Impact of Sand and Gravel Dredging on the Environment

Etah Emmanuel Etah
Department Of Geography and Environmental Studies,
Ignatius Ajuru University Portharcourt Rivers State, Nigeria.

Akiang Joseph And Fidelis Ishoja
Department Of Geography, Federal College of Education,
Obudu Cross River State Nigeria.
DOI: 10.56201/ijgem.vol.11.no1.2025.pg90.101

Abstract

Sand and gravel dredging, driven by the global demand for construction materials, has significant environmental impacts on aquatic and terrestrial ecosystems. The extraction process disrupts habitats, particularly benthic ecosystems, leading to biodiversity loss and the degradation of ecosystem services. Dredging suspends fine sediments, reducing water quality and impairing photosynthesis in aquatic plants, which further destabilizes food chains. Coastal and riverside areas face increased erosion as sediment transport is altered, threatening flood defenses and exacerbating the effects of climate change. Socioeconomic consequences also arise, as communities reliant on fisheries and tourism suffer from environmental degradation. This paper highlights the ecological, hydrological, and socioeconomic impacts of sand and gravels dredging and calls for sustainable practices and stronger regulatory frameworks to mitigate these adverse effects.

Introduction

Sand and gravel dredging, a critical activity supporting the construction industry, plays a vital role in infrastructure development worldwide. These materials are essential for making concrete, asphalt, and glass, driving their high demand in rapidly urbanizing regions (Peduzzi, 2014). However, the environmental impacts of this dredging are profound and multifaceted, affecting both aquatic and terrestrial ecosystems. Dredging operations, which involve the extraction of sediment from riverbeds, lakes, and coastal areas, can cause significant disruption to natural habitats, leading to biodiversity loss, water quality degradation, and the alteration of hydrological processes (Kondolf, 1997). One of the most immediate environmental consequences of dredging is the destruction of benthic habitats. These habitats are critical for various aquatic species, providing feeding, breeding, and sheltering grounds. The removal of sediment not only directly affects these species but also destabilizes food chains and ecosystem services (Wright & Phillips, 2016). Additionally, dredging often results in the suspension of fine sediments, creating sediment plumes that reduce water clarity. This reduction in water transparency limits the ability of aquatic plants to perform photosynthesis, further impacting the ecosystem's health (Newell, Seiderer, & Hitchcock, 1998). Moreover, dredging can release harmful pollutants trapped in the sediment, contributing to water contamination and threatening both aquatic life and human populations (Apitz & Brils, 2004).

Coastal and riverbank erosion is another significant consequence of sand and gravel dredging. By removing sediment that would naturally replenish shorelines, dredging accelerates erosion processes, weakening natural defenses against storm surges and floods (Syvitski et al., 2009). This exacerbates the vulnerability of coastal communities, especially in the context of rising sea levels and increasing storm intensity due to climate change (Ericson et al., 2006). Furthermore, changes in sediment transport disrupt natural hydrological systems, leading to sedimentation in areas where it is not needed, while leaving other regions deprived of necessary sediments (Kondolf, 1997). The socioeconomic impacts are equally significant. Communities that depend on fishing, agriculture, and tourism suffer from the environmental degradation caused by dredging. The depletion of fish stocks due to habitat loss and water contamination, along with the erosion of coastal tourist areas, undermines local economies and the livelihoods of many (Tubb, 2003). Without adequate regulation, these adverse effects will continue to compound, threatening both environmental sustainability and human welfare.

Given the scale of the global dredging industry, it is crucial to address its environmental and social impacts. This paper will explore the ecological consequences of sand and gravel dredging, including habitat destruction, biodiversity loss, water quality degradation, and erosion. It will also discuss the importance of sustainable dredging practices and stronger regulatory frameworks to mitigate these effects and promote long-term environmental stewardship.

Sand and Gravel Dredging Globally

Sand mining and gravel extraction are a worldwide activity in both developed and developing countries as was realized by Draggan (2008). Industrial sand and gravel are produced, processed and used in construction industries all over the world. The leading nations in mining and processing sand and gravel are United States of America, Australia, Austria, Belgium, Brazil, India, Spain, Nigeria, Kenya and South Africa. As a cheap and readily accessible resource, many companies are involved in its mining both legally and illegally without considering the damage they are causing to the environment (Draggan, 2008).

Sand mining and gravel extraction is a common activity in United States of America. A publication by Schaetzl (1990) showed that historically, from 1920s many states in USA relied on mining of gravel and sand for road and cement aggregate. The uses had doubled by 2008 to date. Sand and gravel are mined more than all other minerals in most States in America. According to Draggan (2008), USA is the largest producer and consumer of sand and gravel in the world as well as the leading exporter of silica sand to every region of the world. This is because it has extensive high quality deposits of the resource combined with technology to process it into any product.

Construction sand and gravel are produced in all states. The highest producers are California, Texas, Michigan, Minnesota, Ohio, Arizona, Utah, Colorado and Washington. They all produce about 52% of total amount of construction sand and gravel.

