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Artisanal opal mining and associated environmental and socio-economic issues in opal mine sites of Wollo province, Ethiopia

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Abstract This research is conducted in Wollo province, northern Ethiopia. The main objective of the research is to assess the environmental and socio-economic impact of opal mining. The study was conducted through qualitative and quantitative data collection on the natural environment and socio-economic situation of the study area. Results showed that opal mining activity brought benefits to the local community. It improved the livelihood and food security through creation of alternative means of income, job creation and related side business opportunities. However, the negative impacts are found to outweigh the positive ones. Local communities ($\sim$ 35% of the respondents) believe that the main beneficiaries of the opal business are brokers. Absence of firm legal framework; very poor mining techniques and weak position of illiterate and uninformed small-scale miners in purchase, sales and marketing of opal undermined the benefits. Survey results showed that around 86.3% of deaths in the mining sites are caused by rock collapse. Further impacts include prevalence of disease (mainly HIV/AIDS), child labor and school dropout (up to 7%), unplanned growth and expansion of settlements, and illegal opal trading. Acceleration of soil erosion, loss of vegetation, disturbance of the natural landscape, waste rock accumulation, mass movement on steep slope and associated hazards are the main impacts of opal mining on the natural environment. It is concluded that most of the negative consequences emanate from lack of necessary support, training and proper governance of the resource development process.

Keywords Artisanal mining · Opal · Wollo · Semi precious stone · Ethiopia

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Introduction

The mining industry of Ethiopia has been dominated by gold mining for many years. Gemstone mining came to the mix in the 1990's where a precious chocolate opal was discovered in north Shewa province around a locality called Mezzezzo. This was later followed by the discovery of even more precious and stable white opal in Wollo province specifically Delanta district around localities called Wogeltena and Tsehay Mewcha in 2008 (Rondeau et al., 2009, 2010). A number of other localities in Wollo are now sites of intensive opal search and extraction by locals. The discovery of opal deposit in north central Ethiopia brought a shift and diversification not only in the type of minerals extracted but also a new geographic territory of mineral resource in Ethiopia.

Estimation of the contribution of the mining sector to the national economy of Ethiopia vary from source to source. Recent estimate by the World Bank Group (WBG) gives a 1.5% contribution to the national GDP and about 19% of the country's export for the year 2012 (WBG 2014). According to Ministry of Mines (MoM) of Ethiopia, the major and significant input of the mining industry to the national economy is twofold: as a source of foreign currency next to coffee and sesame seed and the employment opportunities provided to many unemployed rural communities through Artisanal and Small-Scale Mining (ASM) (MoM, 2009). Ministry of Mines of Ethiopia estimates the employment by ASM in Ethiopia to be up to 1 million and supports the livelihood of more than 5 million people (MoM, 2012). A study sponsored by Ethiopian Extractive Industries Transparency Initiative (EEITI) revised the direct employment figure to be around 1.3 million and the direct/indirect dependents on the sector to be 7.5 million people (EEITI, 2016). Artisanal and Small-Scale Mining in Ethiopia is dominated by alluvial gold mining and gemstones, and almost 90% of the latter comes from opal mining in Wollo (WGB, 2014). According to the annual reports of the MoM, production and export of gemstone through the formal channel is estimated to be 20,285 kg for the fiscal years 2008/09 to 2011/12 (MoM, 2012). Moreover, the EEITI report estimated that close to 18,660 people are involved in opal mining in Wollo and North Shewa zones where opal is mined since 1990's (EEITI, 2016).

The gemstone mining sector in north central Ethiopia is the least researched sector because it is relatively a recent economic activity in the region. There is no research conducted on opal mining and its impact in this part of the country. The limited reports produced by different organizations on mining in Ethiopia focus on country level issues, not specifically on this part of the country except mentioning its presence. There is no primary survey data collected on these localities as to how the gemstone mining is affecting or contributing to the wellbeing of the local community. This research is aimed at evaluating the environmental, social and economic impact of gemstone mining in Wollo province of Ethiopia. We further examine what factors should be considered to maximize the benefits from this natural resource in the region and mitigate the impacts on the natural and social environment.

Artisanal and small-scale mining in the literature

In many geographic regions of the world, mining acts as a catalyst both for the local socio-economic development and for national economic stability (Bebbington et al., 2008a; Bridge, 2004, 2008; Buxton, 2013; Hilson, 2009, 2016a, b; ICMM, 2014). Regional and local development efforts are assisted by extraction and development of mineral and energy resources from the earth. Especially since the industrialization era of the twentieth century the mining industry is considered as a propellant to modernization, economic and social transformation (Bridge, 2004, 2008; Hart, 2001). This is because regions rich in mineral and energy resources are able to easily join and have access to the global investment and commodity flow by attracting external financial investments and external markets available for mineral products (Bridge, 2008). Development of mineral resources creates a series of 'spread effects' which drive broad economic expansion and high levels of social benefits (Gunton, 2003) by initiating cycles of economic growth. Countries of the world employed such opportunities at different times depending on availability of the earth resources within their territories and their technological advancement required for locating, extracting, refining and manufacturing commodities from mineral raw materials. Countries located in Europe, Australia and North America are the first to pursue their socio-economic transformation through the help of mining (Gunton, 2003). Mining activities and related investments are thus taking geographical form, expanding to many territories of the world from the traditionally mining dominated countries like those mentioned above to developing countries and emerging economies like South Africa, Ghana, China, India, Brazil and the likes. Extraction of mineral and energy resources from the subsurface earth brings values of minerals into the economy and triggers development. The nexus between the extractive industry, regional and local economic development, and social transformation are expressed by different authors as 'territorial modernization' (Hart, 2001), 'the theory of comparative advantage' in international trade, and the theory of 'big-push' modernization or regional growth-poles because of the social values that can be attained through large scale infrastructure projects (Sachs & Warner, 1999).

On the other hand, poor performance of many mineral dependent economies, corruption, disparity in mineral wealth distribution, political strife, war, migration, human right abuses and related misgivings in mineral rich localities and finally the physical, biological and chemical degradation (in some cases irreparable) of the natural environment by mining activities led many authors to explain the phenomenon with the theory of 'resource curse' (Auty, 1993, 1994; Bebbington et al., 2008a; Bridge, 2004; Cuba et al., 2014; Gelb, 1988; Sachs & Warner, 1999 and others), which claims that 'natural resource abundance generates a series of economic and political distortions which ultimately undermine the contributions of extractive industry to development' (Bebbington et al., 2008a). As a result, there are plenty of doubts and arguments on whether the mere presence of mineral resources brings sustainable and all-inclusive development and social transformation or needs additional ingredients. Bridge (2004) explains that the problem of associating mineral extraction and related malfunctioning of the economy should be analyzed if the relationship is one of "causative', or whether it is rooted to the operation of other factors such as weak resource governance.

Artisanal and Small-Scale Mining is a type of mining where mining is by individuals, groups, families or cooperatives with minimal or no mechanization. It is becoming increasingly important in the world economy (Buxton, 2013; Hilson, 2009, 2016a, b; ICMM, 2014; IGF, 2017). It is an important source of employment and income for miners and their dependents especially in the rural areas of developing countries (Brown, 2018; Cartier, 2009; Hilson, 2011, 2016a, b). Specifically, the gemstone market involves a huge financial transaction estimated to be between USD 17 and 23 billion in 2015 (Paul & Emma, 2017). The contribution of ASM is increasing from time to time. Globally it is estimated that the livelihood of close to 100 million people depend on ASM directly or indirectly (IGF, 2017). In addition to sustaining the livelihood of local people, revenues from ASM, if properly managed, can be used to support and catalyze investments in other economic sector, rural transformation (lifting miners beyond subsistence level), improved service delivery and sound macroeconomic improvement (Fraekal & Vangynes, 2018; Hilson, 2013; Puppim & Saleem, 2011). As such ASM is becoming a more integral component of the rural economy (Hilson & Gatsinzi, 2014). The expansion of ASM in the past two to three decades is ascribed to agricultural crises and poverty of the rural community (Cartier & Burge, 2011; Hilson, 2010, 2011; Zvarivadza & Nhleko, 2018 and others).

