The Extractive Industries and Society 16 (2023) 101364

Contents lists available at ScienceDirect

The Extractive Industries and Society

journal homepage: www.elsevier.com/locate/exis

Review article

Drivers and effects of construction-sand mining in Sub-Saharan Africa

Mette Bendixen [a,*], Nakiya Noorbhai [a,b], Joy Zhou [c], Lars Lønsmann Iversen [b], Ke Huang [d]

[a] Department of Geography, McGill University, Montreal, Canada
[b] Department of Biology, McGill University, Montreal, Canada
[c] Department of Computer Science, McGill University, Montreal, Canada
[d] Department of Geosciences and Natural Resource Management, Copenhagen, Denmark

ARTICLE INFO

Keywords:
Sand mining
Urbanisation
Livelihood
Environmental degradation
Economic development

ABSTRACT

Construction-sand is the most used solid material on Earth and is central in developing societies and economies. Recent years' increasing focus on scarcity of sand has focused on global issues arising from it and on environmental consequences of extraction. However, comprehensive research describing the complexity of sand mining in developing nations is lacking. Here, we review literature from Sub-Saharan Africa outlining drivers and effects of construction-sand. We show at regional and national level, population growth and rapid urbanisation are main drivers for the growing sand mining activities observed in all investigated countries. Environmental consequences are solely negative and often observed at or in the vicinity of the mining sites and can be immediate or occur later. For humans and the built environment, the positive effects are seen at a variety of levels spanning national and regional through the creation of necessary buildings, income, taxes, and revenues. At an individual level, little or low education, unemployment and disruption of traditional livelihoods are main drivers for people engaging in sand mining by offering an income. Extraction of the material has negative consequences in the form of pollution and destruction of infrastructure and impact not only people involved in the mining industry but also nearby communities.

1. Introduction

Sand is a key ingredient for modern societies. It is used in concrete, bricks and glass production, and the construction of buildings therefore consume large amounts of this material (OECD, 2019). Increasing pressure on the world's sand resources has potentially large environmental and human consequences. With sand demand outstripping or soon-to outstrip the supply (Bendixen et al., 2019), global extraction is expected to intensify as building demands increase with a growing global population (Zhong et al., 2022). Across all solid materials used by humans, sand and gravel have seen the fastest increase in use (Krausmann et al., 2009). Sand has long been viewed as an abundant, common pool resource (Torres et al., 2017). However, over recent years, momentum has grown with an increasing number of calls for actions from academic scholars and NGOs, and has proven that global sand scarcity is a crucial natural resource with global challenges that deserves greater awareness (United Nations Environment Programme, 2022b; Bendixen et al., 2021; Torres et al., 2017; Bisht, 2021).

Global population increase, urbanisation and economic development are key drivers for a rapid growth in building stock within the coming decades (Zhong et al., 2022). From 2020 to 2060, annual demand for sand used in buildings is seeing the largest increase in lower-middle income regions, where annual demand will grow from 0.7Gt yr-1 to 2.2Gt yr-1. On a global scale, Western and Eastern Africa is expected to see the largest increase (500 %), followed by the rest of Southern Africa (419 %). For comparison, India is projected to see a 294 % increase in demand and the rest of South Asia 269 %, while upper-middle income countries regions and high-income regions are expected to see declining

* Corresponding author.
E-mail address: mette.bendixen@mcgill.ca (M. Bendixen).

https://doi.org/10.1016/j.exis.2023.101364
Received 24 February 2023; Received in revised form 5 October 2023; Accepted 7 October 2023

demand (Zhong et al., 2022).

Despite the long history of mining activity in Africa, and a growing global focus on sand mining, no systematic review has summarised our cumulative knowledge on this topic in a Sub-Saharan context. At a global scale, it has been highlighted that the conflicting impacts on the environment and humans disrupt the net positive effects of aggregate mining on sustainable development (Bendixen et al., 2021), and any sustainable future for aggregates should include holistic and comprehensive assessments covering both human and environmental well-being. In the light of these findings, the knowledge gap regarding the apparent paradox of sand extraction is two-fold. First, there is limited research focusing on understanding the benefits of sand mining and how these activities directly and indirectly support local communities in a Sub-Saharan context. And second, existing research of Sub-Saharan sand mining is often limited to place-based and site-specific research, often focusing on only the environmental impacts and consequences of sand mining. This points to a need for better understanding the complex paradox in developing societies in Sub-Saharan Africa: Sand is essential in aiding national development, building cities and infrastructure and ultimately developing economies and societies and contributes to local livelihoods. However, the over-extraction and mining practices are often unregulated - at times illegal - coming with large environmental and societal consequences. Here we conduct a scoping review to outline the complex relationship between the drivers and effects of sand mining in Sub-Saharan Africa. Additionally, we utilize the literature from the Sub-Saharan African continent to draw from local, place-based experiences to sum up overall recommendations for policy, government, and management to ensure a sustainable extraction of sand.

2. Background

2.1. Urbanisation, migration, and housing in SSA

Sub-Saharan Africa is one of the world's most rapidly urbanising regions in the world (Güneralp et al., 2017). The average annual urban population growth rate in Sub-Saharan Africa is 3.9 %; this is more than double the global urban population growth rate of 1.7 % (The World Bank, 2018a). In developed countries, rapid urban growth, or urbanisation has been a key factor in economic growth and prosperity (Onjala and K'Akumu, 2016). The development and productivity of a country's urban centres are often positively correlated with the country's GDP (Saghir and Santoro, 2018). Productive urban centres often alleviate poverty by providing increased access to housing, resources, and infrastructure, while also helping sustain economic growth by providing access to jobs, and allowing for the development of both private and public sector industries and businesses (The United Nations, 2022). However, unlike in other regions of the world, urbanisation in Sub-Saharan Africa does not necessarily lead to economic growth or better living conditions, as the prerequisite power is not in place, resulting in urban poverty (Mahabir et al., 2016; Onjala and K'Akumu, 2016). Most Sub-Saharan African urban areas lack the infrastructure to face the many challenges associated with increased urbanisation (Abu and Peprahm, 2020). This includes the lack of schools, health facilities, and housing (Abu and Peprah, 2020). In fact, while 42 % of the sub-Saharan African population lives in urban areas, as of 2018, 54 % of this urban population lives in slums (The World Bank, 2018a, 2018b). Moreover, while data is not currently available, this number is likely to have increased with the onset of the COVID-19 pandemic. Cities in sub-saharan Africa have particularly low levels of economic diversification making them extremely vulnerable to external shocks such as the recent pandemic (The United Nations, 2022). According to the UN—HABITAT definition of a slum household, slums do not provide adequate access to at least one of the following resources: protection from climate and disease, sufficient living space, security from eviction, safe drinking water, and sanitation facilities (Ilesanmi et al., 2020). These housing deficits make it difficult for urban slum residents to contribute to urban economic growth, can foster inter-generational poverty (Mahabir et al., 2016; Rains and Krishna, 2020), and overall challenges the abilities to ensure a sustainable development. However, a recent study mapping changes in housing in the region finds that housing conditions have generally improved in urban areas (Tusting et al., 2019). It finds that education, which requires access to facilities such as schools, is a key driver of these improved housing conditions (Tusting et al., 2019). While some sub-Saharan governments have introduced primary mandates to build houses, schools, and hospitals in order to sustain their increasing urban population (Asabonga et al., 2017), this is not an overall trend across the Sub-Saharan African continent. Today, concrete structures and infrastructure have become a symbol of development. Concretisation, the presence of construction projects using concrete made up of sand, gravel, rock, water, and cement, is indicative of a developing country (Abu and Peprah, 2020). The increase in present day concrete use is evident in many developing countries including India, China, and Sub-Saharan Africa (Zhong et al., 2022). In Sub-Saharan Africa specifically, sand mining in some regions has taken place for more than five decades (Correia and Pereira, 2016). Today, the technology used to mine sand in sub-Saharan Africa countries, and in most parts of the developed and less-developed world, remains relatively unchanged from that used to mine sand in the early 1920s (Abu and Peprah, 2020; Beiser, 2018).