More than a billion tons of sand and gravel are produced and used annually. Due to high demand in these States, some sand and gravel are still imported from Canada, Mexico, Bahamas, and Australia (Draggan, 2008). Schaetzl (1990) realized that in California and Michigan, many prime sources of sand and gravel are glacial deposits, eskers, deltaic deposits and old lake beds. These states have an abundant of sand and gravel which are well distributed. Many minerals are mined but sand and gravel are extracted most. Sand and gravel have been exhausted, and the area is now covered by housing developments and farmland. Schaetzl (1990) further noted that river sand; pit sand and gravel are mined around large expanding urban areas. The most urbanized and largest states have greatest areas of sand and gravel pits. The chart below shows that about 58000 acres of land is used to mine sand and gravel which is more compared to all other minerals mined Stebbins (2006) highlighted that in State of Maine, sand and gravel deposits cover up to five percent of the land. The resources are mainly used in construction and pumping drinking water which had increased demand so there are many sand and gravel pits. Approximately two hundred and sixty acres of land is used for mining by both companies with and without licenses. Construction grade sand and gravel has high volume, hence the resources cannot be transported over long distance. Large trucks are used as transport for up forty eight kilometers; therefore most pits are near the consumer as these bulky commodities normally cannot economically stand costs of long distance transportation. Most mining is done near the consumer in USA. The once abundant supply of gravel and sand is rapidly diminishing in areas surrounding cities (Stebbins, 2006). Schaetzl (1990) noted that there are four basic operations used to extract sand and gravel from open pit mines in USA. The operations include site clearing to remove vegetation, then mining, processing and finally reclamation of the mined area. Machinery commonly used for mining includes bulldozers, tractor scrapers, front end loaders and stone crushers. The mining is done almost twenty four hours in order to keep up with the high demand internally and externally for sand and gravel (Schaetzl, 1990).

According to Goddard (2007) soil mining operations began in 1930s in Australia to supply the expanding Sydney building market and continued into 1990s with an estimate of seventy million tons of sand removed. Most important commercial sources of sand and gravel are river floods, river channels and glacial deposits. Goddard (2007) further noted that soil extraction and processing have significant impacts on scenic landscapes. Excessive extraction intensifies coastal and exposed hillside erosion, causing accumulation of seawater upstream of rivers, leaving the coasts more vulnerable to extreme weather conditions. Soil mining contributes to construction of buildings and development but can cause permanent loss of soil as well as major habitat destruction (Goddard, 2007).

Sand and Gravel Dredging in Africa

There is a great concern on the way the environment is disturbed by excessive removal of soil for construction industry especially in urban development in Africa. Mwangi (2008) noted that for thousands of years, sand and gravel had been used to construct strong houses, roads and dams in Africa since they are cheap and readily accessible resources. Today demand has increased as socio-economic life of Africans has improved generally. Sand mining and gravel extraction are common in most African states but done both legally and illegally. Lawal (2011), examined sand and gravel mining activities both on land and in rivers as a business venture in Minna Emirate Council of Niger State. Stakeholders from the mining activities were listed as landowners of quarry sites who sold the sand and gravel to private and government contractors. Local government authorities and Niger State where quarries are located were also listed as beneficiaries. The activities also involve farmers, whose cultivating and grazing lands are destroyed, wildlife community whose habitats are mined areas, aquatic community members as well as miners themselves.

Aromolaran (2012) carried out a study to examine effects of sand mining activities on rural people living on agricultural land in Ogun State, Nigeria. Many people supported the good uses of sand but the negative impacts on their land were more than the benefits. Lawal (2011) highlighted that sand mining is rapidly becoming an ecological problem as demand increases in many states of Nigeria's industry and construction sectors. The mining is done both legally and illegally leading to environmental devaluation. Mwangi (2007) discussed soil mining as a threat to the environment in Kenya though with both positive and negative impacts. The sand mining and gravel extraction are done legally and illegally on rivers, beaches and plain fields.

Wachira (2009) supported Mwangi by reporting on a case study survey on sand mining in Machakos District of Kenya which is increasing due to the need for soil in construction industry. The survey showed that approximately two hundred thousand tones of soil are harvested and mined for construction every year. Streams around Machakos and Mwala Districts are seriously damaged as trucks transporting soil pass along Mombasa and Thika highways. However, sand mining has not been a common business in Zimbabwe Lupande (2012). Similarly, in Nigeria, unregulated sand mining activities along rivers such as the Ogun and Niger have caused water pollution, reduced biodiversity, and disrupted agricultural livelihoods (Omolu & Adebayo, 2018).

Positive Impact of Sand and Gravel Dredging

Sand and gravel had been a useful natural resource for thousands of years worldwide and are fundamental to human existence. Today, demand for sand and gravel has increased. Mining operators in conjunction with resource agencies need to work hard and make sure the extraction is done responsibly. Schaetzl (1990) discussed sand and gravel as crucial resources to economic development activities when making aggregate in United States of America. Development is a process of adding improvements to a piece of land such as grading, drainage and access roads. Schaetzl defined aggregate as a substance made from several materials such as river sand and gravel. Pit sand is mixed with cement to form concrete, mortar and plaster for construction of strong structures. Aggregate is used to make road bases and coverings, concrete products and shoreline protection. Mining of sand and gravel had been done for road and cement aggregate for centuries worldwide.

