Sustaining urbanization while undermining sustainability: the socio-environmental characterization of coastal sand mining in Lagos Nigeria

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Abstract Sand mining is a global activity that has attracted wide attention due partly to its invaluable positive contributions to development and partly to its negative socio-environmental impacts. While sand mining supports urbanization by providing essential aggregate materials for urban real estate and construction sectors, it however undermines environmental sustainability especially in coastal regions. In spite of this, very sparse research has explained the socio-environmental dimensions of sand mining in Nigerian coastal communities. This study therefore explored the drivers and impacts of sand mining based on the data from a survey of residents in four Lagos sand mining coastal communities. Results showed that sand mining activity is driven by a number of urbanization related factors while sand mining impacts are underlined by a number of sustainability related factors. However, using exploratory analytical techniques we found that four urbanization components described the drivers of sand mining and four sustainability components described the impacts of sand mining in Lagos.

Introduction

Sand mining or what is sometimes referred to as ‘sand dredging’ is a thriving vocation world over which has long supported urbanization, general construction, housing and industrialization (Collins & Dunne, 1989; Hilton, 1989; Mensah, 1997; Masalu, 2002; Ashraf et al., 2011; Padmalal & Maya, 2014; Jonah et al., 2015; Asabonga et al., 2017; Djihoussei et al., 2017; Haghnazar & Saneie, 2019; Koehnken et al., 2020). In all parts of the world sand mining produces aggregate sand materials for constructing buildings, roads, bridges, land filling and making silica bottles. The importance of sand as a resource to the built environment and industries cannot be overemphasized as the sand market has contributed tremendously to peoples’ livelihoods, real estate development and nations’
Gross Domestic Product (Awudi, 2002; Akabzaa, 2009; Onwuka et al., 2013; Tariro, 2013; Asante et al., 2014; Djihouessi et al., 2017; Tastet, 2019). Sand is obviously the second most abundant and consumed extractive resource after water (UNEP, 2014; UNEP, 2019). Between 32 and 50 billion tons of sand and gravel are extracted globally each year with increasing demand especially from emerging industrial countries like China, Indonesia, India and Singapore (UNEP, 2014; Koehnken & Rintoul, 2018).

However, because of sand’s slower rate of replenishment on consumption and its undeniable utility in world development, there are both socio-economic and environmental sustainability angles to the phenomenon of sand mining. Unbridled and unfettered sand dredging activity poses great threats to the immediate communities. Sand mining increases the formation of sinkholes, soil contamination, deforestation, coastal erosion, property damage, loss of aquatic biodiversity, alteration of coastal shorelines, and a source of ecological destabilization (Collins & Dunne, 1989; Hilton, 1994; Mensah, 1997; Masalu, 2002; Kelly et al., 2004; Ako et al., 2014; Jonah et al., 2015; Asabonga et al., 2017; Sincovich et al., 2018; Kohasi & Jose, 2018; UNEP, 2019; Da Silva et al., 2020; Koehnken et al., 2020).

At epistemological level, the impacts of sand mining on human development and the environment as revealed in the literature are summarized in three broad themes namely socioeconomic, environmental and hydro-geomorphic impacts (Abam & Oba, 2018; Adeoti & Peter, 2018; Ako et al., 2014; Atejiyo & Odeyemi, 2018; Hilton, 1989; Mensah, 1997; Masalu, 2002; Onwuka et al., 2013). Firstly, several studies have linked socioeconomic prospects and challenges of host communities to sand mining concluding that sand mining contributes to socioeconomic improvement in terms of income and jobs for the communities’ residents (Mngeni et al., 2016; Djihouessi et al., 2017; Masalu, 2002; Rais et al., 2019). Sand and gravel mining is a source of revenue for the government in form of mining lease, royalties levied on gross market value per month including mining companies while at the same time providing jobs for many others (Madyise, 2013). However, sand mining can also have deleterious effects on the social and economic development of the immediate communities (Ahiadu & Ahove, 2005; Onwuka et al., 2013; Johnbull & Brown, 2017; Adeoti & Peter, 2018).

Secondly, sand mining has been widely reported to have negative environmental effects. According to Dissanayake and Rupasinghe (1996) almost all forms of mining cause erosion and sedimentation, which have negative consequences for the physical environment. There is correlation between sand mining activities and soil erosion, vegetation loss, aquatic biodiversity richness reduction and landslides (Asabonga et al., 2017; Jonah et al., 2015). Some studies have also found that sand mining activities easily lead to the destruction in landscape, reduction in farm and grazing land areas, collapse of river dams, deforestation, and water pollution with severe implications for plant and animal biodiversity (Ako et al., 2014; Mensah, 1997). As an earth related vocation Atejiyo and Odeyemi (2018) observed the enormity of sand excavated from designated places may lead to earth subsidence and sinkholes. An interesting coastal sand mining study by Sridhar et al. (2019) has revealed that sand mining causes water pollution and poor water quality for the communities with concentration of Lead (Pb) and Cadmium (Cd) as well as more particulate being found in the air. In the study of impacts of sand exploitation Gavriletea (2017) argued that either surface or underground sand mining activities connected to the industry produces serious negative environmental impacts that lead to major changes in the flora and fauna, contaminate the groundwater and disrupt the landscape.