Box 1

Box 1
Diverse terminology on the practices of sand mining/harvesting/winning/dredging.

The practice of extracting sediments is described in the Sub-Saharan African literature in a variety of ways. The most commonly used term '*sand mining*' refers to the general process of extracting sand from its original location. Mining involves the removal of sand from the earth's surface such as beaches, dunes, or quarries (open pits for mineral excavation) for developmental purposes. However, other terms and phrases defining similar procedures to sand mining exist such as *'sand harvesting'* or *'sand winning'* (*Sumani, 2019; Daghar 2022; Vieira and Rocha, 2021; Abu and Peprah, 2020)*, which are often used alongside mining in the literature. '*Sand dredging*' often refers to more mechanised sand mining operations using equipment to dredge sand from rivers, lakes or the nearshore environment in the process of 'sand dredging' (Lalèyè et al., 2020). *'Sand harvesting'* is a less often used term defined by Daghar (2022) as a sustainable method of sand extraction where sand is only partially removed and argued that it is allowed to regenerate naturally over time, as opposed to the exhaustive 'sand mining' practices that often have significant impacts on the environmental and socio-economic state of developing countries (Sumani 2019). In the present review, we use the definition 'sand mining' as a common term covering also sand harvesting, winning, and dredging. Fig. 1 exhibits a variety of sand mining.

Fig. 1. Examples of sand mining activities from rural Rwanda. Top images: in-stream river mining with piles of material deposited on the riverbanks. Bottom images: Mining in a terrestrial sand pit with a truck transporting material from the mining site.

2.2. Practices of sand mining

In Sub-Saharan Africa, mining operations vary significantly in size, number of workers involved, and the tools and machinery used in the extraction phase (Aliu et al., 2022). Most modern large-scale productions use specialised machinery to remove sand from their desired location. For non-mechanical sand mining extraction, the people involved at the sites have jobs as 'sand miners' and 'sand carriers' as well as '(tipper) truck loaders' also called 'loader boys' and 'drivers'. These jobs are often day-to-day work or offered as short contracts (e.g. weekly) (Mngeni and Musampa, 2016), and tend to be driven by the youth (Mngeni and Musampa, 2016; Abu and Peprah, 2020). Such contracts can be issued when maintenance or opening of new roads is planned or when vegetation needs to be separated from the mined sand (Mngeni and Musampa, 2016). Commercial truck contractors can employ tipper trucks to collect and transport sand to consumers (Boateng Jonah et al. 2016). The sand is sold to mainly truckers, construction contractors or local community members (Boateng Jonah et al. 2016; Correia and Pereira, 2016), and open-pit quarries are typically found close to where demand for construction work is found (Tetsopgang et al., 2020). Tally card recorders and headmen can be involved in the mining practices and be present at the sites, while contractors, land- or pit owners, mining regulators and stakeholders may be involved directly or indirectly (Sumani 2019). Artisanal sand extraction is labour-intensive (Franks, 2020) as the sand is often extracted by hand or with simple tools such as shovels, pick axes, and hoes (Tetsopgang et al., 2020; Lalèyè et al., 2020; Abu and Peprah, 2020). In open quarries or on land, sand loaders shovel and deposit sand directly into vehicles for transportation (Lalèyè et al., 2020) or deposits material into piles adjacent to the mining site. Fig. 1 exhibits a variety of small-scale mining activities in rivers of varying sites and in inland mines.

It is either deposited in piles along riverbanks or the mining site or loaded into buckets, tubs or bags, weighing up to 40 kg (Correia and Pereira, 2016), before being transported to the consumer or to a storage location. Inland sand mining operations often involve clearance of vegetation and the removal of the topsoil layer using scrapers or tracked excavators and off-road trucks (Ako et al., 2014; Adedeji et al., 2014), then allowing for the sand to be extracted. Blasting may be used to loosen the material before extraction. In a rural community along the Wild Coast of South-Africa (Mngeni and Musampa, 2016) describes that once each truck is filled with sand, on-site secretaries collect money from the truck drivers who pay a loading fee depending on the size of the truck (Mngeni and Musampa, 2016).

The secretary then brings the money to a headman who records the registration numbers of trucks that have loaded sand, and how much sand they have collected that day. That money is then used to pay the salaries of the workers (Mngeni and Musampa, 2016). However, contractors are often looking for ways to maximise profits off of these operations, which is why loaders are rarely paid above the daily minimum wage (Mensah, 1997). In the coastal regions of Zanzibar, sand is bought as truckloads or as trips of sand from the truck owners, who buy the material from pit-owners to be sold to individuals or construction companies (Masalu, 2002). Some communities have developed special techniques for sand mining in water bodies; e.g. in the Mono and Oueme basins in southern Benin, loaders traditionally dive deep into the water and extract the sand using shovels and baskets (Lalèyè et al., 2020). In Western part of Cameroun, sand is extracted from an open pit quarry, where water is pumped from a nearby river to the top of the hill, where an artificial stream erodes and transports the sandy material downstream allowing for extraction (Tetsopgang et al., 2020). Fig. 2 exhibits satellite images of a variety of sand mining activities in rivers and a terrestrial mining pit.

3. Methodology

We conducted a scoping review (Arksey and O'Malley, 2005), where we systematically consulted the literature available on the topic on Sub-Saharan sand mining to identify key concepts, topics, theories, and sources while also identifying the main knowledge gaps in the literature.

Fig. 2. Examples of sand mining. Black boxes indicate close-up of each site. A: In-stream river mining. The width of the river is less than 1 m wide, and piles of sediment are visible along the river bank near Runda, 20 km east of Kigali, Rwanda. B: Inland mining in farmfield in Nyamata, 60 km South of Kigali, Rwanda. Mining activities leave behind shallow pits, which after precipitation events get filled with water. C: In-stream river mining in the downstream part of the river running into Lake Kivu. Sediment is deposited in barges in the south-eastern part of the lake, which borders Rwanda and Democratic Republic of Congo. Barges are 45 m long, 8 m wide. All imagery is provided by Google Earth.

3.1. Article search strategy and screening process

A literature review was undertaken adapting the PRISMA approach to provide an overview of present-day literature on sand mining in Sub-Saharan Africa (Page et al., 2021). Web of Science and African Journal Online were searched between May 2-18, 2022 and a follow up search was conducted on December 16, 2022 where four additional references were identified. The search used keywords related to sand mining and countries in sub-Saharan Africa (as defined by the World Bank's list) and the word 'Africa' (see Supplementary Material, Table 1) in their topic sections (title, abstract, keywords) to identify sand-mining related peer-reviewed academic literature to accurately reflect sand mining in a broad sense allowing us to provide an overview of present day knowledge of sand mining in Sub-Saharan Africa. The literature search in the two specified platforms for articles containing a) one of the keywords "sand mining", "sand harvest", "sand harvesting", or "sand dredging", and (b) the name of a Sub-Saharan African country (as defined by the World Bank's list), or the word 'Africa'. The search focus is on Anglophone literature on Sub-Saharan sand mining, thus it does not include literature in Arabic, French, Spanish, or Portuguese or literature on the topic written in other languages. While the Web of Science and African Journals Online searches used the same four parameters and country list, unlike the Web of Science search engine, the African Journals Online search does not provide the option to exclusively search through an article's topic section, and instead looks through entire articles. Our goal was to identify only articles whose topic sections match either of the four parameters. All articles from the African Journals Online search results were manually checked to ensure the search parameters were indeed present in the articles' title, abstract or keywords. Articles that did not live up to this were excluded. All articles found during this search process were then used to build a relational database (PostgreSQL) hosted on the Notion platform where article link, article title, country, year published, journal, author(s), author country, author institution (s)/affiliation(s), keywords, article focus, mining type, latitude/longitude (if mentioned in the text), methodology, sand mining coverage, search database, and search parameters were logged. This procedure resulted in the selection of 85 scientific sandmining-related articles covering 18 unique countries. Criteria for inclusion or exclusion of articles are summarised in Table 1. To be included in the review, articles had to be peer-reviewed, while book chapters, grey literature, organisational reports, and conceptual papers were excluded. There were no restrictions on the date. Of the 85 scientific articles, 52 were deemed of secondary relevance, if they did not contain a discussion of sand mining in relation to either sociological, economical, or environmental topics, and were excluded in the review. In all, 33 articles were included in the review. Search criteria were deliberately chosen to be broad to avoid exclusion of potentially relevant literature, as sand mining and the implications and causes thereof is often mentioned in as a sidenote in literature, supported by the high number (~63 %) of the identified articles only briefly mentioned 'sand mining' and did not offer a discussion of sand mining. The process is documented in the flow chart (Fig. 3).

