Things are different today. The surface gold is depleted and it is becoming increasingly expensive and difficult to excavate ore. In 2019, almost all ASM in Nyarugusu was carried out in underground pits, some over 100 m deep, and mining today requires much more organization, equipment and technology than in the 1990s. To begin mining at a new site, labor, timber, explosives, and, potentially, machines such as water pumps and air compressors are needed.

Equipment is, however, expensive and obtaining loans from banks requires geological data that shows the likelihood of finding and the estimated amount of gold in the area proposed for mining. Such data is often unavailable or hard to acquire. This was clearly expressed in an interview with a claim holder in Geita Town:

Artisanal miners are very unfortunate. We don’t have enough capital and the financial institutions are not very friendly to the artisanal miners. Sometimes they say that mining is like dumping money, because you mine without knowing what is in the ground. Very few artisanal miners are able to do exploration, or to drill, to see how much gold is in the ground and how deep down, because it is expensive.

Access to bank loans for ASM is also closely related to having a Primary Mining License (PML). A PML gives you the legal right to mine a certain area and the banks require this as security before financing mining activities. Formalization via a PML is therefore key to obtaining bank loans needed for mining. Only few actors in the sector have, however, obtained a PML. The ASM sector is diverse and consists of multiple actors. These include PML or claim holders, ASM workers working in the shafts, hoisting and processing ore, pit owners often hiring and organizing the ASM workers, investors, brokers, and dealers. At an ASM workshop in Geita in July 2019, a miner addressed the issue of PML ownership:

Almost 70% of us are doing small-scale mining but do not have a license. How will you formalize us? How can we formalize the business? How can a person trust me and give me a loan?

To obtain and maintain a PML is not easy. Most of the ASM workers had no means to do this as they lacked the capital required for the application fee and annual rent. To acquire a PML, a person must file an application to the Mining Commission with the coordinates of the desired plot. Many of the mineral rich areas, however, are already allocated to other small-scale miners or to domestic (mainly) and international investors. If someone, often well-off ASM entrepreneurs, successfully obtain a PML, they are required to pay an annual rent of 90,000 TZS (approx. 39 USD) per hectare to the Mining Commission. Additionally, the PML holder is required to financially compensate the people who lived on or farmed the land.

The problems associated with obtaining financing, data and a PML are not the only ones experienced by people engaged in artisanal and small-scale mining in Geita. Groundwater in the pits represent a major concern. Due to the increasing depth of the pits, groundwater is seeping into many mines around the villages of Nyarugusu, Rwamgasa and Nyakagwe. This requires a pump and a generator, and these cost money. A PML holder in Nyarugusu explained:

Before there was no water, now there is a lot of water that you have to pump out. Sometimes you can invest 2 million TZS [approximately 860 USD] and you end up getting a loss because the production is low.

He, like other PML holders, consequently had to cease the mining activity. Timber construction is another large expense. As the pits grow

deeper more timber is needed to prevent them from collapsing. Deeper pits also require more labor or an electric winch to hoist the ore.

‘If you don’t have equipment, you can’t mine’ was the conclusion that many drew. Moreover, they expected this situation to become worse in the future. A PML holder explained that there would come a time where they would need drillers, powerful water pumps and air compressors in order to continue mining. The increasing reliance on advanced equipment was also expected to result in increased dependence upon a more educated labor force within the sector. This would mean less work for many of the current ASM workers since ‘you cannot come from nowhere and then be given an excavator to drive’, as one worker put it.

The need for technology and educated labor would, according to many interviewees, transform all mining into large-scale production. ‘The areas will be fenced by the owners and they might deny us employment’, an ASM worker explained. The general concern that ASM actors would be without work in the future was expressed in several interviews, particularly by ASM workers. The concerns voiced included such statements as: ‘if gold runs out, we remain poor’, ‘there will be more people, but nothing to do’ and ‘we, small-scale miners will have no power in this activity’. Indeed, some ASM workers predicted that the decreasing reserves and increasing expenses would be the end of ASM: ‘In 20 years there will be no small miners because when the years come this gold decreases. Only the big miners will remain’.