However, ASM is usually blamed for a series of environmental, social, economic, political, safety, and health challenges (Bridge, 2008; Bebbington et al., 2008; Benjaminsen, 2015; Duffy, 2007; Getaneh & Alemayehu, 2006; Hilson 2003, 2006; Melaku, 2007; Zvarivadza & Nhleko, 2018 and others). The informal, unorganized and illegal mining degrades the natural environment. Absence of a fair market forces miners to sell their products at a cheap price. This situation leaves them in a disadvantaged position. Therefore, they cannot improve their livelihood and remain trapped in poverty and exploited by others (Brazeal, 2017; Cuba et al., 2014; Fisher, 1997, 2012, 2018; Fraser et al., 2014). Artisanal and Small-Scale Mining is characterized by diffuse (unorganized), informal, temporal (usually between harvesting seasons) and low capacity of miners which hinder effective, profitable and proper extraction and governance of the resource development process. This situation results in the ASM to be illegal, reducing revenue and profit to local miners, environmental degradation and trapping of miners in perpetual poverty (Bebbington, 2013; Bridge, 2004, 2008). As many of the income-generating activities along the gemstone supply chain such as gemstone cutting and polishing are performed outside countries of gem origin (IGF, 2017; Puppim & Saleem, 2011), benefits to local miners remain minimal. The overall scenario leads to inability of miners to secure sustainable livelihood and the social and environmental costs stay at the local level (Paul & Emma, 2017). In developing countries like Ethiopia, effective development of gemstone resources is undermined by an ineffective regulatory framework, low capacity in the private sector and weak rule of law. These are further fueled by absence of geological data on the deposit, ineffective fiscal framework, poor access to credit and technology and also corruption preventing profitable development of gemstone by local miners (Paul & Emma, 2017). Absence of effective marketing and promotion are also barriers of gemstone development in the developing world. The advent of ASM activities in a certain area attracts many people to the ASM business where communities

tend to replace their traditional subsistence agriculture with artisanal mining hoping it will bring them quick money to sustain their livelihood (Hilson, 2016a, b; Lahiri-Dutt, 2014). Many studies showed that much of their hopes remain unfulfilled (Cartier, 2009; IGF, 2017; Puppim & Saleem, 2011). Rather their move brings them unintended consequences of losing their gain through extravagant expenditures (Walsh, 2003), or to opportunistic people drawn to the business, or their limited knowledge of the sector and other related factors mentioned above. Consequently, gem production generally contributes little to miners and local development except the temporary employment (Hilson, 2009; Paul & Emma, 2017). The scientific literature on curbing these undesirable consequences of ASM proposed a number of measures among which is organizing local miners into cooperatives. Some of these literature suggest that formalizing the operation, organizing miners in groups and their supporting organizations could bring local solutions by creating favorable conditions through creating access to formalized working conditions, credit, new market and collective negotiation power and technical support (Hilson, 2017; Puppim & Saleem, 2011; Siwale & Siwale, 2017; Verbrugge & Besmanos, 2016).

The study area

The study area is located in the north central plateau of Ethiopia specifically called Wollo, Delanta district (Fig. 1). The nearby major towns are Wogeltena and Tsehay Mewcha. The mining sites are about 650 km from Addis Ababa. In the district there are a number of opal mining sites including Tsehay Mewcha, Mehal Ways, Chegien, Gengena and many others. The district is a highland area (reaching up to 3800 m above sea level) characterized by highly rugged, cliffy, rocky and mountainous terrain. The landform presents a real challenge to access different parts of the area where the opal deposits are exposed. Absence of rainfall (average annual 83 mm, NMSA, 2010) throughout the year, except between June and September in which almost all of the rainfall occurs, characterizes the district. Consequently, water shortage is critical in the region. This coupled with the fact that the major economic activity is rain-fed agriculture and animal husbandry created insecure livelihood of local communities. The area is highly degraded. Because of the long history of agricultural practice and high population density in the area, vegetation cover is very low. Consequently, soil erosion on the steep slope areas is enormous. Gullies are commonly observed everywhere including the mining sites where soils are totally removed beyond recovery. This resulted in food deficiency and resource degradation is severe further aggravating land degradation, soil erosion, and shortage of water supply. The recent discovery of the opal deposit brought new hopes of securing livelihood by engaging in artisanal opal mining and related economic activities. According to the last national population census conducted in 2007 (CSA, 2007), the total population of the district was 135,246 out of which 67,581 (50.24%) are male and 67,946 (49.76%) are female. Economically active population of the district (15–55 years of age) is 102,176; out of which 55,668 (54.48%) are male and 46,508 (45.51%) are female.

Methods

Preliminary field survey has been conducted just before the actual sampling survey. Observation was also made on the geology, distribution of mining activities, and topographic features of selected mining sites, specifically Chegien, Minychil, Tach Amba and Gengena. In order to identify and analyze the major socio-economic impacts in the study area, socioeconomic data were obtained from administrators and sampled households. A total of 92 individuals were sampled for the questionnaire. Based on the research questions, observation, survey, and interviews were conducted. The informal survey was used to gather information on the management and state of the community. The outcomes from the informal survey were used as a basis for the preparation of questionnaires for the formal survey. The formal survey, using semi-structured questionnaire, was conducted on 10, 21 and 61 respondents which were selected from administrators, non-mining community living in nearby areas to the four mining sites and miners of the study area respectively. We used a purposive sampling method to select groups and individuals for both the questionnaire and focus group discussion. The questionnaire was prepared in the local language (Amharic) and so was the interview. Local experts from the District Office of Agriculture and Rural

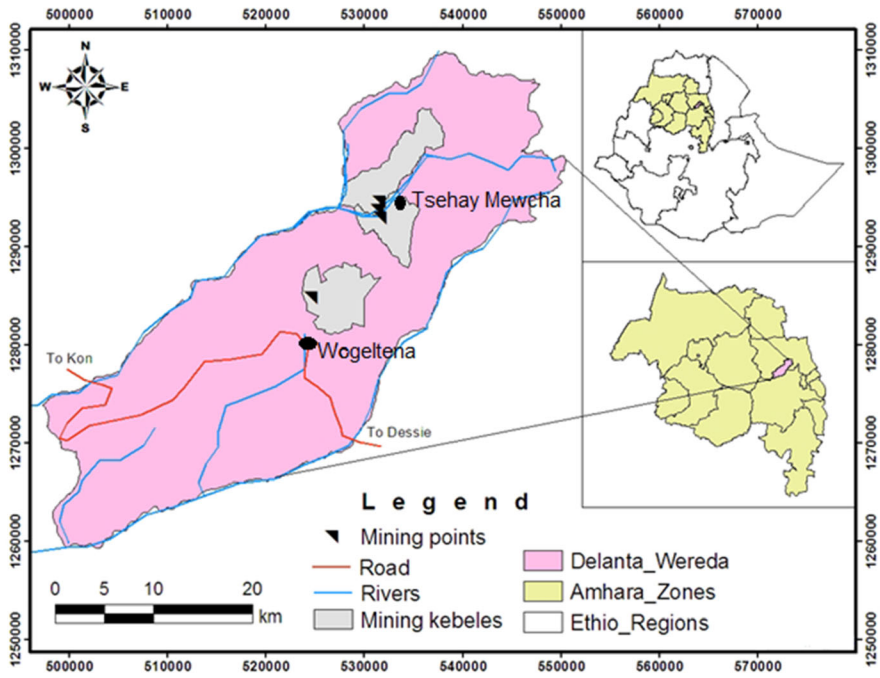

Fig. 1 Location of the study area and mining sites

Development were hired and trained to administer the interview. Relevant socio-economic data were also collected from government offices (mainly schools, health centers, and local courts) for the years 2007 to 2011 in which the opal mining was at its peak.