4. Identifying drivers and effects of sand mining

Of the 34 articles examined, 11 different countries were represented (Benin, Cabo Verde/Cape Verde Cameroon, Comoros, Ethiopia, Ghana, Kenya, Nigeria, South Africa, Tanzania), with Nigeria and Ghana being the most reported countries (nine and eight articles respectively), with a vast majority of this work focusing on beach sand mining or sand mining taking place in coastal regions. From our analysis, the first published article on sand mining is the comprehensive analysis by Mensah from 1997, discussing the causes and effects of coastal sand mining in Ghana. Only two articles on sand mining were published in the 2010′s (Zabbey et al., 2008; Abam, 2004) meaning that 90 % of the literature is published within the most recent five years. This strongly indicates the recent rapidly growing interest in the topic. Across the 34 investigated

Table 1
Inclusion/Exclusion criteria in search strategy and article screening process.

Included if	(i) Peer-reviewed journal article; (ii) mentions one or more of the following keywords: "sand mining", "sand harvest", "sand harvesting", "sand dredging" as well as (iii) one of the 48 Sub-Saharan African countries or "Africa" in either the journal title, abstract, or article keywords
Excluded if	Paper is a (i) master's thesis; (ii) grey literature; (iii) policy brief and organisational reports, (iv) book chapters

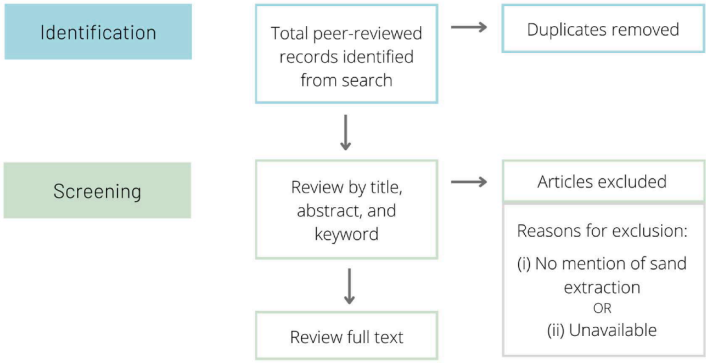

Fig. 3. Flowchart of the search strategy adapted from PRISMA.

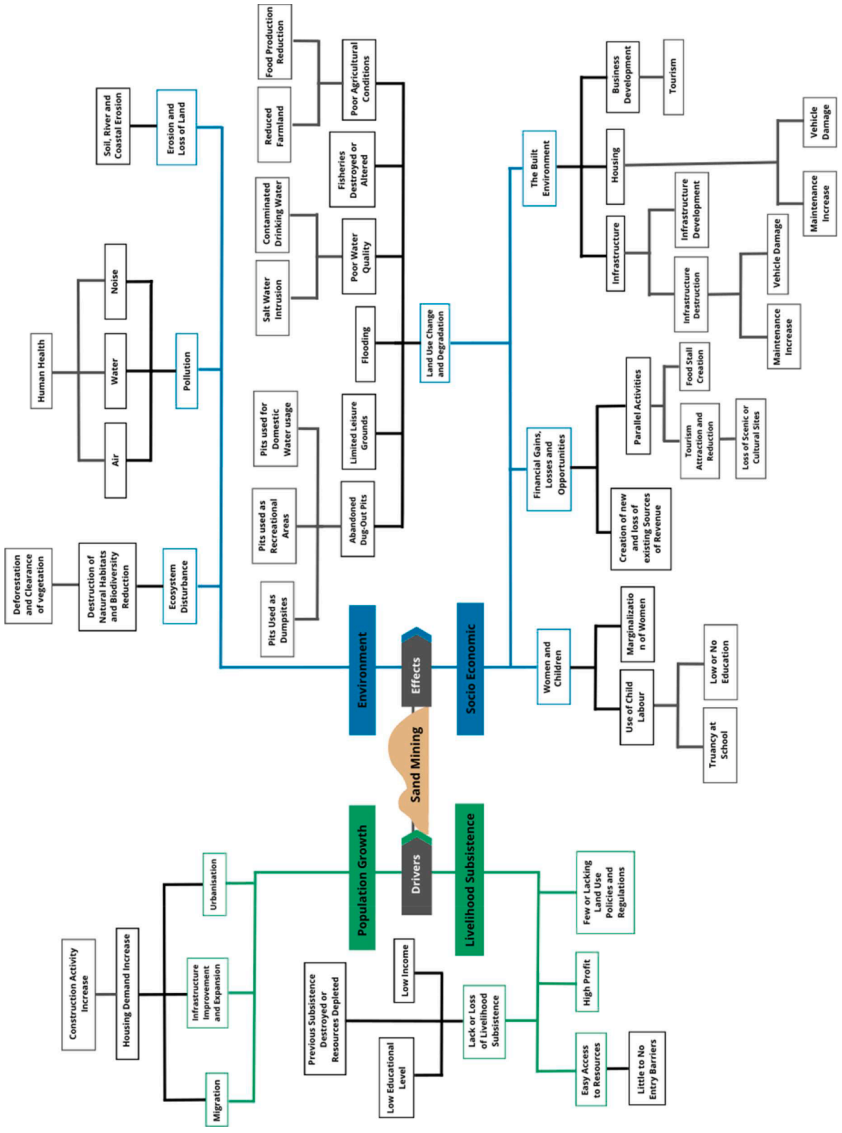

Fig. 4. Drivers and effects of sand mining in Sub-Saharan Africa.

articles, beach, coastal, and river mining are the main types of interests, focusing largely on the environmental impacts of the mining activities. A minor portion focuses on terrestrial mining activities and tends to be concerned with social or anthropogenic studies of the livelihood implications of sand mining.

4.1. Drivers

By examining the literature, we find that external forces are increasing the pressure on the resources, while simultaneously, personal subsistence needs act as local drivers for resource extraction. We discuss the economic, social, and environmental effects of sand mining by assessing the challenges and benefits of the activities (Fig. 4).