The decline in gold and the associated difficulty and cost of extracting it, forced workers, pit owners and claim holders to rethink their future. Many had already diversified their livelihoods and Nyarugusu had become a vibrant village with markets, bars, restaurants and hotels. Maize, cassava, beans, rice, and other crops were often cultivated next to mining sites, and livestock, such as chicken, cattle and goats, were kept. ASM workers were also found to invest in land, transport, commerce, tailoring and mechanics. One common strategy observed, was to import cheap commodities manufactured in China via middlemen which could then be sold locally. Indeed, interviewees occupying different positions within the ASM sector hoped that diversified activities would help them cope with mineral exhaustion. A local mining engineer described how people had invested their money from ASM into other businesses, because ‘they all know that this is not like grass that we grow all the time. Once we exhaust gold, then it is gone’. A PML holder in Nyarugusu even defined sustainability as the diversification of investments, saying: ‘sustainability is when you invest in different things. That way, you can still earn money even if the production is low’. Another claim holder similarly argued that livelihood diversification was important for future survival:

You should always think that one day there will be no gold. Now what do you do after there is a gold closure? Should you refrain from surviving? That is why you have to make another business. That is why people are building hotels and so forth, because when there is no gold, they can earn money by renting out the houses, because one day there will be no gold. That is for sure.

Particularly ASM workers expressed how they wanted to engage in other activities ‘after they got money’. ‘If you succeed in mining, you can do other things’, an ASM worker explained. However, during interviews it became evident that many, especially the workers, could barely sustain a basic living. In fact, many described how only ASM investors were able to profit from mining. Such investors had built several hotels and a gas station in the village. For the ASM workers and less resourceful claim holders and pit owners, such investments were not possible. ‘The artisanal miner is there today and tomorrow, it is the same. He is shedding a lot of tears and sweating a lot of sweat, but he remains there’, a claim holder stated. Consequently, diversifying out of ASM remained a dream for many.

Migration to other areas with more minerals was another often mentioned way to deal with the diminishing resources. The ASM sector

has a low entry barrier and people can in general easily move in and out of the sector as well as to new sites. In Nyarugusu many ASM workers, particularly those processing the ore, were for example only hired on a daily basis. ASM workers migrate according to the ‘gold rushes’, where new deposits have been located. Many ASM workers explained how they had partaken in several gold rushes. Others, especially the young men without family, stated that they were willing to move anywhere to make a living and, as they expressed it, ‘find life’. However, diminishing reserves are not only a challenge in Geita. All over the country, a government official explained, it is becoming harder to mine, and fewer gold rushes are occurring. ‘Gold is not over, but it is at a deeper depth’, he stated. Another government official agreed that Tanzania had much undiscovered gold but that it was located at a deeper level than what had previously been mined. As such, the mining opportunities for both ASM workers, claim holders and pit owners are decreasing across Tanzania. A point echoed during conversations with ASM actors in Geita.

Diminishing gold reserves and current and future livelihoods were also concerns expressed by NGOs, mining associations and government officials. A leader of a regional miner association advocated for diversifying investments out of mining and into agriculture and husbandry. As he explained in July 2019 during a workshop for 400 artisanal and small-scale miners in Geita:

I have been 30 years in the business. I understand that when we get money we end up investing in gold, but why not in other activities? The gold is deep down in the soil, not up on the surface like the rain. 30 years from now there will be no gold, so the children will not be able to survive on mining.

Government officials at the meeting, including the deputy minister from the Ministry of Minerals, concurred with this. Referring to the town of Kahama in the Shinyanga Region, where gold supplies were nearly exhausted and the ASM activities had decreased during the last two years, he explained that ‘you, small-scale miners need to prepare for the day when gold runs out’. Government institutions and NGOs echoed this during interviews. A regional administrative employee in Geita explained in an interview that ‘gold is being exhausted, we have to think about the sustainability of the people. That is why we are trying to emphasize the importance of agriculture’. An engineer from a governmental mining institution argued that the entire Geita district was indeed vulnerable to gold exhaustion:

In Geita you see a lot of leaching and elution plants. All of them depend on gold. So if gold is depleted, there will be no industry in Geita. [...] But if people were investing in other industries maybe related to crops or fishing, Geita could exist even if there were no minerals.