Thirdly, sand mining has been linked to hydrological and geomorphic alterations. Sand mining activities have shown to have negative effects on stream sedimentation rate (Hagnazar and Saneie, 2019), alteration of shorelines, change in micro-climatic dynamics and landslides (Ashraf et al., 2011; Jonah et al., 2015). Sand mining also adversely influences river beds, lake catchment areas and loss in aquatic biodiversity (Padmalal et al., 2008; Sheeba, 2009). It also affects the turbidity of rivers (Abam & Oba, 2018; Yen & Rohasliney, 2013). A study of impacts of sand mining on groundwater depletion revealed that intensity of sand mining of the dried river paths reflects in inability of the groundwater to recharge (Hemalatha et al., 2005). Costea (2017) found the impact of flood plain assessment of gravel mining on landforms and processes that, given the local geomorphic conditions and the flow variability, the intense harvesting of gravels is the most important control factor that
contributes to the changing of floodplain morphology, fluvial processes and riverbed pattern.

In the Vembanad Lake in India, the riverbed lowers approximately 7–15 cm a year due to the removal of more than 12,000,000 tons of sand (Tastet, 2019). In San Diego, the San Luis Rey River experienced significant erosion due to sand mining, which undermined infrastructure and aqueducts and caused a large loss of vegetation and animal habitats leading to destruction of wildlife in the rivers (Aurora et al., 2017). Due to sand mining across rivers the local ecology experiences problems, such as reduced fish resources, insect population, and diversity in wildlife, as well as other effects caused by a physical disturbance to the habitat (Harold, 2005; Tastet, 2019). According to Kelly et al. (2005), Rinaldi et al. (2005) and Collins et al. (1990), the potential impacts of sand and gravel mining include river bed degradation and consequent effects on channel and bank stability can undermine bridge supports, pipelines, or other structures. Consequently, Gondo et al. (2019) advised that effective regulatory guidelines to govern sand mining need to be put in place. The multiple negative externalities of pervasive sand mining suggests that unregulated sand mining in the coastal region may have far reaching consequences for the physical and socio-economic wellbeing of the coastal regions’ population.

This study is important for a number of reasons. Firstly, there is paucity of research on the socio-environmental aspects of coastal sand mining in Nigeria. Even when many studies in Nigeria have examined the inherent issues in sand mining activities generally (for example Ahiadu & Abohe, 2005; Onwuka et al., 2013; Ako et al., 2014; Jonah et al., 2015; Abam & Oba, 2018; Asabonga et al., 2017; Adeoti & Peter, 2018), only scanty studies have evaluated sand mining activities in the coastal region of Nigeria from the residents’ perspectives. A socio-environmental analysis of sand mining in the Lagos will account for variations in residents’ views of the impacts of sand mining and support the stakeholders on policy to regulate mining activities in the region. Secondly, this study also unravels the intricate processes that underlie coastal sand mining and highlights the operational characteristics of sand mining in the region. Lastly, the study reveals more facts on the social, health, economic and environmental drivers and impacts of sand mining that could be of immense importance for policy on coastal environmental planning. The research questions are—what are the operational patterns of coastal sand mining sites? What are the drivers and socio-environmental impacts of sand mining on the coastal communities in Lagos? What are the implications for the built environment sustainability?

Theoretical framework

The link between human livelihood activities like mining and the built environment conditions is quite explicit but complex. While some of the livelihood activities actually support the growth of the built environment majority of them impacts negatively on the conditions of the built environment. Therefore, at theoretical level, the concern really is how to understand the link between sustainable built environment (SBE) and livelihood activities. The built environment comprises all man-made material components such as buildings, institutions, markets, shopping malls, schools, commercial outfits, roads, sidewalks, communication facilities, open spaces, drainages, bridges and other infrastructure that are available in human communities. Given these enormous components, the built environment is critical to human progress and sustainable development which according to the World Commission on Environment and Development’s Brundtland report is an environmental, social, economic and ethical concept that seeks to achieve economic growth, social equity and ecological stability simultaneously for the present generation and future generations (WCED, 1987; World Bank, 2013; UNEP, 2019). Incidentally, these sustainable development agenda have been transformed by the United Nations Organization (UNO) into global decisions which culminated in the formulation of Millennium Development Goals (MDGs) at the beginning of the twenty-first century in 2000 and sustainable development goals (SDGs) in 2015.

While sand is a valuable resource for human development, its process of extraction and transport threatens the built environment in many ways. Sand mining increases land degradation, building collapse, deforestation, coastal erosion, noise, property damage, dusts, water pollution, loss of aquatic biodiversity, alteration of coastal shorelines, and flooding (Mensah, 1997; Masalu, 2002; Kelly et al., 2004; Asante et al.,
2014; Ako et al., 2014; Jonah et al., 2015; Asabonga et al., 2017; Sincovich et al., 2018; Kohasi and Jose, 2018; UNEP, 2019; Da Silva et al., 2020; Koehnken et al., 2020). All these go to show that if not well managed sand mining though a thriving livelihood could cause a huge threat to human habitat and community’s sustainability.

Sustainability comprises three components namely: (I) physical environment (II) economic conditions and (III) social conditions. All mainstream ideas about sustainability share three characteristics: first, sustainability requires integrating policies related to economic development, environmental protection and social justice; second, the interest of future generations is inviolable; and third, transparency and public participation at all levels of decision-making from local to global scale are essential (Aliu, 2016; Smets & van Lindert, 2016). Sustainable development therefore presupposes the sustainability of natural and artificial resources including sand and the built environment.