4.1.1. Population growth

A growing population accelerates the pressure on housing, buildings, institutions, markets, shopping malls, schools, basic needs for health facilities, as well as critical infrastructure such as roads, sidewalks, drainage systems, and bridges. Sand is the key ingredient in delivering materials for building and road construction, thereby also public services such as building of schools, health facilities and housing (Asabonga et al., 2017). Therefore, a growing population adds pressure to the built environment. As urbanisation increases, changes in occupation, lifestyle, socio-economic activities, and behaviour result in a need for viewing urban areas and the overall built environment in a new light. Across numerous countries in Sub-Saharan Africa, the consequences of the growing population is evident; In the areas around Dar as Salaam, Kenya, increasing urbanisation has in recent decades added a growing pressure on the demand for construction material (Shaghude et al., 2012). Rapid urbanisation in Nigeria has resulted in more sand mining activities taking place in urban and residential areas (Adedeji et al., 2014). A boom in residential and commercial construction activities along the Njelele River, South Africa, has caused a soaring demand for sand, leading to extensive sand mining along rivers (Gondo et al., 2019). In a 2019 study, community members reported to have witnessed *"the biggest surge in sand mining activities*" in the last five years, when asked to share their perceptions of the impacts of sand mining in the region over the past two decades (Gondo et al., 2019). Along the coast of Accra, Ghana, the urbanisation rate is higher compared to the national growth rate (55 % and 35 % respectively) (Addo 2011), occurring alongside increasing opportunities for employment and thus migration (Boateng Jonah et al. 2016). As a part of the urbanisation process, urban slum sprawling and overall urban decay as well as urban housing deficit, poor-quality housing failing to meet minimum standards, are consequences that are difficult to avoid, and are seen in Ghana in e.g. the regions of Accra-Tema, Kumasi, Sekondi-Takoradi and Tamale (Abu and Peprah, 2020). Along the central part of Ghana's coast, at Cape Coast, its population has doubled between 2000 and 2010 (82,291 to 169,894, respectively) increasing the need for cheap residential facilities and thus adding a pressure to the demand for sand and gravel (Jonah et al. 2016). On the archipelago of Santiago Island, Cape Verde, migration of rural populations to the cities has increased the use of sand, gravel, and cement. Prior to the 1980′s, sand was only used in the lining of the outer stone walls. With the evolution of building techniques, the building technique using stones has been replaced by the use of aggregates (Correia and Pereira, 2016). While a majority of the extracted material rarely is used for local purposes, sand mining's effect on a variety of rural activities has been documented in rural communities in the Wild Coast of South Africa (Chwebeni, Mngazi, and Coffee Bay); as the miners described how they manage to build churches for the local communities, and how the funds obtained from mining helped contribute towards funeral arrangements when someone has passed away in the community (Mngeni et al., 2016). As such, where there is a high demand for community development projects, sand mining activities act not only as an income generator, but also to initiate housing and infrastructure projects benefiting locals.

In addition to providing materials for concrete buildings, an increasing number of people needing infrastructure facilities, and the general infrastructure maintenance, add additional pressure on aggregate resources (Sumani 2019). Paradoxically, the extraction of sand and gravel causes damage to and deterioration of existing infrastructure (Aliu et al., 2022) as heavy vehicles loaded with sand contribute to road decay (Adedeji et al., 2014) by creating potholes and causing the collapse of culverts (Mensah, 1997). Already in the 1970′s in Ghana, tipper trucks were banned from using specific roads along the central coast of Ghana, as they have caused considerable destruction to community roads (Mensah 1997). While sand and gravel can lead to improvement in the road networking system, Tetsopgang et al. (2020) found in a study on geotechnical assessment of sand in Cameroon, that the infrastructure constructed from sand extracted from both the river and quarry sources are of a poor quality, due to the fine-grained particle sizes and the presence of clay.

4.1.2. Livelihood subsistence

Widespread economic instability is a key factor for the majority of the people involved in sand mining activities (Mensah, 1997). Poverty and unemployment are major drivers for people engaging in sand extraction (Mngeni et al., 2016; Sumani 2019; Abu and Peprah, 2020), offering a variety of roles in the process from extraction to deliverance of the material. Some miners engage in the activities as a strategy for survival (Jørgensen, 2016). When unschooled or low-educational locals find an opportunity for mining, they take it to sustain their livelihoods as they often find there are no other sources of income (Sumani 2019). Thus, unemployment or under-employment are main factors in explaining people's involvement in sand mining (Mensah 1997). A loading boy in Ghana described the flexibility required from the involved: *"Today I am a loading boy, tomorrow I may not be a loading boy, because if the pressing needs are solved with today's earnings I may not come here again. I will either rest or go to different workplace. So I say that if you want to be a loading boy today, you just look for a shovel and move to any of the site that may be convenient to you"* (Mensah, 1997). Employment is lacking for the increasing coastal population around Ghana's capital Accra, which has made beach sand mining an opportunity for income-generation (Addo, 2011). Sand mining activities in rivers around Dar Es Salaam employs many youths, who with low educational levels have few opportunities for alternative employment (Masalu, 2002). With sand mining, a new livelihood opportunity and income source is introduced.

Sand miners in the Saint Port region in South Africa see the activities as their "gold mine": "Sand mining serves as income generator for our community, we managed to build a community hall and there are people who earn living through the income generated through this industry" and "this is where we make money as there are no jobs anymore in our community" (Mngeni and Musampa, 2016). In many countries, sand mining replaces or complements other livelihoods (Jørgensen, 2016; Aliu et al., 2022; Mngeni et al., 2016). Large parts of the people involved in sand mining have other activities to ensure an income, such as farming and fishing (Mensah, 1997). However, during off-season most people are unemployed and search for other ways to generate an income. Sand mining is not only seasonable, but is also not sustainable, as the resources are non-renewable, and demand can be low at times. During the dry season, sand mining can take place without any hindrance, whereas in the rainy season, the transport of sand can be hindered by unmotorable roads or rivers with elevated water levels. Sand miners in Tamale, Ghana, have developed an approach to manage the low supply during the rainy season by heaping large amounts of sand on higher grounds during the dry season. During the rainy season, the heap supplies the sand (Abu and Peprah, 2020). In coastal sand mining communities in Lagos, Nigeria, the population has traditionally been fishermen and farmers, but has in recent decades turned increasingly towards sand mining as means of livelihood (Aliu et al., 2022). In Cape Verde, Santiago, self-identifying fishermen reported that when the sea was rough, they had no choice but to mine sand to ensure an income and see this as a coping strategy. Local fishermen cannot compete with more modernized fishing practices and equipment, and when they cannot catch fish, there are few other alternatives for them than to mine (Vieira and Rocha, 2021). Similarly, poor agricultural conditions have resulted in an increasing need for diversifying household economies and to ensure an extra income to sustain local livelihoods through mining (Vieira and Rocha, 2021).

Sand carriers and sand loaders are often driven to sand mining because of unemployment or inadequate employment opportunities in their communities (Mensah, 1997). Despite the labour-intensive nature and harsh physical demands of sand mining, carriers and loaders are often paid much below a daily minimum wage by their contractors (Sumani, 2019). With few or no entry barriers, and for individuals with

low educational levels, sand mining becomes an easy means for money making, a supplement, or main income generator (Gondo et al., 2019; Mensah, 1997) and with potential high profit for the involved sand contractors (Mngeni and Musampa, 2016; Mensah, 1997). Among approximately 200 sand miners in Ghana, a vast majority report to have their economic status increased significantly as a result of their participation in sand mining activities (Abu and Peprah, 2020).

4.2. Effects

4.2.1. Environment

Sand mining activities extract sediment from their natural configuration, often with wide-ranging environmental impacts. The environmental effects span broadly from ecosystem disturbance to pollution of water and air as well as noise. The most immediate consequence of extraction is erosion and loss of land and is also what a majority of the Sub-Saharan African literature on sand mining reports on. Research on these aspects is often descriptive, focusing on relatively small geographical areas or confined rural communities. The following describes the environmental consequences by including examples from the existing literature.