As the engineer’s argument exemplifies, diversification was encouraged by several government institutions, as well as NGOs. According to the engineer, the challenge was to convince people to invest in mining districts. ‘People might be afraid that this is just a mineral town, and when the minerals are depleted, people will run away from it, and no one will be there’. This fear, he argued, was why regions like Geita continued to be poor, despite their mineral wealth.

6. Discussion

ASM is an important livelihood practice in the Global South (Siegel and Veiga, 2010; Hilson, 2010; Fisher et al., 2009). Its social and environmental impacts have received substantial attention and scholars, policy makers and NGOs have focused on how to improve the socio-environmental conditions and practices in the sector (Mutagwaba et al., 2018; Kitula, 2006; Hilson, 2002), particularly in relation to mercury use (Telmer et al., 2009; Clifford, 2014; Fritz et al., 2016), environmental degradation (Bansah et al., 2018; Ofosu et al., 2020), gender (Werthmann, 2009; Yakovleva, 2007), power asymmetries

(Fisher, 2007; Maconachie and Conteh, 2021; Engwicht, 2018), and health and safety issues (Smith et al., 2016; Logrosa et al., 2018).

Recently, ASM scholars have turned their focus towards the Sustainable Development Goals (SDGs) and how ASM can contribute and adhere to these (Hilson and Maconachie, 2020a; Sturman et al., 2020; Mensah et al., 2020; Hirons, 2020; Laing and Moonsammy, 2021; Niesenbaum, 2020). This focus is motivated by the fact that improving the sector can play a central role in achieving a number of the 2015 SDGs, including reducing poverty (SDG 1), promoting gender equality (SDG 5), ensuring better working conditions and economic growth (SDG 8) (Laing and Moonsammy, 2021). It can also aid with SDGs that revolve around better health (SDG 3) and clean water (SDG 6) (Hilson and Maconachie, 2020a; Hirons, 2020). Scholarly focus is also motivated by the absence of ASM in the reports and roadmaps of the SDGs (Hilson and Maconachie, 2020a; Hirons, 2020).

The connection between mineral depletion and the social, economic and environmental consequences of mining closure remain unexplored in the context of the SDGs and sustainability of ASM. Our results illustrate the importance of addressing this issue as mineral exhaustion is currently being experienced in the Geita Region and is an increasing concern among people whose livelihoods depend on the presence of gold (see also Bryceson et al., 2020). Deeper pits, the flooding of pits, and the need for more timber to secure pits were all mentioned by our informants as challenging ASM, along with the need for more knowhow and equipment (see also Mwaipopo et al., 2004). This caused ASM workers and claim holders, among other actors, to fear for the future of ASM and to think about how to completely exit the sector.

Mineral depletion is not a sudden event, but a process occurring over time. As such, many are adapting to this process by diversifying livelihoods and investments away from ASM (see also Maconachie, 2011). Yet, the ASM sector is heterogeneous, comprising both poverty-driven and profit-driven actors with widely different opportunities and resources (Hilson and Maconachie, 2020b). Power asymmetries prevail in the sector (Maconachie and Conteh, 2021; van Bockstael, 2019), with ASM workers earning only a fraction of what other actors earn (van Bockstael, 2014). Consequently, most ASM workers fail to escape poverty (Niesenbaum, 2020), and it has been argued that current development and formalization agendas are further marginalizing the poorest within the sector (Hirons, 2020).