An aspect of sustainability theoretically relates to the livelihood of the individuals and households in a community. The livelihoods framework encompasses the skills, assets (both material and social), and the approaches that are used by individuals and communities to survive (Asante et al., 2014). It is also viewed as a framework for understanding the various factors that affect choices of human subsistence and how these factors interact amongst themselves. Theoretically, sustainable livelihood (SL) is characterized by all strategies and principles geared towards improving the quality of human life, providing resources and life support services at all times as the human society seeks to satisfy its needs of survival and well-being. The concept of SL is guided by some principles namely right to own, use or exploit resources without damaging the environment; the need for all sectors of the economy (government, education, business) and the community to work together to create a booming local economy and the need to set plans and the implementation of goals and strategies for sustained economic development (Hilton, 1989; World Bank, 2013). The attainment of sustainable livelihoods, economic growth, social equity and environmental stability leads to the attainment of sustainable built environment. The sustainability framework was used in this study to give more insights to sand mining as a livelihood activity and its impacts on the social, economic and environmental conditions in Lagos coastal marginal communities.

Study area

Location and physical setting

The study area consisted of four (4) Local Government Areas (LGAs) namely Badagry, Ojo, Amuwo-Odofin, and Eti-Osa in Lagos Nigeria. As indicated in Fig. 1, the four areas are among the nine (9) coastal settlements that share boundaries with lagoons and Atlantic Ocean. Badagry is located outside of the Metropolis while Ojo, Amuwo-Odofin and Eti-Osa are located within the Metropolitan area of Lagos. The Badagry Creek and Ojo LGAs are on the western flank, while Eti-Osa is on the eastern flank of Lagos. The Lagos coastal regions extend to about 75 km along the Atlantic Ocean and cover about 60% of the total land areas of Lagos. They cover areas with more natural vegetation and with soil and geologic formations of the pre-Cambrian era. The climate is tropical type with mean daily temperature of about 30 °C, annual mean rainfall of about 1532 mm, two major seasons namely the dry season between November and March and the wet season spanning between April and October (Odumosu et al., 1999).

The major vegetation consists of tropical swamp forest (fresh water/mangrove swamp forests and dry lowland rain forest). The drainage system consists of Lagoons which occupies almost 22% of the state’s total landmass. The area is drained by River Ogun at the centre, River Osun towards the east while it is drained by River Yewa in the west.

Population and economy

The study area is home to the Awori and Ogu people of Yoruba ethnic group in South-Western Nigeria. The Ogu people are majorly confined to Badagry area while the Aworis are found in all parts of Lagos. The Lagos Metropolitan Area including the study area as at 2006 had a population of 6,684,105, which was nearly 50 percent of Lagos total population of 9,013,534 (NPC, 2006). As indicated in Table 1, the largest of the four LGAs covered is Ojo with a population of 598,071 in 2006 and 838,900 in 2016, and the smallest LGA is Badagry with a population of 241,093 in 2006.
and 327,400 in 2016. The National Bureau of Statistics’ population estimates put Lagos Metropolitan Area at 10,778,000 in 2011 and 12,634,000 in 2016 (NBS, 2016). Majority of Lagos megacity including the study area is located in riparian water logged coastal environment within sensitive ecological zones which create land management challenges (Aliu, 2016).

The study area as a part of Lagos Metropolitan Area (LMA) has very strong and complex economy. Majority of the residents engage in informal activities like trading, fishing, cottage production and sand mining. As the most virile economy in Nigeria, Lagos accounted for 26.7% of Nigeria total GDP in 2015. It is the economic nerve centre of the nation with over 70% of the industrial entities. Lagos plays host to Apapa port which is the largest maritime port in Africa. The study area comprises major markets like Alaba International Market, Trade Fair Complex, Dangote Oil Refinery, Lagos State University (LASU), 81 Naval Command, Administrative Staff College of Nigeria (ASCON) and other important economic entities. The huge Lagos population and the burgeoning economy are supported by sand markets that are majorly concentrated along the coastal regions of the state. Most of the sand dredging is done in the Creeks.

![Fig.1 The study area (Source: Authors, 2021)](image)

| LGA          | Population from 1991–2016 | Areas covered in Square km |
|--------------|---------------------------|---------------------------|
|              | 1991  | 2006  | 2016  |          |
| Amuwo-Odofin | 225,823 | 318,166 | 453,000 | 134.6   |
| Badagry      | 119,267 | 241,093 | 327,400 | 393.9   |
| Eti-Osa      | 157,387 | 287,785 | 390,800 | 192.3   |
| Ojo          | 215,837 | 598,071 | 838,900 | 158.2   |

*Table 1* Population of the Study area. *Source: NBS (2016) [http://www.citypopulation.de](http://www.citypopulation.de)*
and the Lagoon edges that abut the communities. Traditionally, the residents are fishermen and farmers, but have in recent decades turned to sand mining as means of livelihood. The sand mining activity is common in all communities that share boundaries directly with the Atlantic Ocean and the Lagoon. Fourteen (14) of these communities namely Ajido, Topo, Gberefu in Badagry; Otto, Era, Ijede, and Muwo in Ojo; Abule-Osun, Imore and Ijegun in Amuwo-Odofin; Sangotedo, Ajah, Ilaje and Ikota in Eti-Osa were covered in the study (See Figs. 2, 3, 4, 5, 6, 7).

**Materials and methods**

Research design and data collection

The study was a perceptive cross sectional survey based research which employed quantitative analytical frameworks (see Fig. 8). The study used primary data drawn from a field survey of the selected coastal communities and sand miners using a structured questionnaire with appropriate design. Secondary data including population figures, base maps of the region were procured from the Lagos Ministry of Environment, Alausa. In addition, an in-depth survey (IDS) was conducted on the sand miners. The research instrument—the structured questionnaire—contained two sections. Section A consisted of drivers of the sand mining; Section B comprised questions on the socio-environmental impacts of sand mining in Lagos. In total, 31 variables covering sand mining drivers and socio-environmental impacts were employed to describe sand mining activities in Lagos. The variables were coded as ordinal variables and measured using 5-point-Likert scale. Data on sand mining operations were collected using nine (9) variables including

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**Fig. 2** Sand mining at Gberefu in Badagry (*Source*: authors, 2021)

**Fig. 3** Sand mining at Otto in Ojo (*Source*: Authors, 2021)

**Fig. 4** Sand mining at Era in Ojo (*Source*: authors, 2021)
operational status, scale of operation, years in operation, machinery used, number of workers, tons of sand dredged, number of trucks, operational charges paid to government and operational charges paid to community leaders.