4.2.1.1. Erosion and loss of land. The loss of land is one of the most direct effects when sediment resources are extracted, no matter the geographical position. When vegetation is cleared to allow for mining, soil erosion is more prone to occur. The growing instability caused by the removal of vegetation is known to also lead to hillside erosion and landslides (Gondo et al., 2019; Asabonga et al., 2017). A 2017 study from the Eastern Cape Province, South Africa showed that soil erosion and landslides were among the most common impacts of sand mining on the environment (Asabonga et al., 2017). Soil erosion also affects farmland as seeds are washed away and thus impacting the opportunity for future agricultural practices and for vegetation to establish, thus the regenerative opportunities are weakened (Adedeji et al., 2014). When sand is mined from riverbeds and riverbanks, erosion is one of the most commonly reported consequences. Constant extraction of riverine sediments reduces the overall sediment transport capacity of a river and alters river channel morphology. River bank erosion and altered river morphology have been a key focuses in the Sub-Saharan African literature on sand mining: Riverbank collapse is observed in rivers in North Central Nigeria (Ako et al., 2014), along several rivers in South Africa, including the Limpopo, instream sand mining has resulted in river bank erosion (Gondo et al., 2019), in the Ribb River, Ethiopia, years of in-stream sand mining activities has clearly affected the natural riverbed topography (Mingist and Gebremedhin 2016; Mulatu et al., 2018), and bed level has been lowered (Mulatu et al., 2018). In Tanzania and Kenya, lower regions of the Mbezi, Mlalakuwa, Mdumbwe and Tegeta Rivers have been heavily mined, leaving large sections of the riverbeds bare, exposing the underlying parent material (Shaghude et al., 2012). Aside from more local and regional impacts of the extraction of sand, the altered sediment transport eventually threatens the natural replenishment of sediment with potential consequences for the depositional environments, where shoreline retreat can become a consequence. The consequences on the coastal zone of coastal sand mining have been documented substantially in the Sub-Saharan African literature, and coastal erosion is the most reported consequence, and is linked to sand mining activities in a variety of countries throughout the continent: local coastal erosion is accelerating in Tanzania and is attributed to the large extent of unregulated (often also illegal) sand mining (Masalu, 2002). The extensive removal of sediments at the beach allows for wave run up reaching further landward of the beach profile. Increasing human activities, also including sand mining, have resulted in sediment deficit and exacerbated coastal erosion along the shoreline of Accra, Ghana (Jonah and Adu-Boahen, 2016; Addo, 2011). Coastline retreat of more than 1 m/yr (from 1974 to 2012) and erosion scarps are identified as morphological changes caused by the widespread practices of sand mining (Boateng Jonah et al. 2016; Jonah, 2015). Coastal erosion is identified as the most serious environmental problem in the coastal areas of Coffee Bay, South Africa, and is considered a direct consequence of sand mining (Asabonga et al., 2017). Similarly, in the islands of Cape Verde, shoreline retreat and environmental degradation caused by sand mining activities taking place over the last 50 years, are also identified as a key environmental problems in the coastal zone (Correia and Pereira, 2016).

4.2.1.2. Ecosystem disturbance. From an ecosystem perspective, it has long been understood by the people affected by the activities, that sand mining pose challenges to landscape patterns and ecosystem functioning. However, from an academic perspective, very little research has focused on the ecological consequences of mining. Land cover and land type changes are closely related to mining activities and landscape fragmentation is a known consequence of sand mining (Aliu et al., 2022). The degradation of habitats, loss of biodiversity and habitat, and subsequent landscape fragmentation further impact ecosystem functioning. From the landscape perspective, the destruction of surface vegetation causes bare soil in patches, residual waste during extraction leads to visually unpleasant landscapes and further decreases the aesthetic quality of landscapes. In terrestrial sand mining, vegetation and topsoils may be cleared to allow for easier access to the sediments (Asabonga et al., 2017; Sumani, 2019), leading to land degradation. A commonly observed consequence in riverine environments is the degradation of flora and fauna habitats (Gondo et al., 2019; Shaghude et al., 2012). Sand mining in inland water bodies in South-west Nigeria showed that the area of the lakes decreased, as miners filled up the areas with sand and dredging piles (Ndimele et al., 2022). Extensive sand extraction in the Imo River and mid-Ethiope River, Nigeria has changed the macroinvertebrate community compositions, reducing species richness (Zabbey et al., 2008; Iloba et al., 2019; Iloba, 2021). Riverbed mining have been shown to alter phytoplankton species compositions towards species communities with lowered primary productivity capacities (Iloba, 2021). Fishermen in the region report to have their fishery activities impacted by sand mining, which as such also impact the ecosystem services in the areas where mining takes place (Ndimele et al., 2022). Ecosystem destruction and disturbance is less well-documented in the Sub-Saharan African literature, however sand mining in the coastal regions of Cape Verde has shown to disturb turtle nesting and breeding sites (Correia and Pereira, 2016), and in Ghana, beach sand mining was found to negatively affect ghost crab populations (Jonah et al., 2015).

4.2.1.3. Pollution. Whether in the form of air, water, or as noise, all exemplify how pollution in a variety of forms are consequences of sand mining activities which all impact human health directly or indirectly. When extraction of sand is taking place on land, dust particles are dispersed into the air, and noise from heavy traffic, trucks, and vehicles is a consequence caused by the transport of the material to and from the mining sites. Dust particles are present due to the actual extraction of sediments but also as a consequence of the vehicle traffic transporting the material, impacting not only air quality at the mining site but also nearby communities (Lalèyè et al., 2020; Adedeji et al., 2014). The literature reports that villagers living in close proximity to a sand mining site in the Abeokuta region, Nigeria (Adedeji et al., 2014) and in Yaounde, Cameroon are exposed to this pollution. The dust irritates lungs and skin, and is, besides from being physically uncomfortable, also increasing miners and nearby community members' risk of and exposure towards asthma, bronchitis, eye diseases, and blindness (Ekengoue et al., 2018). Water pollution can occur in a variety of ways: the act of extracting sediments from water bodies resuspends the sediments and decreases the visibility of the water (Ako et al., 2014; Zabbey et al., 2008). Dissolved and suspended particles are impacting water qualities

and potentially contaminating the water, and saltwater intrusion is affecting drinking and irrigation water. Stakeholders involved in small-scale mining activities in the Danko region of Ghana identified air pollution as a negative impacts of the activities (Sumani, 2019). Saline water intrusion into groundwater and freshwater systems decrease the water quality for human use. Coastal sand mining in the Santiago Island of Cape Verde has created saltwater ponds along the beach (Correia and Pereira, 2016), increasing the risk for salinization of the groundwater. Sand mining in the Nzhelele River in South Africa is taking place in close proximity to local communities, and the water in these areas is found to be posing serious health challenges due to its often contaminated quality (Gondo et al., 2019). A study of the presence of heavy metals in ponds where sand mining is taking place in Owerri, Nigeria shows elevated concentrations of Fe, Cu, Zn, MN as well as Pb, all above the regulatory limits (Ogbuagu and Samuel, 2014). Similarly, a region in Kenya where sand mining is abundant shows that the activities have exposed the aquifers to contamination and some wells have been destroyed and are no longer useful as water pumping stations (Opiyo-Akech et al., 2000). In the Sub-Saharan African literature on sand mining, there has generally been little focus on the impact of mining on health through pollution, which is in line with the global trend on this aspect of mining (Bendixen et al., 2021). An indirect health threat from sand mining comes from the dug-out pits that are left behind when sand mining activities have stopped. The threats include pollution, noise, and odours resulting in these sites being unsanitary waste dumping sites (Ratter et al., 2016). Abandoned pits have been associated with disease dispersion, such as cholera, dysentery, and diarrhoea, as well as the spread of malaria (Adedeji et al., 2014). The shallow abandoned pits act as breeding grounds for mosquitos during the rainy season where they collect water and attract malaria parasites.