Samples of waste rock and river/spring water were collected for chemical analysis of potentially toxic metals which might come from host rocks of the opal deposit. Moreover, in situ measurement of water quality parameters, viz. pH, electrical conductivity and total dissolved solids (TDS) was conducted. The status of soil erosion around the mine sites was also assessed using the revised RUSLE model (Renard et al., 1997). The detailed method of assessing soil erosion using the RUSLE method, the parameters used and how these parameters are derived from geospatial data are discussed in Renard et al. (1997) and Habtamu et al. (2020). The collected qualitative and quantitative data were integrated and analyzed to assess the impacts of the gemstone mining in the study area.

Results and discussion

Socio-economic status of respondents involved in the survey

Table 1 presents the socio-economic characteristics of respondents who participated in this survey. The willingness to participate and availability of females for the survey was limited (15.2%) as a result of which the dataset is significantly gender-skewed. All respondents except the civil servants earn their living mainly through agriculture (farming and animal husbandry). The opal mining activity is a recent coming

Table 1 Socio-economic characteristics of individuals involved in this study

Characteristic	Category	Number (%)
Sex	Male	78 (84.8)
	Female	14 (15.2)
Occupation	Farmers	34 (37)
	Civil Servants	10 (10.9)
	Students	16 (17.4)
	Petty Business	9 (9.8)
	Unemployed	23 (25)

occupation and is practiced in addition to the major activity. Moreover, even the civil servants are involved in the mining business as brokers or intermediaries in the opal transaction chain to supplement their major source of income. The term "unemployed" in this study denotes people of the rural community who have no farms; consequently, they earn their living by renting farm lands or as daily laborers in farms and opal mining sites.

Economic significance of the opal mining to the local community

Artisanal and Small-Scale Mining of mineral commodities is a major source of income for people living in poverty. As such in many parts of the world, it became a means of maintaining livelihood of poor communities which have no or limited alternative economic opportunities (Antonio, 2004; Buxton, 2013; CDS, 2004; Franks et al., 2016; Hayes, 2008; Hentschel et al., 2003; ICMM, 2014; Noetstaller et al., 2004). The opal mining activity in Delanta District is not exceptional to this worldwide reality. People in the area have benefited from it and improved their livelihood through direct and indirect economic activities related to opal mining. Nearly 90% of the respondents confirmed that the opal mining has brought benefits to them and improved their livelihood (Table 2). However, miners were not willing to disclose their actual income from opal mining. Other studies conducted indirectly estimated the average annual income of the miners to be around 8200 Ethiopian birr (USD $29) (EEITI, 2016).

The direct economic benefits are realized through direct employment which involves opal digging where many youths (individually or mostly with friends or family members and are usually without legal permit or as members of licensed cooperatives) have their own mining pits from which they extract opal. Alternatively, those who do not have their own pit will be hired as daily laborers to dig and extract opal to the pit owners. Children of age below 15 years are also involved in recovering and selling small sized opal which locally is called "Ajara" from mine waste rocks around the pits. Direct employment is also realized through selling opal to brokers, foreigners or to people coming from cities. Such people can be considered as "intermediaries" in the opal business transaction route. Local farmers also benefit by selling eucalyptus wood and other supplies needed for opal excavation (e.g., as mining equipment). Many women created jobs in selling foods, drinks and other items/consumables needed by the miners (Fig. 2). The number of females in the mining community of Ethiopia is insignificant except few of them are involved in side businesses like selling foods and beverages. Earlier studies estimated the proportion of females involved in mining to be less than 20% (EEITI, 2016). In the four mining sites visited during this survey 15 females (out of a total of 80 mine workers) were found involved in the direct and indirect activities around the mine sites. Females were engaged only in selling food items (Fig. 2). The national data on women in ASM gives 30–40% of participation (MoM, 2009). The number of miners varies from day to day and from season to season in which the number significantly decreases during rainy and farming/harvesting seasons. The whole chain of opal business brought a stimulus to local economic development and market boom of many things including hotels, textile markets, all-weather road construction, construction related to establishment of new and expansion of existing villages which are developing to township (e.g., Tsehay Mewcha, Fig. 2). People start to build their houses using concrete and corrugated iron instead of the common huts and mud houses. Hopefully, such a trend of villagization, if properly managed can help the government to supply services (electricity, pumped water, health, education etc.) to the community which is difficult where people live scattered in the rural area.

Table 2 Local community's perception on economic significance of opal mining

Opal mining improved your livelihood?			Nature of the benefit (out of those who responded "Yes")		
Yes	73	89%	Direct	67	81.7%
No	9	11%	Indirect	6	7.3%

Fig. 2 Opal miners and side businesses around opal mining sites (**a**–**c**) and unplanned villagization of Tsehay Mewcha locality (**d**)

Marketing

The opal business involves many actors in the market chain. The economic gain of the local miners depends on the presence of a transparent, fair and well managed market in which they will get a fair price for their product. The concerned government offices are expected to make everybody accountable, create market links and prevent fraud victimization of the rural mining community by buyers and brokers. However, it has been found from the survey and focused group discussion that the opal market is benefiting (Fig. 3) primarily the brokers. Opal miners are at disadvantage because of many reasons among which three of them are the following.

Weak position of miners in setting price

Prices are determined only by the brokers or other buyers coming from cities. People coming from the township have the capacity and exposure to manipulate the local miners which are farmers, uneducated and have no information about the application, price or market of opal. During the focused group discussion, local miners strongly complained about the misconduct of these buyers or brokers. They informed the discussants that the buyers/brokers set the price and if opal diggers do not agree, they keep their opal with themselves. Unfortunately, when the opal stays with the miners for a long time, it will craze (crack) and becomes valueless. They have no training, the skill or the technology to prevent crazing. Therefore, the only choice they have is to sell it with the price the brokers offered them. Otherwise, they will remain empty