Sampling procedures

The field work for primary data collection was conducted between November 2020 and January 2021. The Cochran (1953) equation for sample size estimation was used to yield a representative sample of 420 for the population of the study area as presented in Eq. 1 below:

$$ s = \frac{Z^2 \cdot p(1 - p)}{e^2} \quad (1) $$

where $S$ represents sample size; $Z$ represents the value at 95% confidence levels usually 1.96; $p$ is the proportion of the target population that could be surveyed usually 50%; $e$ represents the error margin 5%. The equation parameters ordinarily gave a sample of 384 respondents which were rounded off to 420 respondents to allow for shortage due to loss and non-retrieval of questionnaire.

Multisampling procedure was used to select the respondents. Firstly, four (4) Local Government Areas out of nine (9) Local Government Areas along the Atlantic Ocean with numerous coastal communities where sand mining activities are thriving—BADAGRY, OJO, AMUWO-ODOFIN and ETIOSA—were selected as the sampling units for the study. Secondly, as displayed in Fig. 7 and Table 2, fourteen (14) coastal communities/neighborhoods were selected such that 3 neighborhoods were selected in Badagry, 4 neighborhoods were selected in OJO, 3 neighborhoods were from Amuwo-Odofin and 4 neighborhoods from ETIOSA (see Table 2). Thirdly, in each selected neighborhood 30 respondents were randomly given structured questionnaires to fill. All together 420 respondents were interviewed with the questionnaire. Additionally, one sand miner in each sand mining site participated in IDS on sand mining operations. However, 350 copies of the questionnaire (83.3%) were retrieved for analysis.

Analytical techniques

The data collected were organized, coded and computed using Statistical Package for Social Sciences (SPSS) version 22.0. As indicated in Fig. 8 the study used a number of statistical and geo-spatial techniques for analysis of data. Firstly, the descriptive statistics such as frequencies and percentages derived from the analysis were presented in tables and charts to describe and organize information on various issues addressed by the study objectives. Secondly, the multivariate statistical techniques such as Chi-square $\chi^2$ and Analysis of Variance (ANOVA) were used to estimate significant differences in variables of interest across sand mining locations and communities. Also factor (principal component) analysis was used to group the main drivers and impacts of sand mining activity in the region. To facilitate the factor and ANOVA analyses the variables were normalized so that they assumed
Fig. 6  Sand mining at Ijegun in Amuwo-Odofin (Source: Authors, 2021)

Fig. 7  The sampling units (Source: Authors, 2021)
normal distribution—as a condition for using the multivariate statistics (see Gondo et al., 2019).

Ethical considerations

The study employed and considered all ethical issues in research as stipulated in the LASU Research Policy 2020. The respondents were well informed of the purpose of the study, the voluntary participation, the anonymity of respondents and confidentiality of their responses. Due to the COVID-19 pandemic the field assistants and respondents were asked to observe all the protocols.

Fig. 8 Research design (Source: Authors, 2021)
Results

Sand mining sites and operational characterization in Lagos

Sand mining activities in the coastal communities of Lagos displayed some regularity. Analysis of sand mining operations across 14 mining sites based on operational status, scale of operation, years in operation, machinery used, number of workers, mass of sand dredged, number of trucks, operational charges paid to government and operational charges paid to community leaders revealed some puzzling facts about coastal mining activities in Lagos (see Figs. 9, 10, 11).

Information on Figs. 9a, b, and 10a, b shows that majority of the sand miners are formally registered with relevant government agencies, they are majorly small scale operators and they have been in operation for very long time. The implication of these findings is that sand mining activities in Lagos coastal zones are well organized and perhaps controlled by the relevant environmental and official agencies in the state. Sand mining is a thriving business along the coastal region of Lagos and this vocation has become an economic livelihood matter with different social and economic underlying interests.

As indicated in Fig. 11a sand mining is a major labor employer as majority of the mining outfits employed more than 11 people each with different skills and capacities including engineers, local divers, unskilled dredgers, and loaders. The multiplier effects of mining activities also make the participation of other groups such as drivers, and truck pushers relevant in the business. The second graph Fig. 11b also shows that the mass of sand dredged daily in Lagos coastal areas is huge. Majority of the observed sites dredged over 16 tons of sand per day. Figure 11c shows that most of the sites uploaded between 10 and 20 trucks of sand daily. This is a huge extraction from the coastal region of Lagos.

Since sand mining in Lagos has become more of a livelihood and an economic concern, the activity has been a source of revenue to both government and groups. In order to establish the involvement of community and government in sand mining activity in the state the charges paid by the sand mining entrepreneurs were investigated and analysis as indicated in Fig. 12a, b show that they paid different amounts of money depending on the scale of operation to both governments and the community leaders. Three tiers of government in Nigeria that are involved in land and water resources collect money from sand miners. The federal government represented by the National Inland Waterways Agency (NIWA),2 the State government represented State Inland Waterways Agency (SIWA) and the Local Government Area collect money from these sand miners regularly.