4.2.2. Socio-economic

4.2.2.1. Land-use change and degradation. Mining and agricultural activities represent a conflict in their competing land uses. While poor agricultural conditions can be a driver for people to start engaging in mining activities, the effects of mining can have detrimental effects on farmland and agricultural areas and practices. This is particularly true where sand mining is intruding in areas where high-value farmland is scarce. Some studies have shown that mining leads to reduction in farm and grazing land area (Aliu et al., 2022). In a 2020 study from Ghana, more than 90 % of the respondents ($n = 59$) confirmed that sand mining activities are particularly conflicting with farming (Abu and Peprah, 2020). As topsoil is often removed before mining takes place, ecologically valuable seeds are removed, thereby challenging the capability for regeneration of vegetation (Adedeji et al., 2014). A farmer in the Danko region, Ghana, described his land: *"This 5-acre land you are looking at has been completely destroyed by a road contractor. They pushed aside the top fertile soil, scooped the gravel, and left behind this wide pit"* (Sumani, 2019). Pastoralist communities in Kenya say sand mining is destroying the land they depend upon, allowing no areas for livestock to graze (Jørgensen, 2016). In North Central parts of Nigeria, locals report to have lost most of the productive land traditionally used for farming and animal rearing due to sand mining (Ako et al., 2014). In Ghana, agricultural land and 'economic trees' (shea and dawadawa trees) were destroyed (Sumani, 2019) and in Comoros, several rows of coconut trees were removed (Ratter et al., 2016) as they were cleared to allow for sand mining. Thus some agricultural lands are threatened and degraded by sand mining, and these competing interest in land-use can lead to conflicts. In Kenya, particularly among elders, sand mining is viewed as a cultural taboo as the activities are believed to be cursed and as result can lead to a variety of misfortune (Jørgensen 2016). When agricultural land is reduced or degraded, it has come to confrontations between farmers and mining contractors in Nigeria (Adedeji et al., 2014). In Ghana, a majority of the interviewees reported that no prior agreement with sand miners operating on the lands was in place, resulting in sand producers using force to mine sand (Abu and Peprah, 2020). In Tamale, Kenya's third largest region, sand miners have been shown to be the ones to benefit economically from sand mining at the expense of local farmers (Abu and Peprah, 2020). Sand mining activities can directly or indirectly affect nearby waters, whether freshwater or coastal areas as well as the groundwater. This effect on drinking and irrigation water has been identified by the Charco residents in Cape Verde, who complained about the infiltration of saltwater into their drinking water (Vieira and Rocha, 2021). In Kenya, sand quarries operating in close proximity to potable groundwater supply areas have been shown to pose serious threats to the quality of the water (Opiyo-Akech et al., 2000). Another example of land-use changes is that of abandoned sand-pits used for dry season gardening and livestock drinking, for washing of clothes and vehicles, and for providing water for individual households (Sumani 2019; Iloba et al., 2019), while in other regions for example in one community in Lusada, Nigeria, sand pits are used by community members as waste dumps (Adedeji et al., 2014).

4.2.2.2. The built environment. While it is evident that one of the strongest drivers of sand mining is caused by the growing need for housing and overall construction projects and development, the actual effects of sand mining on the built environment are poorly understood. Only few studies report on the immediate consequences of sand mining activities, for example the increased vehicle traffic to and from the extraction sites (Adedeji et al., 2014). A rural community in the Wild Coast, South Africa, has experienced considerable damage to road infrastructure due to heavy traffic to and from mining sites, and is filling up holes in the damaged roads with wood, tree branches, stones or rocks (Mngeni et al., 2016) to reduce damage to vehicles using the roads and repair and improve road conditions. A study from Lagos, Nigeria, also showed that among the negative consequences of mining activities for the built environment was the road damage and destruction as well as threats and destruction to existing buildings (Aliu et al., 2022). An indirect consequence of the mining activities to critical infrastructure is caused by the alterations in river stream-morphology, which leads to serious damage to for example water pipes and bridge piers (Gondo et al., 2019), ultimately risking the safety for the people using these (Masalu, 2002). With little understanding of the consequences and outcomes of sand mining for the built environment, the knowledge on the quality of the material used for construction remains poor. In Cameroon, infrastructure constructed from both river and quarry sand extracted in western regions of the country is deemed to be of poor quality (Tetsopgang et al., 2020), due to the presence of clay and too fine-grained materials. In Zanzibar, the growing demand for sand has pushed a greater exploitation of beach sand, where a broad range of users spanning government, private sector and local individuals, are known to use the sand derived from local beaches in construction (Masalu, 2002). This type of extraction is carried out as an unregulated activity, with no insurance of the quality of the material. Communities also rarely directly benefit from commercial sand mining practices in their area despite the high revenue that comes from the operations. As such, it becomes the satellite communities surrounding the metropolis that feel and live with the implications of the huge demand. Social infrastructure like roads and pipe borne water regularly gets damaged and flooded as a result of expedited coastal erosion, which forces governments to invest large amounts of money to repair the damage (Boateng Jonah et al., 2016).

4.2.2.3. Financial gains and opportunities. The clear financial gain from sand mining at an individual or household level is the generation of jobs for both youth and adults, whether part-time or seasonal. Drivers involved in the industry in the Tamale region, Ghana, reported to be organized in unions, though 'sand loaders' or 'loading boys' work on an individual basis and are not known to organize in unions (Abu and

Peprah 2020). Activities in the Ogun State, Nigeria, also indicate that miners do not operate in unions, whereas those selling the sand do (Adedeji et al., 2014). In addition to providing income and employment opportunities for people involved in the sector, sand mining offers a variety of financial benefits at different levels beyond the individual. Tax revenues can be mobilised at a variety of levels, from local governments to municipality and district assemblies (Abu and Peprah, 2020). Taxes may be paid per truck load when passing by checkpoints or barriers, as seen in Comoros (Ratter et al., 2016; Sumani, 2019). When the activities are organised and legal, they additionally act as a source of revenue for governments in the form of mining leases and royalties. Sand mining entrepreneurs involved in activities in the coastal regions around Lagos, Nigeria, indicated to be paying a different amount of money to both governments and the community leaders, depending on the scale of the operation (Aliu et al., 2022). In Comoros, the individual truck drivers pay taxes to political and municipal authorities, and the practice of sand mining is considered a principal source of revenue by the local mayor (Ratter et al., 2016). An additional gain spurred by the activities of sand mining is the direct effects on parallel activities, either in close proximity or with larger distance to the mining sites. These effects can be identified on a smaller, individual scale and a broader local societal scale. On a smaller level, the effects can be seen in the creation of small food stalls, sale of snacks, beverages and cigarettes (Masalu, 2002), and fuel and gas stations are known to also benefit from the activities (Abu and Peprah, 2020). On a larger scale, sand mining in coastal areas has both positive and negative implications for the tourism industry. As sand provides material for the construction industry, hotels, and housing facilities, there is a positive link between the activities and the indirect support and attraction of tourism and activities supporting tourism (Jonah, 2015). Paradoxically, the tourism industry can be negatively affected by sand mining activities, which disrupt and greatly compromise the scenic beauty of a landscape, leaving behind visually unpleasant views. This becomes particularly critical in areas, where tourism is important for local economies. Furthermore, when sand mining takes place in areas attractive for tourists, for example beach areas, the activities have negative implication by causing shoreline erosion, changing swimming and safety conditions for beach-goers, diminishing the aesthetics of the beach, and eventually causing fewer visitors (Jonah and Adu-Boahen, 2016; Correia and Pereira 2016). In Comoros, residents have long acknowledged the value of the beach, both for local recreational activities, but also acknowledging the important role of preserving it for its attractive and inviting status as a tourist destination (Ratter et al., 2016).