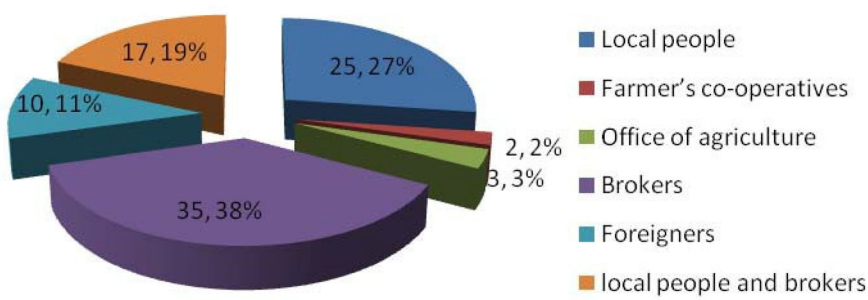

Fig. 3 Respondents' perception on beneficiaries of the opal business

handed as the crazed opal will not have any value. It has also been indicated by the local miners that they do not want to leave their digging holes. Because if they go to nearby cities to sell their opal at a relatively better price, someone else will overtake their pits/-holes from which they extract opal. This is clearly related to the absence of licensing and management of the mining operation. Recently, the government is trying to organize people in mining cooperatives and license them. However, only very few are functional at present. Joining or forming mining co-operatives has proven to be the most effective strategy for miners to earn a decent living, and defend their human and environmental rights (Hayes, 2008; Hentschel et al., 2003; Noetstaller et al., 2004). Miners' unions can force buyers, companies and governments to make and follow rules that protect miners' interest including health and safety. However, locals of the Delanta district are skeptical of associations for various reasons. This survey showed that a majority of respondents do not prefer cooperatives (Fig. 4). Almost 60% of the respondents indicated that they have no interest to join cooperatives for opal mining. Rather, most of the respondents prefer to work individually. This is because most miners believe that if they work in group, they cannot easily find the deposit as 'the devil hides the opal'. The regional and federal governments tried to intervene and sometimes force miners to form cooperatives as a result of which around 2000 miners were organized under seven associations since 2011. However, the associations were fragile and their continuity was in doubt as local communities were skeptical of the associations.

Illegality/contraband

The illicit dealing (mining and trading) in gemstones is a fast-growing activity in African countries producing these minerals. This is not unexpected, as these gemstones have huge unit values, small volume and low transport costs. Artisanal and Small-Scale Mining productions of gemstones are thus easily traded illegally causing significant direct and potential economic losses to affected communities and countries (Kambani, 1995). Even if Ethiopia has the legal framework to formalize artisanal mining, illegal opal mining and trading is a serious problem in opal mining areas. The weak administration, absence of strong and favored cooperatives that assure legality and fair trade and very low awareness of the opal diggers about the legal framework exacerbated the illegal trade. For the year 2011, 51 individuals were sentenced for imprisonments of 3 months to 5 years, and financial fines of up to 10,000 Ethiopian Birr. A total of 54 people have been confiscated for more than 255 kg of rough opal (Table 3). However, such limited efforts by local law enforcement bodies to control illegal trade are not at par with the widespread contraband.

The loss is not limited only to the miners but extends to the district administration which could have collected considerable taxes. As the local administrators iterated during the focused group discussion, no tax is collected from opal traders until the year 2011

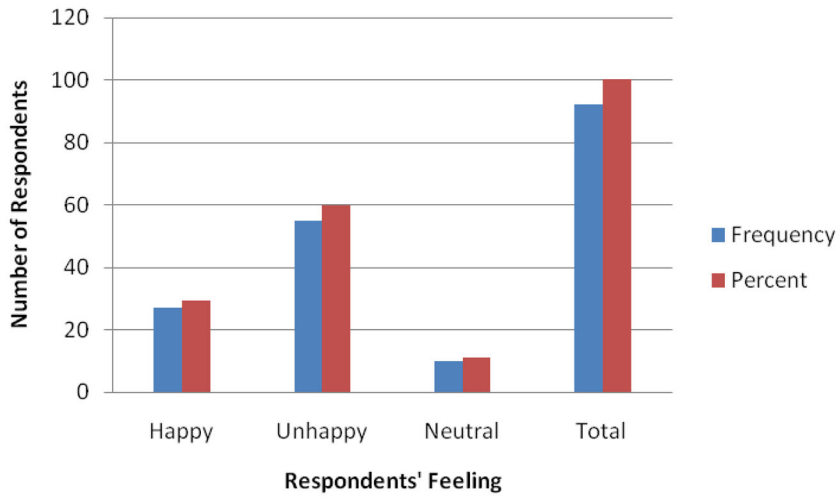

Fig. 4 Perception of respondents on farmers' cooperatives

Table 3 Decisions passed by Delanta District Court on illegal opal traders for the year 2011. *Source*: Delanta District Court

	Corresponding fines in Ethiopian birr	Number of people
Imprisonment in months		
3–6	300–1000	24
8–12	300–2000	11
36–48	100–1000	15
60	10,000	1
Confiscation (amount of opal in KG)		
≤ 1		20
1–5		17
6–10		11
11–15		3
16–20		1
> 20		2

(i.e., more than four years from the beginning of opal extraction in the district). Studies conducted for the year 2015 estimated that the Amhara Regional State, in which all opal deposits of Ethiopia are present, collected only 274,966 Ethiopian Birr out of the collectable amount of Birr 1,968,000 (EEITI, 2016). That means only about 14% of the potential is collected. The unorganized nature and illegality of the mining and mineral transaction practice goes beyond short term losses. It will be manifested also in terms of perpetual trapping of miners in the poverty cycle, inefficient use of natural resources, poor health and safety of miners and environmental damage. Discussants participated in the focused group discussion mentioned that in addition to inability to control the ASM because of limited capacity and remoteness of the mining sites, corruption among authorities, lack of transparency and poor governance have contributed to the illegal opal transaction in the district. Therefore, the informality of the sector is fueled by both the smugglers on one hand and the local authorities on the other (Fig. 5). Such reinforcement and its consequences are depicted as a cyclic chain in which if the cycles are not broken, they will lead to poor social, economic and environmental performance (WBG, 2014). The severity of illegality in the ASM sector is serious when one considers the EEITI report of 2016 in which it is indicated that out of the total estimated number of artisanal miners, about 94% are operating informally (unlicensed) and only about 6% are formally organized and licensed.

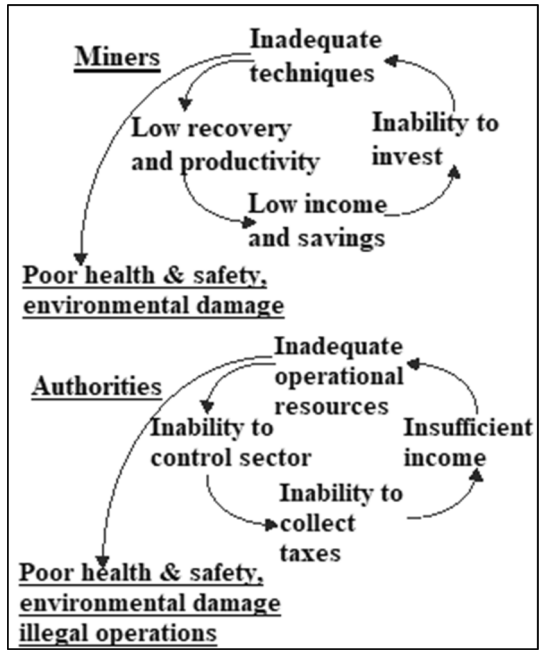

Fig. 5 The two cycles of cause and effect affecting the ASM sector (WBG, 2014)

Lengthy market chain

The economic benefit from ASM is maximized when there is access to a market that is transparent and fair in which miners get fair prices commensurate with the quality and quantity of the material they present and the time and energy they spent for extracting the mineral. Unfortunately, opal miners in Delanta are far from the actual opal market which is mainly exporting abroad and/or supply to very few lapidaries and

cutting shops situated in major cities, mainly Addis Ababa. Therefore, the opal passes through a complex path before it reaches to the exporter or lapidaries and cutting shops. During the focused group discussion, we tried to roughly map how opal passes from opal diggers to the cutters or exporters. As can be seen from the diagram (Fig. 6), the locals are completely cut-off from the major business transaction cycle (the real market). During this survey, it has been found that 1 kg of opal is sold on average at 2000br whereas the minimum price of 1 kg of rough opal is estimated to be 350 USD (GSE, 2009) which is equivalent to around 9450 Ethiopian birr. Therefore, as the opal passes through each marketing node, the price would have increased by nearly fivefold.