Although we found it difficult extracting the actual fees paid to these tiers of government evidence shows that all tiers of government collect certain yearly dues from the operators. Also the local community leaders under the suzerainty of the ‘Oba or Baale’ collect as a pre-condition for operation an undisclosed sum of money for peaceful operation within the coastal area adjoining their territories. In fact, the emerging facts about sand mining activities in Lagos indicate that both formal and informal agencies are being settled regularly to keep the activity going.

Table 2 Sampling of respondents for survey

| SN | Community  | Neighborhood                  | Questionnaire administered | Questionnaire retrieved |
|----|------------|-------------------------------|----------------------------|-------------------------|
| 1  | Badagry    | Ajido, Gberefu & Topo         | 90                         | 72                      |
| 2  | Ojo        | Otto, Era, Muwo & Ijede       | 120                        | 92                      |
| 3  | Amuwo-odofin | Abule-Osun, Imore & Ijegun   | 90                         | 80                      |
| 4  | Etiosa     | Sangotedo, Ajah, Ilaje & Ikota| 120                        | 106                     |
| Total | 4   | 14                            | 420                        | 350                     |

2 NIWA issues licenses for inland navigation, piers, jetties and dockyards; examines and surveys inland watercraft and shipyard operators, grants permit and licenses for sand dredging, pipeline construction, dredging of slot and approves designs and construction of inland river crafts.
Drivers of sand mining in coastal areas of Lagos

Table 3 consists of results on the drivers of sand mining activities in the coastal communities of Lagos. There are thirteen (13) variables that drive sand mining in Lagos and these include job sources, marginal plain, livelihood, economic gain, economic viability, revenues and taxes, housing development, urbanization, community support, syndicate and groups, concealment, government policy and poverty alleviation. Particularly from Table 3, it is very clear that community support (M = 4.42), syndicate group (M = 4.27), housing development (M = 4.20), urbanization (M = 4.17) and revenues for government (M = 4.11) constituted the major drivers of sand mining activities in Lagos. Other very important variables include livelihood (M = 3.83), economic gain (M = 3.90), viability (M = 3.57), marginal plain (M = 2.83) and Job sources (M = 2.65). Of course, the least drivers of sand mining were marginal plain, government policy, and job opportunities.
According to Table 3 it is very clear that community support, syndicate, poverty alleviation and government support are major drivers of sand mining activities in Lagos. Variation also exists among the communities in terms of their perception of the drivers of sand mining. As could be seen in Table 4, there were significant differences in the means of the drivers of sand mining among the four communities as most of F-test values were significant at \( p < 0.05 \). However, the exception was syndicate with F-test 2.492 at \( p = 0.06 \) which was marginally insignificant at 95% confidence level.

Due to the multiple variables or indicators of drivers of sand mining, we further analyzed the data using principal component analysis (PCA) which helped to reduce and re-order the indicators into smaller but more meaningful components. Table 5 shows the results from the PCA analysis of the factors. From this table it is glaring that the 13 drivers of sand mining could be summarized into four (4) major components. The first component tagged URBAN HOUSING was extracted from six variables namely housing development, urbanization, syndicate, community support, concealment and revenues. The first component accounted for 32.60% of the variance in the data. The second extracted component was captioned LIVELIHOOD because three variables namely economic viability, economic gain and livelihood loaded strongly on it and the component accounted for 12.87% of the total variance.
The third extracted component was JOB primarily because the variables that loaded highly on the component namely job and marginal plain are related to the ecological conditions of the areas. The component accounted for 10.71% of the variance. The fourth component extracted was captioned POLICY because the two highly loaded variables policy and poverty alleviation are related to government policy. This component actually accounted for 8.25% of the total variance. All the four components accounted for 64.43% of the variance. Hence, the whole 13 sand mining drivers-variables could be summarized by just 4 uncorrelated components which give greater clarity and understanding of the urbanization related drivers of sand mining in the coastal regions of Lagos.

Socio-environmental impacts of sand mining in Lagos coastal regions

Table 6 consists of results on the socio-environmental impacts of sand mining activities on the immediate communities. Accordingly, eighteen (18) variables...
were put to the residents to evaluate their opinions on the negative impacts of sand mining on the society and the built environment. Results showed that in terms of negative impacts dredging was the major cause of noise, public health, road damage, erosion in the coastal communities of Lagos. From Table 6 it is very clear that these five variables with mean ranging from 4.2286 to 3.6029 summarized the worst effects of dredging in Lagos. Of course, the least effects of sand mining were on farm, vegetation, water and animals. The order of impacts between the communities is only tenuous as in most of the communities’ noise, public health; road damage and erosion had very high mean values compared to other environmental variables.

A cursory look at Table 6 again shows that the mean values of the impact variables across communities varied although the first five variables of noise, dust, road, erosion and flood were quite high enough compared to other variables like crops, animals, water and vegetations with low mean values. Analysis of variance in Table 7 however shows that the environmental impacts of sand mining varied across locations significantly. Apart from erosion, flood and land value all other variables displayed significant variation across the four locations. This simply implies that the respondent perceptions of environmental impacts of sand mining are not the same. This inference confirms variations in the means of their perceptions of sand mining impacts as displayed in the earlier table.