4.2.2.4. The gendered aspect of mining. The role of women in the sector varies significantly from country to country and is determined by a range of social and cultural variables such as power relations, responsibilities, possibilities, level of affluences, norms, religion, class, and ethnicity. Mensah (1997) finds from their study in the late 1990′s Ghana, that the activity is gender-specific, meaning the ‘sand carriers’ are women, while the loaders and truck drivers are men. In another study also from Ghana (Sumani 2019), documents show that only a small number of women are involved in the sector, and that they all collect rent on behalf of the landowners. In an example from Ogun State, Nigeria, women are also only marginally involved in the activities, here through them selling the sand product (Adedeji et al., 2014). An example of river mining activities in River Ethiope, Nigeria, documents that throughout some stretches of the river, women are forbidden access, and thereby allowing only men the opportunity for being involved in the activity (Iloba et al., 2019). A different pattern of women-engagement is visible in Cape Verde (Correia and Pereira, 2016). Here 25 heads of households extracting sand were interviewed, indicating that most are women between 40 and 59 years of age, otherwise unemployed and with low educational levels. The ownership and control of the actual resources are a male domain. Many of the women have been involved in the activities for decades and are known to be blamed for the environmental degradation. The sand mining activities are thus contributing to the inequalities in gender and class in Cape Verde. Also in Cape Verde, children are known to participate in mining activities during school off-days and holidays (Vieira and Rocha, 2021) thereby subsidising household economies. In Ghana, women involved in the extraction have engaged their children during weekends and when not in school to assist them (Mensah, 1997). This has been shown to result in truancy and increased drop-out rates especially among schoolgirls (Sumani, 2019; Mensah, 1997). As has been previously shown in the literature and documented in the variety of examples mentioned above, the participation of women in the extraction activities is highly context dependant (Bendixen et al., 2021). While the inclusion of women in the sector offers employment and livelihood opportunities, it has also introduced inequalities. Direct consequences of inequalities are seen in the pay gaps existing between men and women involved in the sector (United Nations Environment Programme, 2022b), while indirect consequences are the ones affecting the livelihoods and everyday lives of women. Land degradation caused by sand mining, means poorer soil fertility, which in turns increases food insecurity, a portion of household work that women often are responsible for. Similarly, riverbed mining decrease water qualities, meaning women, who are often responsible for ensuring water for the household, need to walk further distances (Global Alliance for Green and Gender Action, 2018). As such, the overall benefit of sand mining on women are widely ranging and point towards a need for policy actions specifically targeting the gendered inequality aspect of mining activities.

4.3. Legislation

Many countries do have legislation and policies on sand mining in place, however, it is no assurance the policies sufficiently address the quality of the construction materials being mined, nor that they address the multifaceted problems arising from the mining activities. Throughout the investigated literature, there is a general trend showing no efforts on enforcing legislation or strategies to discourage sand extraction in local communities or find alternative solutions. Existing legislative instruments often fail to include procedures for the extracted materials. In Ghana, construction materials are not included in the broad policies and legal framework surrounding sand mining (Abu and Peprah, 2020). In Cameroon, The Title III regulates the administrative procedure to operate a quarry for extraction, but not the extracted materials. In addition, sand quarries mostly occur in Cameroon without any regulations, and certificates and EIA are not required when applying for an authorization to open a sand quarry (Tetsopgang et al., 2020). An example from sand mining activities in rural Nigeria shows that the policies in place for sand extraction activities are either urban-orientated, or not being implemented, or the with slow pace of implementation (Olufayo et al., 2013). In Cape Verde, the extent and consequences of mining activities have been known for decades, causing the Cape Verdean government to introduce legislation prohibiting the extraction of sand with the exception of duly authorised areas (Correia and Pereira, 2016). Similarly, the Tanzanian government has had well-established legislation in place for decades to govern the extraction and mining of minerals, which include sand (Masalu, 2002). While local chiefs in some communities are responsible for the management of the coastal area, coastal sand is seen as a communal property and traditional authorities do not have authority to lease coastal lands to sand miners (Mensah, 1997). An additional challenge related to the lack of management is the continuous lack of adequate peoplepower and logistics to regulate and monitor coastal sand mining activities (Boateng Jonah et al., 2016). Having policies and legislation in place is no guarantee for a successful implementation of these. Challenges have been observed surrounding the implementation of laws in communities with high literacy among the sand producers, as in the case of the study in the Tamale Region, Kenya (Abu and Peprah, 2020). A similar problem with

broadening out the information on sand mining activities has been observed in Cape Verde, where part of the solution to inform the public has been to raise awareness through TV-broadcasts (Vieira and Rocha, 2021). Despite policies being in place in some countries and with activities remaining unreported, it remains hard to estimate extraction numbers (Shaghude et al., 2012), and thus to determine the resource's actual value and contribution to a country's GPD (Mngeni and Musampa, 2016). This was however not within the scope of the present review, but points towards the need for future work focusing on increasing transparency and increased monitoring of the activities.

4.4. Illegal and unregulated activities

The term 'illegal' should be used with utmost consideration and respect for the informal miners engaged in the activities solely to make a living. In several countries, sand is not included in the mineral acts, meaning it can only be mined through an unregulated process. Unregulated extraction takes place where there is no permit, no extraction or rehabilitation plans in rivers, beaches, lakes and in inland sand deposits. Within the literature, it becomes evident that unregulated and illegal sand mining is extensive throughout the continent and has been carried out for decades in numerous Sub-Saharan Africa countries (Vieira and Rocha, 2021; Mensah, 1997; Ekwu and Udo 2014; Iloba, 2021; Correia and Pereira, 2016; Shaghude et al., 2012). Miners often report to have no other option to sustain their livelihoods, and miners have reported that while the work involves quick cash, it is hard and physically tough labour (Jørgensen, 2016). People involved in the mining activities may see the material as a common pool resource with no limit to who can engage and no organized rules around the commodity. For example, beach sand in Tanzania and in Comoros are viewed as a source of building material among the miners (Masalu, 2002; Ratter et al., 2016), and in a study from Nigeria, the miners indicated no need for control measures as the mining took place on private land (Adedeji et al., 2014). One study from Northern Kenya shows how the school system introduces to the children that materials formed in the environment should be exploited as they provide economic wealth (Jørgensen, 2016). Evaluating the literature published from Sub-Saharan Africa, it is clear that these unregulated activities are playing a significant role when discussing the implications of sand mining. The term 'illegal' is frequently used to describe the unregulated sand mining (Correia and Pereira, 2016; Shaghude et al., 2012; Mngeni et al., 2016; Masalu, 2002; Abu and Peprah, 2020; Adedeji et al., 2014; Ako et al., 2014) and has been reported in Cape Verde, Kenya, South Africa, Ghana and Nigeria. Unregulated mining activities occurs in a variety of ways: The mining sites can be poorly operated as is seen in Lagos, Nigeria, where operators claimed to have registered their extraction activities, though evidence of environmental impact assessments (EIA) or documentation of the properly carried out activities were lacking (Aliu et al., 2022). Or as in South Africa where a site officially was shut down by local municipalities and government officials, but extraction continued at night by illegal miners (Mngeni and Musampa, 2016). This practice of activities taking place during off-hours is continuously reported in the literature (Mngeni et al., 2016; Masalu 2002; Correia and Pereira 2016; Jonah and Adu-Boahen 2016). This is done to avoid catching attention, and when law enforcement is less likely to notice the practices. Mining without adequate authority approvals was made illegal in Cap Verde in 2007, after the country had introduced legislation prohibiting sand mining in dunes, beaches, and inland waters (Correia and Pereira, 2016). In Tanzania, the Mining Act of 1979 prohibits mining of sand from coastal streams and beaches (Masalu, 2002), and the government has well-established legislation that govern the extraction and mining of minerals, including sand (Shaghude et al., 2012). While efforts have been made to control mining activities, mainly negative outcomes are still being reported. Government officials and state security officials, whose purpose is to enforce the law, have received or asked for bribes (Masalu, 2002), or given it the blind eye (Abu and Peprah, 2020). An example from South Africa shows how government officials have been locked up by local community members, when enforcing the law (Mngeni and Musampa, 2016). In Tanzania, growing hostility was seen between community members owning land and local authorities on one hand and sand miners on the other (Masalu, 2002). Authorities continuously attempted to stop sand miners from operating in unauthorised areas along the coast in Tanzania, while the miners' responses were threats directed towards property owners (Masalu, 2002). Local fishermen at the Cape Coast, Ghana confronted sand miners after several unsuccessful dialogues between the two groups (Jonah and Adu-Boahen, 2016). Along coastal communities in Ghana, there have been numerous instances of conflicts between residents and contractors over disputes of road usage, as tipper trucks are known to cause considerable destruction to roads, by creating potholes and causing the collapse of culverts (Mensah, 1997; Mensah and Mattah, 2023). Tensions are known to occur through interpersonal relations in family disputes over land use (Mensah, 1997; Sumani, 2019). Sumani (2019) interviewed local miners in Ghana, where a respondent revealed that his family head had given away the family's farmland to sand operators. This led to the destruction of agricultural land and economic/money trees (shea and dawadawa trees) ultimately resulting in family disputes and forcing them to seek alternative livelihoods (Sumani, 2019). Little research has focused on the gendered aspect of the illegality, however in Cape Verde, Correia and Pereira (2016) identified women as dominating the illegal activities. With little or no alternative job opportunities existing for women, few if any opportunities were left for women with low education levels and heads of poorer households, than to engage in illegal activities. A vast majority of the reporting on the illegal activities focus on the disputes arising and little research effort has been put into understanding how to mitigate conflicts. However, a local community in the Coffee Bay region in South Africa, successfully engaged volunteers to help the local headman monitoring and patrolling, ensuring that no illegal mining activities were taking place in the area (Mngeni and Musampa, 2016). Local villagers of the Moya beach, Comoros have organized beach cleans and banned any sort of sand extraction in their decade-long protection of the beach due to its scenic beauty and its value for locals, livelihoods and tourism (Ratter et al., 2016).