As the path gets longer the price gets higher as individuals at each step want to get some profit. However, the price at the exporters, lapidaries or cutting shops is determined based on the prevailing price of opal on the world market and based on their anticipated profit margin. Hence, people involved in the business chain try to buy at the minimum possible price from the miners. This situation puts opal diggers at clear disadvantage as they do not know how the opal market functions. The government or other organizations are not helping the miners to get fair prices by creating market links or establishing local market stations or lapidary shops where miners can directly negotiate prices. This would have shortened the market chain and would have allowed better price compared to selling to brokers. Moreover, absence of gem quality grading (standardization) system and unawareness of the miners about it contributed to the poor marketing and loss of revenue by locals. In addition to this, opal price is not regulated by the government like that of gold in which case price is determined by the national bank of Ethiopia.

Child labor and school dropout

Child labor is a common encounter in mining areas (CDS, 2004; Edmonds, 2008; Hayes, 2008; ILO, 1999). Especially in poor communities and where children are considered as means of income, parents prefer to engage children in relatively quick money generating activities like mining. Children themselves are also lured by the business as they can get money and aspire to be independent of their parents. In Delanta district underage children (Fig. 2 and Table 4) are involved in mining and related activities by abandoning school. The nearby "Tsehay Mewcha first cycle" school was inspected for school dropouts for the academic years 2009, 2010 and 1st semester of 2011 (Table 4).

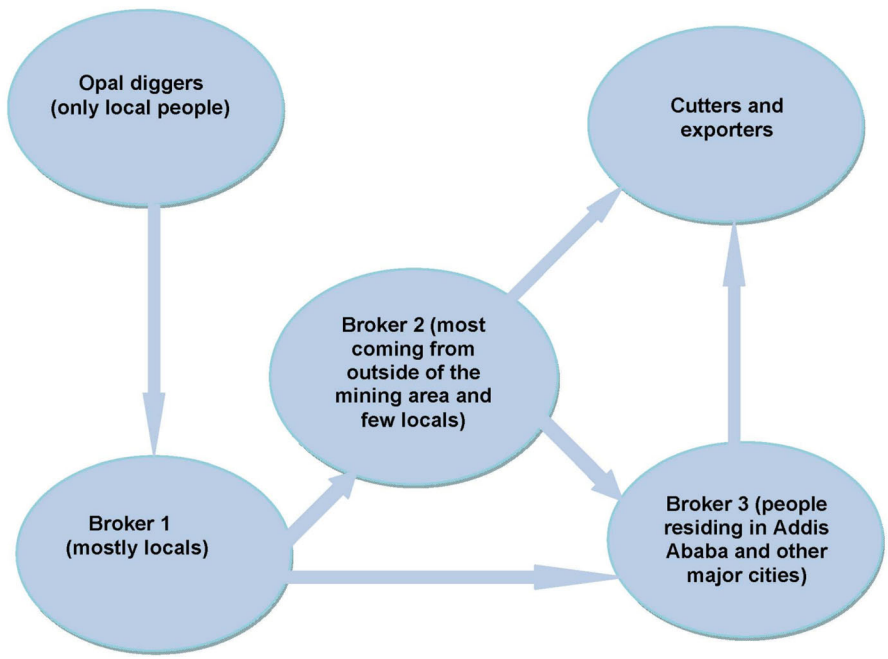

Fig. 6 Market chain of the opal transaction in Delanta District

Table 4 Dropout rates of Tsehay Mewcha1st cycle school (*Source*: Tsehay Mewcha Primary School)

Year	Grade	Total enrollment			Dropout			Dropout %	Remark
		Male	Female	Total	Male	Female	Total		
2009/10	1–8	694	761	1455	49	30	79	5.43	
2010/11	1–8	666	747	1413	53	37	90	6.37	
2011/12	1–8	544	685	1229	82	24	106	8.62	

The overall trend of dropout increases from 2009 onwards. This trend indicates children are being more aware of the mining and the income generated from it as a result of which they are more inclined, from time to time, to abandon school and join the mining occupation. In 2011/12 the dropout was the highest one (8.62%). Even though the number of female enrollments exceeded that of male in all of the three years surveyed, the number of male dropouts is by far greater than that of females. Probably this is because mostly men are engaged in the mining sites. Unfortunately, engaging children in mining activity, in addition to being illegal (Edmonds, 2008; Hayes, 2008) leads them to abandoning school. Moreover, working long hours under difficult conditions is dangerous for children, creating serious problems for their growing bodies and soft bones.

Community health and safety

Mining is known for its impact on health and safety. Problems range from short term injuries and associated deaths to long lasting infections and spread of diseases. Crimes associated with alcoholism, theft and misappropriation of materials including the mineral extracted are sources of insecurity to mining communities and their environs. The sudden wealth and sudden poverty that mining brings is often accompanied by increased violence against women and children, abuse of workers by mine owners, and fights for control over resources (IGF, 2018; Noetstaller et al., 2004). All of these issues appeared in and around the opal mining sites of Delanta. Tables 5 and 6, and Fig. 7 show the survey results on injuries, deaths and HIV/AIDS infections in the community.

The main cause of death near the mining sites is the collapse of rock which has killed 44 (86.3%) individuals in three years. This is because the miners do not take the necessary safety measures during mining. The other causes of death are rock slide, flood and disease which have killed three, two and two individuals respectively. Mining damages health in many ways: heavy lifting and working with the body in awkward positions can lead to injuries to the arms, legs, and back. Long hours working underground with little light can harm vision. Working in very hot conditions without drinking enough water can cause heat stress. Signs of heat stress include: dizziness, weakness, rapid heartbeat, extreme thirst, and fainting.

The data collected from the Tsehay Mewcha clinic indicated that typhoid is the main disease affecting the mining site (29.66%) followed by pneumonia (12.71%). Injury is the most severe problem in the mining site (45.76%). The prime contributor to injuries is collapse of mining pits and tunnels. The opal bearing layer is thin with a thickness of a few centimeters to a meter. As mining progresses and near surface accumulations are exhausted, miners dig long and dip tunnels into the hillside (Fig. 8). These tunnels are vertically short (50 cm to 1 m) but horizontally (2–34 m) and laterally (30–270 m) continuous for considerable length. Especially at Minychil site one tunnel was measured to be 34 m long into the cliff with about 270 m lateral width (Fig. 8). This situation creates an inconvenient mining environment such as collapse of rocks, insufficient work space, suffocation, darkness and others.