However, for the multiple variables or indicators of socio-environmental impacts of sand mining, we

| Drivers variable       | Sources of variation | Sum of squares | DF | Mean square | F-test | Sig  |
|------------------------|----------------------|----------------|----|-------------|--------|------|
| Job                    | Between groups       | 39.922         | 3  | 13.307      | 6.639  | .000 |
|                        | Within groups        | 693.553        | 346| 2.004       |        |      |
| Marginal plain         | Between groups       | 40.690         | 3  | 13.563      | 9.716  | .000 |
|                        | Within groups        | 483.024        | 346| 1.396       |        |      |
| Livelihood             | Between groups       | 73.594         | 3  | 24.531      | 17.927 | .000 |
|                        | Within groups        | 473.461        | 346| 1.368       |        |      |
| Economic gain          | Between groups       | 14.937         | 3  | 4.979       | 3.994  | .008 |
|                        | Within groups        | 431.360        | 346| 1.247       |        |      |
| Viability              | Between groups       | 25.538         | 3  | 8.513       | 6.621  | .000 |
|                        | Within groups        | 444.831        | 346| 1.286       |        |      |
| Revenues & taxes       | Between groups       | 57.879         | 3  | 19.293      | 19.519 | .000 |
|                        | Within groups        | 341.995        | 346| .988        |        |      |
| Housing                | Between groups       | 21.190         | 3  | 7.063       | 9.494  | .000 |
|                        | Within groups        | 257.407        | 346| .744        |        |      |
| Urbanization           | Between groups       | 35.558         | 3  | 11.853      | 19.090 | .000 |
|                        | Within groups        | 214.830        | 346| .621        |        |      |
| Community support      | Between groups       | 9.782          | 3  | 3.261       | 4.123  | .007 |
|                        | Within groups        | 273.635        | 346| .791        |        |      |
| Syndicate group        | Between groups       | 5.420          | 3  | 1.807       | 2.492  | .060 |
|                        | Within groups        | 250.869        | 346| .725        |        |      |
| Government policy      | Between groups       | 21.324         | 3  | 7.108       | 5.723  | .001 |
|                        | Within groups        | 429.773        | 346| 1.242       |        |      |
| Concealment            | Between groups       | 10.368         | 3  | 3.456       | 2.759  | .042 |
|                        | Within groups        | 433.429        | 346| 1.253       |        |      |
| Poverty                | Between groups       | 12.936         | 3  | 4.312       | 2.976  | .032 |
|                        | Within groups        | 501.361        | 346| 1.449       |        |      |
Table 5  PCA of drivers of sand mining activities in Lagos. Source: Fieldwork, 2021

| Drivers variable | Component | C1-urban housing | C2-economic livelihood | C3-job suitability | C4-policy | Communality | Mean  |
|------------------|-----------|------------------|------------------------|--------------------|-----------|-------------|-------|
| Housing          |           | 0.790            | 0.363                  | -0.056             | 0.018     | 0.759       | 4.2029|
| Urbanization     |           | 0.775            | 0.361                  | -0.149             | 0.008     | 0.753       | 4.1657|
| Syndicate group  |           | 0.762            | -0.003                 | 0.182              | 0.127     | 0.630       | 4.2657|
| Community support|           | 0.757            | 0.098                  | 0.123              | -0.230    | 0.651       | 4.4229|
| Concealment      |           | 0.643            | 0.105                  | -0.045             | 0.213     | 0.472       | 3.6029|
| Revenue and taxes|           | 0.506            | 0.470                  | -0.133             | -0.263    | 0.564       | 4.1086|
| Viability        |           | 0.101            | 0.800                  | 0.087              | 0.095     | 0.667       | 3.7457|
| Economic gain    |           | 0.189            | 0.783                  | 0.069              | 0.098     | 0.644       | 3.8971|
| Livelihood       |           | 0.196            | 0.678                  | 0.229              | -0.182    | 0.684       | 3.8314|
| Job              |           | 0.019            | 0.125                  | 0.822              | 0.163     | 0.719       | 2.6514|
| Marginal plain   |           | -0.008           | 0.102                  | 0.816              | -0.072    | 0.681       | 2.8296|
| Government policy|           | -0.111           | -0.040                 | -0.050             | 0.812     | 0.677       | 2.2971|
| Poverty          |           | 0.363            | 0.083                  | 0.214              | 0.608     | 0.554       | 3.8171|
| Eigen value      |           | 4.24             | 1.67                   | 1.39               | 1.07      |             |       |
| % variance explained |       | 32.60           | 12.87                  | 10.71              | 8.25      |             |       |
| % total variance exp |     | 32.60           | 45.47                  | 56.18              | 64.43     |             |       |

Table 6  Descriptives of socio-environmental impacts of sand mining. Source: Fieldwork, 2021