5. The paradox of sand mining

The growing focus on the sustainability challenges linked to sand extraction and usage has led to the recognition that initiatives on a variety of levels are necessary (Bendixen et al., 2019). An essential part of ensuring a sustainable mining sector is the realisation of the apparent paradox, that sand mining contributes to the development of societies, generate incomes at national levels, and, on individual levels, provide livelihoods for millions of people worldwide. Simultaneously, the practices of mining, whether on land, in lakes and rivers or along coastlines, have negative consequences for both the environment and societies. The rapidly growing and intense exploitation of sand throughout the world has received increasing attention from the research community over the last decade (United Nations Environment Programme, 2022a; Peduzzi, 2014). To sustainably manage the environmental and societal consequences of mining, it is essential to address all levels and players involved, spanning the extraction phase to the sourcing, usage, and management. A key component are policy initiatives which effectively manage the resource, and balance the delicate act of extracting a natural resource while avoid creating permanent damage to the environment. Simultaneously, initiatives must be constructed with an awareness and respect for local dynamics. A place-based understanding and assessment of the emergence, development, and practices of the activities will be essential for successful governance and implementation (Dar et al., 2023; Mushonga, 2022). More work is needed focusing on the political nature of sand frontiers to better understand the paradox in how sand extraction alters the environment, while including the realization that the actual extraction itself is shaped

by socio-economic, political, and financial relations, and that these dynamics are rapidly developing in large parts of the world.

6. Conclusion and further research

This paper documents that, for the majority of countries investigated throughout Sub-Saharan Africa, local development and livelihood sustainability is strongly dependant on sand resources. When these extraction activities are carried out as unregulated and/or illegal activities, the consequences for the miners are that they unwillingly become involved in dishonourable activities, which is harmful to the local environment and to parallel activities, such as farming. The effects of the sand mining activities go beyond the immediate negative environmental consequences. For humans and the built environment, consequences are both positive and negative seen in the construction of critical health facilities, community-based improvements in the form of churches or infrastructure, or for housing tourists, at individual level by offering livelihoods and income to often poorly educated youth involved in the extraction or as part-time employment opportunities during off-seasons for fishermen or farmers. The paradox thus arises when this exact material is ensuring a livelihood for the numerous people involved in the sector, while simultaneously improving the built-environment and impacting the natural environment. If the sand material is transported outside the local communities, the local benefit diminishes.

In the literature examined, there are three key action points that consistently are pointed out and are described as ways forward to manage and ensure a sustainable future for the resources and the countries, which so heavily depend on them:

Regulate, monitor, and limit sand mining activities. Enforce control and inspection (Vieira and Rocha, 2021) along with setting standards and regulations (Adedeji et al., 2014; Aliu et al., 2022). Strengthening and improving governance will be essential for fighting illegal activities, bribery and unfaithful officials (Masalu, 2002). Abu and Pepra (2020) and Aliu et al. (2022) recommend governments creating agencies to manage sand mining activities. Jonah and Adu-Boahen (2016) highlight that adequate people-power and logistics is critical in ensuring proper management and control. (Adedeji et al., 2014) encourage integrated environmental assessments, monitoring and management programs at national, regional, district, and local levels. The procedure of obtaining legal permits for mining should be simplified while being widely and clearly publicised to small-scale miners (Masalu 2002). Planning efforts should happen through intersectoral cooperation between policy makers, engineers, communities, and local residents (Mensah 1997). Mitigation of the impacts of mining will lessen and or limit the negative consequences of mining (Tetsopgang et al., 2020). Initiatives to recycle wastewater and to dump mine tailings within the mining sites will lessen the demand for water and limit soil erosion and degradation (Tetsopgang et al., 2020). Imposing restrictions on sand mining in critical areas, where mining has already been intense, such as beach environments (Jonah, 2015).

Increase awareness levels of the adverse effects of sand mining (Sumani, 2019) which should go beyond educating on harmful effects (Masalu, 2002; Mensah and Mattah, 2023). Masalu (2002) argues that focus should be on changing the involved participants' mindsets to make everyone feel responsible for their role in sand mining activities. Efforts should focus also on ensuring layman's understanding of the importance of overall land and resource management (Adedeji et al., 2014), which can be done using the media as seen in the case of Cape Verde (Vieira and Rocha, 2021) or through coordinated community programmes (Adedeji et al., 2014), or via the government launching large-scale educative campaigns through radio, television, and newspapers (Masalu, 2002).

Identify more sustainable sources of sand for the construction industry (Jonah, 2015), and push the evolution of new scientific knowledge and engineering as well as new practices and methods (Mensah, 1997). Practical solutions could be to further develop the technology used to build traditional mud houses (Mensah, 1997).

The overall challenge in managing the resources of sand remains to ensure that economic prosperity does not occur at the expense of environmental disaster with potentially far-reaching consequences for future generations. For optimal decision making and guideline making for sand mining and post sand mining operations, identifying, and addressing the environment damage from mining activities is essential. Understanding how mining activities affect the ecosystem in those regions can provide guidelines for the environmental management practice for restoration and re-use of the disturbed areas in the post-mining stage.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

MB supported by CarlsbergFoundation CF20-0129, Villumfoundation research grant number 40634, NSERC Discovery Grant number 202200146. LLI is supported by NSERC Discovery Grant 2022-00328
KH is supported by Villumfoundation research grant number 40634.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.exis.2023.101364.

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