Given the inequality within the ASM sector, mineral depletion will effect actors differently. Venturing out of ASM requires capital which can be difficult to obtain for the less resourceful ASM workers in Tanzania or elsewhere (Hilson, 2012; Fisher, 2008). The restriction of access to loans, land, equipment and networks needed to, for example, engage fully in agriculture, transport or commerce also hinder movement away from the sector for the more marginalized actors (Perks, 2011). If, as our results suggest, migration to new mining sites becomes more difficult due to mineral decline, ASM workers will also have decreasing livelihood options within ASM. Moreover, dwindling quantities of gold were a concern among many, despite high gold prices. If the price drops, as it has done historically (World Gold Council, 2020), the impact of mineral decline will be significantly more pronounced.

ASM is the most important non-farm rural livelihood activity in Sub-Saharan Africa (Maconachie and Conteh, 2021). The sector provides work for the otherwise unemployed (Hilson et al., 2021) and secures livelihoods when agriculture is unviable (Hilson and Maconachie, 2020b; Ofofu et al., 2020; Siegel and Veiga, 2010). A central question is thus, if enough work is available in other sectors to employ the many Tanzanians whose livelihoods are threatened by mineral decline. Generally, economic growth in Tanzania has not resulted in more opportunities for formal employment, and the small-scale agricultural sector, on which many rely, continues to be under pressure since much land is being allocated for large-scale mining, agriculture, tourism and conservation (Bluwstein et al., 2018). Moreover, the population in Tanzania is expected to rise rapidly from 58 million in 2019 (United Nations, 2020) to an estimated 137 million in 2050 (Bluwstein et al.,

2018). However, the number of investments in Tanzania are decreasing and this is resulting in the creation of fewer jobs for a growing population (Kinyondo and Pelizzo, 2018). The increasing rate of urbanization is similarly putting pressure on both the formal and informal economy in places such as Dar-es-Salaam where the unemployment rates are even higher than in rural areas (Banks, 2016). Furthermore, many other livelihoods are directly connected to ASM activities in mining areas (Bryceson et al., 2012) as well as further away via remittances (Bryceson et al., 2013), and is, thus similarly vulnerable to mineral decline. Fertilization and mechanization is, for example, often sponsored by money made through mining (Hilson, 2016). Given these circumstances, the availability of alternative livelihoods is unlikely (see also Siegel and Veiga, 2010).

The increasing need for knowledge, materials and capital to mine deposits deep underground increases the pressure on unskilled workers and makes it more difficult for them to make a living from mining. This concern was raised by ASM workers who often mentioned how mining would transform into large-scale production without providing more work: ‘there will be more people, but nothing to do’. Similar processes have been seen in Sierra Leone, where mechanization of ASM practices and mineral decline are jeopardizing the livelihoods of thousands (Maconachie and Conteh, 2021). Moreover, it has been argued that an increased mechanization of ASM will significantly impact the sectors’ distribution effects, producing resource enclaves as seen in the large-scale mining sector (Ofofu et al., 2020). This mirrors the general development across the Global South. Li has, for example, raised this issue in relation to agricultural industrialization in South East Asia (Li, 2010, 2017). Capitalist modes of production based on large land acquisitions, yet with minimal labor requirements, result in the displacement of people from their land when their labor is no longer needed. If the mineral decline makes it impossible for ASM activities to continue at the current pace, mining will increasingly be something conducted by large companies, and fewer jobs will consequently be available. Less resourceful miners, particularly ASM workers, might indeed, like rural populations in areas of South East Asia, find themselves ‘surplus to society’ (Li, 2010, 2017) if they fail to diversify out of ASM. Consequently, the loss of jobs becomes a significant barrier to achieving many of the SDGs through the ASM sector (Maconachie and Conteh, 2021).

This issue of post-mining livelihoods is already being addressed in relation to large-scale mining closures worldwide. Research and policy findings from this field emphasize the need for socio-economic recovery plans in order to secure a sustainable future for mining communities after mining ceases (Halvaksz, 2008; Mfune et al., 2018; Strambo et al., 2019). ‘Ghost towns’ or ‘shanty towns’ are to be avoided (Mfune et al., 2018; Veiga et al., 2001) and it has been argued that large-scale companies often fail to take social impacts into account when planning for mining closure (Halvaksz, 2008). The impacts of mining closure on communities in the Global South is less researched (Strambo et al., 2019; Mfune et al., 2018). It has, however, been pointed out that claim holders and pit owners in the ASM sector rarely have the resources to plan closures in a systematic manner, or to compensate workers for lost income and mitigate socioeconomic and environmental consequences in the same way as large-scale companies do in the Global North (Andrews-Speed et al., 2005). Consequently, there has been a call to better our understanding of the impacts of mining closure in the Global South and how to alleviate its negative impacts (Strambo et al., 2019).