Miners work for long hours inside a hole of underground mining sites (tunnels) which suffocates miners. People remove their wastes and faeces near the mining sites. All of these circumstances lead to pneumonia and typhoid. The number of injured persons by far exceeds the number of persons caught by pneumonia and AFI. Injury is a big problem of the mining sites. It is because the miners do not use safety tools while mining. They are new to a mining operation, neither have the necessary training to operate and manage mine sites. They do not know how to adapt the different mining conditions which vary depending on the location, type, and size of the mineral deposit and associated mining operations. According to the result of the field survey women and

Table 5 Common disease in the study area (*Source*: Tsehay Mewcha Clinic for the year 2011)

Type of disease	Age				Sex			
	≤ 15	16–30	31–45	> 45	M	F	Total	%
Pneumonia	0	11	2	2	13	2	15	12.71
Bronchitis	2	9	0	0	11	0	11	9.32
AFI	1	2	0	0	3	0	3	2.54
Typhoid	15	7	4	9	–	–	35	29.66
Injured persons	4	29	13	8	47	7	54	45.76
Total	22	58	19	19	74	9	118	100.00

Table 6 HIV/AIDS infection rate by age and sex. *Source*: Wogeltena Health Center

Year	Age				Sex			
	≤ 14	> 14	Total	% increment of HIV infection from 2008	M > 14	F > 14	Total	Proportion of female infected with HIV (%)
2008 (June–Aug)	2	53	55	–	20	33	53	62
2008/9	9	121	130	136%	42	99	121	82
2009/10	28	144	172	212%	48	96	144	67
2010 (Sep–Oct)	11	58	69	– (only 2 months data)	18	40	58	69
Total	50	376	426		128	268	376	72

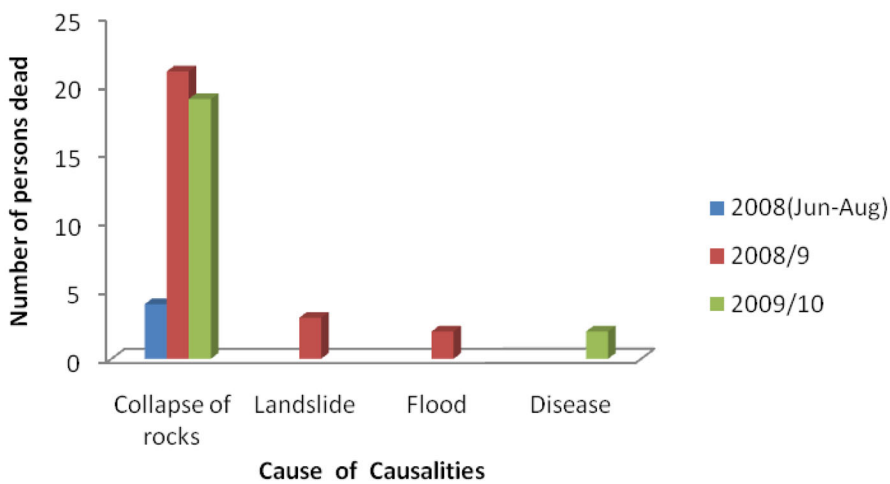

Fig. 7 Documented causalities and their causes

men who are more than 14 years old are highly infected with HIV/AIDS. This may be related to quickly developing mining towns and alcoholism. Moreover, many people migrate looking for jobs in the mines, women become sex workers, and this combination led to the rapid transmission of HIV/AIDS and other sexually transmitted diseases.

Impacts on the natural environment

One of the major consequences of mining is the impact on the natural environment (e.g., Bridge, 2004; Brown, 2018; Buxton, 2013; Getaneh & Alemayehu, 2006; Melaku, 2007 and others). It brings chemical change (pollution of water, air and land) and/or

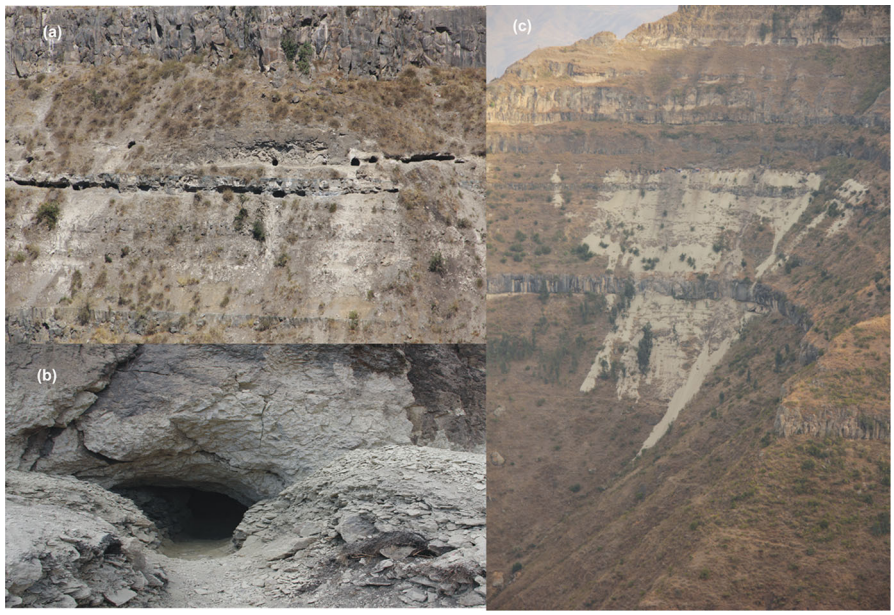

Fig. 8 The panoramic view and tunnel configurations of some of Delanta opal mining sites (**a**, **b**) and waste rock accumulation, mass movement and loss of vegetation (**c**)

physical land degradation (deforestation, soil erosion, steepening of slopes, acceleration of mass movement etc.). Since impacts from mining depend on the location of the mine site, the specific activities, and materials/chemicals used, the nature and extent of undesirable consequences vary from place to place and from deposit type to deposit type.

When we see the opal mining sites of the research area, almost all of the mining tunnels are located in the steep slope terrain (Fig. 8) in which slopes attain up to 90° inclination. Moreover, the mining is characterized by extensive digging along and into the ridges and mountainsides (Fig. 8). There are no chemicals used in the mining activity. Moreover, the chemical analyses results of waste rocks (Table 7) around the mining sites show that the concentration of potentially toxic heavy metals is very low and does not pose any immediate danger of geogenic pollution even in the presence of crushing and dissolution during mining and processing of the mineral resource. Hence chemical changes in the different environmental components are not expected. The immediate challenge to the natural environment is therefore the physical degradation. These challenges include:

- Acceleration of soil erosion—the research area is one of the most degraded areas in Ethiopia due to soil erosion. The loss of soil through erosion in Ethiopian highlands is estimated to be 1248–23,400 million tons of soil per year from 78 million hectare of pasture, range and cultivated fields (FAO, 1986). We have estimated the rate of soil erosion in the study area using the RUSLE model in which the runoff erosivity factor (R), soil erodibility factor (K), slope length factor (L), slope steepness factor (S), cover management factor (C), and support practice factor (P) are considered. Accordingly, the annual rate of soil loss in the research area is found to be 13,200t/ha/yr. The

Table 7 Chemical analysis results of waste rocks in opal mine sites of Delanta District

Mine site	Pb (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)
Minyichel	5	15	4	8	113
Chegien	< 1	17	6	8	99
Tachamba	10	17	8	9	140
Gengena	10	10	2	4	101

Fig. 9 Excavation of the steep slope and accompanying soil and vegetation loss in Tsehay Mewcha Opal mine sites

existing soil erosion problem of the mine sites will be aggravated by the extensive digging, steepening of the slope and accumulation of waste rock on the steep slopes (Figs.8, 9).This will in turn accelerate the annual reduction of agricultural GDP due to soil erosion in Ethiopia, which is estimated to be around 2% (FAO, 1986; Pescod, 1992). Therefore, unless corrective and rehabilitation measures are taken, sustainability of the agricultural sector (which is the lifeline of the local community) in the area will be at risk.