| Impact variable       | Min | Max | Total mean | Badagry mean | Ojo mean | Amuwo mean | Etiosa mean |
|-----------------------|-----|-----|------------|-------------|----------|------------|-------------|
| Impact on noise       | 1.00| 5.00| 4.2286     | 3.8451      | 4.0753   | 4.3250     | 4.5472      |
| Impact on dusts       | 1.00| 5.00| 3.9571     | 3.8732      | 3.5161   | 3.8250     | 4.5000      |
| Impact on roads       | 1.00| 5.00| 3.9029     | 3.6761      | 3.7419   | 4.3500     | 3.8585      |
| impact on erosion     | 1.00| 5.00| 3.6257     | 3.4930      | 3.7849   | 3.4625     | 3.6981      |
| Impact on flood       | 1.00| 5.00| 3.6029     | 3.4085      | 3.7742   | 3.5125     | 3.6509      |
| Impact on terrain     | 1.00| 5.00| 3.2314     | 3.6479      | 3.3441   | 3.2625     | 2.8302      |
| Impact on landslide   | 1.00| 5.00| 3.1200     | 3.4648      | 3.2258   | 2.9875     | 2.8962      |
| Impact on fishing     | 1.00| 5.00| 3.0486     | 3.2535      | 3.4409   | 2.4625     | 3.0094      |
| Impact on traffic     | 1.00| 5.00| 2.8600     | 2.8169      | 2.0000   | 2.7375     | 3.7358      |
| Impact on land value  | 1.00| 5.00| 2.8457     | 3.0845      | 2.6237   | 2.7750     | 2.9340      |
| Impact on geology     | 1.00| 5.00| 2.7371     | 3.4648      | 2.7204   | 2.3250     | 2.5755      |
| Impact on housing     | 1.00| 5.00| 2.7257     | 2.8732      | 2.4194   | 2.6645     | 2.9434      |
| Impact on crops       | 1.00| 5.00| 2.5029     | 3.2394      | 2.6882   | 1.7750     | 2.3962      |
| Impact on farm        | 1.00| 5.00| 2.4743     | 3.2958      | 2.3763   | 1.9250     | 2.4245      |
| Impact on deforestation| 1.00| 5.00| 2.4714     | 3.0423      | 2.3978   | 2.0250     | 2.4906      |
| Impact on vegetation  | 1.00| 5.00| 2.4486     | 3.2817      | 2.3548   | 1.9125     | 2.3774      |
| Impact on water       | 1.00| 5.00| 2.4114     | 2.8592      | 2.5376   | 2.0625     | 2.2642      |
| Impact on animals     | 1.00| 5.00| 2.3714     | 3.2394      | 2.4731   | 1.6875     | 2.2170      |
further analyzed the data using principal component analysis (PCA) which helped to reduce and re-order the indicators into smaller but more meaningful components. Table 8 shows the results from the PCA analysis of the indicators. From this table it is glaring that the 18 indicators of sand mining impacts could be reduced to 4 major impact components. The first component tagged LIVELIHOOD IMPACT was from eight primary variables of crops, animals, farming, geology, deforestation and fishing. This first component accounted for 32.22% of the variance in the data. The second extracted component was

Table 7 ANOVA of socio-environmental impacts of sand mining. Source: Fieldwork, 2021

| Impact variable          | Sources of variation | Sum of squares | DF  | Mean square | F-test | Sig |
|--------------------------|----------------------|----------------|-----|-------------|--------|-----|
| Impact on fishing        | Between groups       | 45.484         | 3   | 15.161      | 7.508  | .000|
|                          | Within groups        | 698.690        | 346 | 2.019       |        |     |
| Impact on farming        | Between groups       | 716.93         | 3   | 23.898      | 15.381 | .000|
|                          | Within groups        | 537.575        | 346 | 1.554       |        |     |
| Impact on water          | Between groups       | 27.317         | 3   | 9.106       | 5.274  | .001|
|                          | Within groups        | 597.437        | 346 | 1.727       |        |     |
| Impact on vegetation     | Between groups       | 72.132         | 3   | 24.044      | 14.533 | .000|
|                          | Within groups        | 572.442        | 346 | 1.654       |        |     |
| Impact on terrain        | Between groups       | 29.785         | 3   | 9.928       | 5.721  | .001|
|                          | Within groups        | 600.469        | 346 | 1.735       |        |     |
| Impact on erosion        | Between groups       | 7.319          | 3   | 2.440       | 1.208  | .307|
|                          | Within groups        | 698.650        | 346 | 2.019       |        |     |
| Impact on flood          | Between groups       | 7.538          | 3   | 2.513       | 1.249  | .292|
|                          | Within groups        | 696.260        | 346 | 2.012       |        |     |
| Impact on landslide      | Between groups       | 16.032         | 3   | 5.344       | 2.949  | .033|
|                          | Within groups        | 626.928        | 346 | 1.812       |        |     |
| Impact on deforestation  | Between groups       | 39.986         | 3   | 13.329      | 10.452 | .000|
|                          | Within groups        | 441.229        | 346 | 1.275       |        |     |
| Impact on crops          | Between groups       | 85.344         | 3   | 28.448      | 20.330 | .000|
|                          | Within groups        | 484.153        | 346 | 1.399       |        |     |
| Impact on animals        | Between groups       | 93.116         | 3   | 31.039      | 25.656 | .000|
|                          | Within groups        | 418.598        | 346 | 1.210       |        |     |
| Impact on geology        | Between groups       | 52.387         | 3   | 17.462      | 13.037 | .000|
|                          | Within groups        | 463.431        | 346 | 1.339       |        |     |
| Impact on noise          | Between groups       | 25.128         | 3   | 8.376       | 6.460  | .000|
|                          | Within groups        | 448.586        | 346 | 1.296       |        |     |
| Impact on traffic        | Between groups       | 152.407        | 3   | 50.802      | 24.355 | .000|
|                          | Within groups        | 721.733        | 346 | 2.086       |        |     |
| Impact on dusts          | Between groups       | 50.740         | 3   | 16.913      | 9.537  | .000|
|                          | Within groups        | 613.618        | 346 | 1.773       |        |     |
| Impact on housing        | Between groups       | 15.941         | 3   | 5.314       | 3.511  | .016|
|                          | Within groups        | 523.727        | 346 | 1.514       |        |     |
| Impact on land value     | Between groups       | 9.093          | 3   | 3.031       | 2.030  | .109|
|                          | Within groups        | 516.575        | 346 | 1.493       |        |     |
| Impact on roads          | Between groups       | 22.561         | 3   | 7.520       | 3.895  | .009|
|                          | Within groups        | 668.136        | 346 | 1.931       |        |     |

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captioned ENVIRONMENTAL QUALITY IMPACT because four primary variables namely erosion, flood, landslide and terrain constituted environmental risks to the communities and the component accounted for 12.24% of the total variance.