Our results respond to this call. Mineral depletion happens slowly over a range of years, and new ASM dynamics and adaptation strategies might emerge from this challenge. Yet, based on our findings, we do suggest that there is a need for policy makers, scholars and NGOs to consider mineral exhaustion when designing agendas and roadmaps for sustainable mining. While important, the emphasis on making the sector more sustainable, i.e. implementing better practices, will potentially be of less importance once ASM practices disappear. Mineral exhaustion is an inevitable aspect of mining and must be addressed in order for communities and individuals to sustain themselves in a post-mining

environment. Indeed, within the ASM hierarchy, actors will be positioned very differently when mineral depletion occurs. In Geita, livelihood diversification was highlighted as a way to safeguard livelihoods, mirroring a general trend across Sub-Saharan Africa (Cartier and Bürge, 2011; Hilson et al., 2021). In fact, livelihood diversification was even referred to by local actors as *the* definition of sustainability. Yet, as we have shown, ASM is already a diversification *out of* agriculture (Siegel and Veiga, 2010) and venturing into new livelihoods is not simple (Perks, 2011), particularly not for the less resourceful ASM actors. Population growth, reduced accessibility of land due to privatization, and limited job creation across Tanzania (Bluwstein et al., 2018; Kinyondo and Pelizzo, 2018) narrow the range of alternative income sources. Similar processes can be observed in many countries within Sub-Saharan Africa (Fox and Thomas, 2016; United Nations, 2020). In fact, youth unemployment is considered one of the biggest development problems in Sub-Saharan Africa (Hilson et al., 2021). Consequently, while many will inevitably adapt to the decrease of mineral deposits, others might struggle to do so and potentially become surplus to society with few livelihood opportunities. As such, to realize the motto of ‘leaving no one behind’ (United Nations Development Program, 2018), the SDG agendas must directly engage the ASM sector and address the millions of people in the extractive industries whose livelihoods are threatened by declining resources.

7. Conclusion

Socio-economic impacts of mineral exhaustion have not been given much attention in ASM literature. In this paper, we addressed this knowledge gap, highlighting how mineral exhaustion is a concern among artisanal and small-scale miners in the Geita region of Tanzania. We showed how mineral decline affects miners’ ability to continue mining activities as minerals are increasingly found deeper in the ground and require more labor, equipment and knowhow to extract. Moreover, we showed how future livelihoods are a concern among miners, particularly ASM workers, and how many seek to diversify their income sources in the wake of mineral exhaustion. Yet, venturing out of ASM is a challenge for the less resourceful actors who do not have capital to re-invest in other sectors. These findings have implications for the sustainability of the sector. Specifically, the goals of reducing poverty (SDG 1) and securing resilient and sustainable communities (SDG 11) are threatened by the fact that mineral resources are non-renewable and will eventually diminish. If so, the less resourceful ASM actors risk being ‘left behind’. Consequently, a better integration of ASM and, in particular, mineral decline into the SDG agendas on mining is needed. This should consider the challenges of livelihood diversification and exit strategies for the miners and communities whose livelihoods are dependent on non-renewable resources.

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CRediT authorship contribution statement

Anna Frohn Pedersen: Conceptualization, Methodology, Investigation, Validation, Visualization, Project administration, Writing - original draft. **Jonas Østergaard Nielsen:** Supervision, Writing - review & editing, Project administration, Funding acquisition. **Cecilie Friis:** Writing - review & editing. **Jesper Bosse Jønsson:** Writing - review & editing, Project administration.

Declaration of Competing Interest

The authors report no declarations of interest.

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