- Landslide and other mass movement along steep slopes—excavation works make slopes unstable by loosening the rock mass and increasing slope (steepness). The ultimate result of such practices is mass movement including land slide, rock fall and others (Fig. 8). Moreover, this landscape modification and mass movement brings accidents to human life and domestic animals, as discussed in part 4.3 above.
- Loss of vegetation/biodiversity and land disturbance—because of long history of intensive farming and high population density, the study area has very poor vegetation cover. The commonly observed scattered remnant vegetation covers are shrubs, bushes, small trees and eucalyptus. Unfortunately, this scarce vegetation cover is endangered because of the extensive digging which removes and/or buries the scarce vegetation cover along the steep slopes. This created a scar on the landscape (Figs.8, 9). Loss of vegetation, in addition to loss of biodiversity, loosens up the ground and fastens water movement during rainy seasons thereby accelerating soil erosion and modification of the landscape.
- Siltation of rivers and other water bodies—the materials eroded along the steep slopes end up in low land areas and valleys which might have running and standing bodies of water. The eroded sediment joining the water body becomes a suspended or dissolved component within the water. There are both seasonal and perennial rivers and springs in and around the mine sites. We measured the total dissolved solid (TDS) of these water bodies (Table 8). The results show tthe TDS is negligible and is below the FAO standard for agricultural water. The low content of the TDS in the local water bodies may be due to the short life span of the mining activity in the area and will be felt in the future as time passes and eroded rock fragments undergo weathering and hence dissolution.

Conclusion

The discovery and subsequent mining of opal has brought significant input to improving the livelihood

Table 8 In-situ measurement results of physico-chemical water quality parameters around opal mining sites of Tsehay Mewcha

Sample	T°C	pH	EC (μs/m) at local T°C	EC (μs/m) at 25 °C	TDS (mg/l) at 25 °C
Weul.1	12.1	7.15	68.4	47.70	31.00
Wed.2	12.2	7.55	73.6	51.15	33.25
Wmu.1	15.3	6.83	74.0	45.70	29.71
Wmd.2	16	6.60	70.5	41.95	27.27
Average	13.95	7.03	71.62	46.62	30.31

of many poor people in Delanta District. However, the ASM in the study area is done in an unorganized way. Therefore, it does not provide, compared to its potential, the expected benefits to the community and the country at large. The absence of a fair and transparent market and absence of backward or forward economic linkages with the gemstone sector limited the potential contribution of the sector to employment and overall economic development of the community and the country. Therefore, even if it has provided limited economic benefits, its negative impacts are also significant. Moreover, the usual impacts of mining which are common in other countries are becoming serious. These include accidents and subsequent injury and death of miners, spread of disease (especially HIV/AIDS which victimizes women more than men), illegal mining and smuggling of the mineral products. It is concluded that most of the negative consequences originate from

- Miners have no the necessary knowledge and skill on how to manage the business (lack of entrepreneurial skills),
- Miners are unable to conduct safe and productive mining and processing,
- The community is new to mining (because they are farming communities),
- Local opal diggers have no bargaining power on opal price and
- There is no proper law enforcement and governance of the resource and the mining activity in the district.

Moreover, absence of mining skill and safety measures and lack of support from concerned government and non-government bodies (which can support through training, creating market attachment, etc.) exacerbated the problem.

As a recommendation, projects related to capacity building of ASM miners in terms of technical, economic and environmental management skills should be aggressively worked out. The government should find a way to create market links and value addition mechanisms, and build local institutional capacity to manage the resource development process.

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References

Antonio, M. A. P. (2004). *Mainstreaming mineral wealth in growth and poverty reduction strategies*. ECA Policy Paper, Economic Commission for Africa. 26 p.

Auty, R. L. (1993). *Sustaining development in mineral economies: The resource curse thesis*. (p. 288p). Routledge.

Auty, R. M. (1994). The resource curse thesis: Minerals in Bolivian development, 1970–90. *Singapore Journal of Tropical Geography, 15*(2), 95–111

Bebbington, A. (2013). *Natural resource extraction and the possibilities of inclusive development: Politics across space and time*. ESID Working Paper No. 21. Manchester, 40 p.

Bebbington, A., Hinojosa, L., Bebbington, D. H., Burneo, M. L., & Warnaars, X. (2008a). Contention and ambiguity: Mining and the possibilities of development. *Development and Change, 39*(6), 965–992

Bebbington, A., Bury, J., Bebbington, D. S., Lingan, J., Munoz, J. B., & Scurahh, M. (2008). *Mining and social movements: Struggles over livelihoods and rural territorial development in the Andes*. BWPI Working Papers 33, Brooks World Poverty Institute, Manchester, 36 p.

Benjaminsen, T. (2015). Political ecologies of environmental degradation and marginalization. In T. Perreault, G. Bridge, & J. McCarthy (Eds.), *The Routledge handbook of political ecology*. (pp. 354–365). Routledge.

Brazeal, B. (2017). Austerity, luxury and uncertainty in the Indian emerald trade. *Journal of Material Culture, 22*(4), 437–452

Bridge, G. (2004). Contested terrain: Mining and the environment. *Annual Review of Environment and Resources, 29*, 205–259

Bridge, G. (2008). Global production networks and the extractive sector: Governing resource-based development. *Journal of Economic Geography, 8*, 389–419

Brown, E. K. (2018). *Artisanal mining and sustainable development*. SDC EVENT.

Buxton, A. (2013). *Responding to the challenge of artisanal and small-scale mining. How can knowledge networks help?* IIED.

Cartier, L. E. (2009). Livelihoods and production cycles in the Malagasy artisanal ruby–sapphire trade: A critical examination. *Resources Policy, 34*(2009), 80–86

Cartier, L. E., & Burge, M. (2011). Agriculture and artisanal gold mining in Sierra Leone: Alternatives or complements? *Journal of International Development, 23*, 1080–1099

Center for Development Studies (CDS). (2004). *Livelihoods and policy in the artisanal and small-scale mining sector—An overview*. University of Wales.

Central Statistical Agency (CSA). (2007). *Census 2007 tables: Amhara Region*. Addis Ababa

Cuba, N., Bebbington, A., Rogan, J., & Millones, M. (2014). Extractive industries, livelihoods and natural resource competition: Mapping overlapping claims in Peru and Ghana. *Applied Geography, 54*, 250–291

Duffy, R. (2007). Gemstone mining in Madagascar: Transnational networks, criminalization and global integration. *Journal of Modern African Studies, 45*(2), 185–206

Edmonds, E. V. (2008). *Defining child labor: A review of the definitions of child labor in policy research*. Working paper, International Labor Organization, Geneva. 56 p.

EEITI. (2016). *Artisanal mining operation and its economic values, Ethiopia*. Addis Ababa. 54 p.

FAO. (1986). *Ethiopia highlands reclamation study*. Final Report, Vol. 1. FAO, Rome. 354 p.

Franks, D. M., Pakoun, L., & Ngonze C. (2016). *Development minerals: Transforming a neglected sector in Africa, the Caribbean and the Pacific*. United Nations Development Program. 110 p.