The third extracted component was PUBLIC HEALTH IMPACT primarily because the variables that loaded highly on the component namely dusts, noise, road damage and traffic constitute public health issues. The component accounted for 10.66% of the variance. The fourth component extracted was captioned REAL PROPERTY IMPACT because the two highly loaded variables housing and land value are related to the real estate. This fourth component actually accounted for 6.78% of the total variance. All the four components accounted for 61.90% of the variance which was over two-third of the total variance. With these 4 components the sustainability related impacts of sand mining activities in the study area were better understood.

**Discussion and implications for sustainability**

The puzzling facts about sand mining globally are its indispensability for urbanization and its risk to environmental sustainability (Gavriletea, 2017). This double-edge nature of sand mining creates a socio-environmental dilemma that requires cautious analysis. Interestingly, this study revealed that sand mining activity in Lagos was driven by urbanization forces such as urban housing, road and bridge construction, livelihood, job and government policy. However, sand mining in Lagos had several negative social and environmental impacts including noise, dusts, road destruction, deforestation, livelihood change, land degradation, flooding, erosion, threat to buildings and water pollution on the built environment in the coastal areas of Lagos. In addition sand mining negatively impacted fishing, farming and water quality in the study area. These negative socio-environmental externalities of sand mining in the coastal regions of Lagos.
Lagos are summarized into four namely livelihood, environmental quality, public health and real-property impacts. While sand mining is driven by urbanization factors the vocation undermines sustainability in the coastal region of Lagos.

Of course, these findings relate with existing studies in Ghana, Malaysia, India and Tanzania (Mensah, 1997; Masalu, 2002; Akabzaa, 2009; Asabonga et al., 2017; Asraf et al., 2018). In Ghana for instance, sand mining activity has led to reduction of farmlands and consequently livelihood security problems (Musah, 2009; Peprah, 2013). Reduced farmlands bring about economic hardships mostly because the affected people are usually given inadequate compensations (Abuodha & Hayombe, 2006). The activities of sand mining also lead to the destruction of public properties such as roads, electricity poles, telephone masts, underground pipes, and other social amenities which support people’s livelihoods (Collins & Dunne, 1990; Viswanathan, 2002; Saviour, 2012). Sand mining activity further weakens the livelihood foundation of people because it brings about land use conflicts due to its numerous negative externalities (Willis & Garrod, 1999; Rodriguez et al., 2006; Turner & Lambin, 2007). While many studies have been conducted on the physical impacts of sand mining activities in Lagos, however, the present study has clearly extended the knowledge on the nature, drivers and socio-environmental impacts of mining from the perspectives of the residents living around the coastal areas. This is an important contribution to our understanding of the complex socio-environmental nature of sand mining as both a vocation and an environmental sustainability issue.

The outcomes of this study have some policy and practical implications for housing and environmental sustainability. On the one hand, sand mining activity has supported implicitly the housing sector as the demand for sharp sand dredged mainly from the sea bed serves to advance the course of urbanization, real estate and the built environment development in Lagos megacity. The urban built environment and the housing industry depend on the sharp sands extracted from the Creeks and Ocean. Access to cheap sand lessens the cost of housing construction, provides opportunities for achieving affordable housing and precludes housing deprivation in the long run. For individual housing, public residential estates and developer property estates, sand is needed and extracted from the coastal areas of Lagos. The Lagos EKO ATLANTIC city was built on the reclamation by the sand drawn from the coast of Atlantic. Many other real estate projects, overhead bridges, road networks across the Lagos metropolitan area are supported by the coastal sand. The sand market generates great profits from urban constructions and property developments and cheaper source of sand to the local residents. On the other hand, sand mining compromises environmental sustainability as the high mass of sand being daily dredged in this region is a source of concern for environmentalists, environmental planners, local residents and other stakeholders in the built environment. Sand dredging in Lagos coastal areas is largely responsible for the loss of habitats for fishes and sea turtles, perennial flooding, coastal erosion, road damage, deforestation, water pollution, noise, dusts, land devaluation and loss of livelihoods.

Conclusions

The goal of this study was to give a socio-environmental analysis of sand mining activities in the coastal areas of Lagos. This goal led to the formulation of four specific objectives which were to describe the operational modalities of sand mining activities in Lagos State, analyze the drivers of sand mining, analyze the socio-environmental impacts and give the implications of sand mining activities in the study area. From the analyses performed in the study using descriptive, ANOVA and PCA techniques, it was found that sand mining sites covered had formal registration with the NIWA and SIWA, operated in low profile, had been in operation for a long time, had over 11 workers each, extracted million tons of sand yearly and engaged a high number of trucks in their fleets. Sand mining had many negative social and environmental effects on the adjacent urban communities.

Given the externalities of sand mining in Lagos coastal communities, drastic measures to control the sand mining business in the areas are urgently required. At policy level, there is need for sincerity and openness in dealing with both illegal and poorly operated sand mining sites in Lagos. Although, majority of the operators claimed to have registered with the right agencies, there is no evidence that they properly carried out environmental impact assessment (EIA). The major stakeholders especially
governments need to intervene urgently to control and mitigate effects of sand mining activities on the immediate communities. Sand mining is a global legitimate vocation no doubt but needs standardization in Nigerian coastal vulnerable regions. There must be an increasing awareness on the measures for ensuring proper operation of sand mining that can guarantee sustainability in the coastal area of Lagos.

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Declarations

Conflict of interest Authors declare that there are no conflicts of interest.

Ethical approval The study employed and considered all ethical issues in research as stipulated in the LASU Research Policy 2020. The respondents were well informed of the purpose of the study, the voluntary participation, the anonymity of respondents and confidentiality of their responses. Due to the COVID-19 pandemic the field assistants and respondents were asked to observe all the protocols.

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