Fisher, E. (1997). Beekeepers in the global 'fair trade'' market: A case from Tabora Region: Tanzania.' *International Journal of the Sociology of Agriculture and Food, 6*, 109–159

Fisher, E. (2012). The fair-trade nation: Market-oriented development in devolved European regions. *Human Organization, 71*(3), 255–267

Fisher, E. (2018). Solidarities at a distance: Extending Fair trade gold to east Africa. *The Extractive Industry and Society, 5*, 81–90

Frækaland Vangsnes, G. (2018). The meanings of mining: A perspective on the regulation of artisanal and small-scale gold mining in southern Ecuador. *The Extractive Industry and Society, 5*, 317–326

Fraser, J., Fisher, E., & Arce, A. (2014). Reframing 'crisis'' in fair trade coffee production: Trajectories of agrarian change in Nicaragua.' *Journal of Agrarian Change, 14*(1), 52–73

Gelb, B. (1988). *Oil windfalls: Blessing or curse?* Oxford Univ. Press.

Geological Survey of Ethiopia (GSE). (2009). *Opportunities for development of gemstone resources*, Addis Ababa. 14 p.

Getaneh, W., & Alemayehu, T. (2006). Metal contamination of the environment by placer and primary gold mining in the Adola region of southern Ethiopia. *Environmental Geology, 50*(3), 339–352

Gunton, T. (2003). Natural resources and regional development: An assessment of dependency and comparative advantage paradigms. *Economic Geography, 79*(1), 67–94

Habtamu, A., Suryabhagavan, K. V., & Balakrishnan, M. (2020). Soil erosion assessment using RUSLE model and GIS in Huluka watershed, Central Ethiopia. *Sustainable Water Resources Management, 6*, 12. https://doi.org/10.1007/s40899-020-00365-z

Hart, G. (2001). Development debates in the 1990s: Culs de Sac and promising paths. *Progress in Human Geography, 25*(4), 605–614

Hayes, K. (2008). *Small-scale mining in Africa—A case for sustainable livelihood*. 2008 Regional Workshop. Common Fund for Communities, Amsterdam. 116 p.

Hentschel, T., Hruschka, F., & Priester, M. (2003). *Artisanal and small-scale mining: Challenges and opportunities*. International Institute for Environment and Development.

Hilson, G. (Ed.). (2003). *The socio-economic impacts of artisanal and small-scale mining in developing countries*. A.A. Balkema Publishers.

Hilson, G. M. (Ed.). (2006). *Small-Scale Mining, Rural Subsistence and Poverty in West Africa*. Intermediate Technology Intermediates Ltd.

Hilson, G. (2009). Small-scale mining, poverty and economic development in Sub-Saharan Africa: An overview. *Resources Policy, 34*(1–2), 1–5

Hilson, G. (2010). "Once a miner, always a miner": Poverty and livelihood diversification in Akwatia, Ghana. *Journal of Rural Studies, 26*(3), 296–307

Hilson, G. (2011). Artisanal mining, smallholder farming and livelihood diversification in rural sub-Saharan Africa: An introduction. *Journal of International Development, 23*, 1031–1041

Hilson, G. (2013). "Creating" rural informality: The case of artisanal gold mining in sub-Saharan Africa. *SAIS Review, 33*(1), 51–64

Hilson, G. (2016a). Farming, small-scale mining and rural livelihoods in Sub-Saharan Africa: A critical overview. *The Extractive Industries and Society, 3*(2016), 547–563

Hilson, G. (2016b). *Artisanal and small-scale mining and agriculture: Exploring their links in rural sub-Saharan Africa*. (p. 24). IIED.

Hilson, G., & Gatsinzi, A. (2014). A rocky road ahead? Critical reflections on the futures of small-scale mining in sub-Saharan Africa. *Futures, 62*(2014), 1–9

Hilson, G., Hilson, A., Maconachiec, R., McQuilken, R., & Goumandakoye, H. (2017). Artisanal and small-scale mining (ASM) in sub-Saharan Africa: Re-conceptualizing formalization and 'illegal' activity. *Geoforum, 83*, 80–90

International Council on Mining and Metals (ICMM). (2014). *The role of mining in national economies*. London. 16 p.

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF). (2017). *Global trends in*

Artisanal and Small-Scale Mining (ASM): A review of key numbers and issues. IISD.

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF). (2018). *Women in artisanal and small-scale mining: Challenges and opportunities for greater participation*. Winnipeg: IISD.

International Labor Organization (ILO). (1999). *Social and labor issues in small-scale mines: Report for discussion at the Tripartite meeting on social and labor issues in small-scale mines*. Sectoral Activities Program, TMSSM/1999, ILO: Geneva. 104 p.

Kambani, S. M. (1995). The illegal trading of high unit value minerals in developing countries. *Natural Resources Forum, 19*(2), 107–112

Lahiri-Dutt, K. (2014). *Extracting peasants from the field: Rushing for a livelihood?* Asia Research Institute, National University of Singapore (Working Paper Series No. 216). 22 p.

Melaku, E. (2007). *Impact assessment and restoration of quarry site in urban environment: The case of Augusta quarry*. MSc thesis, Addis Ababa University, Addis Ababa. 102 p.

Ministry of Mines (MoM). (2009). National report on mining to the United Nation Commission on sustainable development (UNCSD), New York. 11 p.

Ministry of Mines (MoM). (2012). *Artisan mining activities in Ethiopia: challenges & opportunities*. Addis Ababa. 146 p.

National Meteorological Services Agency (NMSA). (2010). *Weather and climate reports*. Addis Ababa. 137 p.

Noetstaller, R., Heemskerk, M., Hruschka, F., & Drechsler, B. (2004). *Program for improvements to the profiling of artisanal and small-scale mining activities in Africa and the implementation of baseline surveys*. CASM Secretariat at the World Bank. 159 p.

Paul, S., & Emma, I. (2017). *Governing the gemstone sector: Lessons from global experience*. (p. 72). Natural Resource Governance Institute.

Pescod. M. B. (1992). *Wastewater treatment and use in agriculture*. FAO. Irrigation and drainage paper 47. 169 p.

Puppim de Oliveira, J. A., & Saleem, H. A. (2011). Gemstone mining as a development cluster: A study of Brazil's emerald mines. *Resources Policy, 36*(2011), 132–141

Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1997). Predicting soil erosion by water: A guide to conservation planning with the revised universal soil loss equation (RUSLE). *Agriculture Handbook, 703*, 1–251

Rondeau, B., Fritsch, E., Mazzero, F., Gauthier, J. P., Bénédicte, C. T., Bekele, E., & Gaillou, E. (2010). Play-Of-Color Opal from Wogeltena, Wollo province, Ethiopia. *Gems & Gemology, 46*(2), 90–105

Rondeau, B., Mazzero, F., Bekele, E., Gauthier, J. P., & Fritsch, E. (2009). Gem News International: New play-of-color opal from Welo, Ethiopia. *Gems & Gemology, 45*(1), 59–60

Sachs, J., & Warner, A. (1999). The big push, natural resource booms and growth. *Journal of Development Economies, 59*, 43–76

Siwale, A., & Siwale, T. (2017). Has the promise of formalizing artisanal and small-scale mining (ASM) failed? The case of Zambia. *The Extractive Industries and Society, 4*, 191–201

Verbrugge, B., & Besmanos, B. (2016). Formalizing artisanal and small-scale mining: Whither the workforce? *Resources Policy, 47*(2016), 134–141

Walsh, A. (2003). "Hot money" and daring consumption in a northern Malagasy sapphire-mining town. *American Ethnologist, 30*(2), 290–305

World Bank Group (WBG). (2014). *Strategic assessment of the Ethiopian Mineral Sector*. Addis Ababa. 114 p.

Zvarivadza, T., & Nhleko, A. S. (2018). Resolving artisanal and small-scale mining challenges: Moving from conflict to cooperation for sustainability in mine planning. *Resources Policy, 56*(2018), 78–86