According to Draggan (2008), 50% of sand and gravel mined in USA is used in construction to make concrete for roads, durable bricks, blocks, pipes construction fill and sometimes mixed with asphalt. In industry, 39% sand is used to make glass, 22% as foundry sand, 5% as abrasive sand while 34% is for other uses. Kondolf (2008) supported the use of active channel deposits (gravel and sand) as desirable for construction aggregates because they are durable, well sorted and frequently located near market and transportation routes. Besides, sand and gravel being useful resources in construction industry, they are useful tools in flood control and river stabilization, in aggrading rivers since most reservoirs are not aggraded in developed countries. Sand mining helps to de-silt rivers which contain a lot of sand (Chimbodza, 2012).

Puller (2009) discussed sand and gravel resources of Europe as large and their geographic distribution, requirements and environmental restrictions for some uses. The resources are mixed with bitumen to make roads, surfaces and gritting. Goddard (2007) viewed sand mining in Australia as important specifically in construction of buildings and economic development. Kuttipuran (2006) supported Goddard (2007) when he discussed the importance of sand and gravel in Indian economy as cheap and most accessible used in construction industry to build strong structures and road bases. Bagchi (2010) realized that sand and gravel are useful in landscaping projects which beautify gardens in India. Sand and gravel are important in construction and manufacturing industries when used in building, use glass foundry sand abrasive sand other uses 23 making glass, electronic chips and ceramics. Sand mining underpins the development engine, so without sand the construction industry will come to a halt (Pereira, 2012). Most African states are still developing and benefit from use of natural resources such as sand and gravel for economic development. Lawal (2011) indicated that Nigerians also benefit a lot from sand and gravel mining which results in building of quality permanent structures from aggregates. The demand for the resources increased in most Nigerian States by 1990s when individuals were getting schemes for home ownership such as increase in salaries and house loans which were easily accessible. Every citizen could afford to build a better house. This led to better socio economic life for rural people. In Kenya, soil mining had led to development of better infrastructure (Mwangi, 2007). This was supported by Mbaiwa (2008) as a positive impact of sand mining in Botswana where more land had been used to develop infrastructure in form of shopping malls and residential areas. Zimbabwe is not an exception in benefiting from sand and gravel through infrastructural development (Lupande, 2012). There is creation of employment for families at mining sites in Indian regions (Saviour, 2012).

Lawal (2011) noted that by year 2001 alone, a total of seven thousand, one hundred and thirty one sand and gravel miners had been employed in Nigeria’s Niger State alone, according to statistics provided by Mine Safety and Health Administration. Mwangi (2007) supported this positive impact of soil mining in Kenya when he highlighted that there is creation of employment to locals above eighteen years as manual loaders at mining sites. In Botswana, Mbaiwa (2008) realized the same impact of employment creation to youth, both citizens and non citizens seasonally at mining and construction sites to load tipper trucks. While in Zimbabwe, Lupande (2012) noted creation of employment for youth who are licensed to mine sand and some to load the trucks as a positive impact of mining. 24 Mining activities brought wealth to Indian communities (Saviour, 2012). Sand and gravel activities generate revenue and income to local governments and land owners in Africa's developing nations which reduce poverty. This was noted by Lawal (2011) in Niger State of Nigeria where financial benefits from mining work shows that local government earn about eight percent of total profits from business while the miner gets about ninety two percent of accrued revenue. Kenyan local government also benefits from soil mining as highlighted by Mwangi (2007), when legal miners are to pay for the licenses'

Negative Impact of Sand and Gravel Dredging

Sand and gravel are important natural resources in economic development worldwide but the continuous removal have adverse effects on the environment. Negative environmental impacts seem to outweigh positive effects in mining worldwide. Different negative impacts had been noted in United States of America due to in stream mining occurring in rivers and streams. Kondolf (2007) defined in stream mining as the mechanical removal of gravel and sand directly from an active channel. Forms of in stream mining such as pit excavation and bar skimming, causes bed degradation of rivers known as channel incision. The process occurs as head cutting or hungry water. When head cutting extraction is done on active channel, it lowers stream bed to create a nick point which steepens channel slope and increases flow energy.

Bagchi (2010) discussed environmental land and surface degradation as a serious impact of in stream mining on Indian rivers. There is damage to river banks and general ecosystems due to access ramps to riverbed. Soil erosion occurs as there is disturbance of groundwater and changes in river courses. Continuous removal of sand from river bed increases velocity of flowing water which erodes beds and banks. Kondolf (2007) noted that as the velocity increases, the river bed can propagate both upstream and downstream for many kilometres. This can lower alluvial water tables. Stebbins (2006) added that in stream sand mining causes destruction of aquatic and riparian habitat through large changes in channel morphology, lowered water table, instability and sedimentation at mining sites due to stock piling and dumping of excess mining materials.

Pereira (2012) revealed that sand mining is a threat to water security resulting from loss of groundwater storage due to lowering of alluvial water table. For example major rivers in India's Kerala district such as Pampa and Manimala have been lowered with four to six meters. If sand mining continues in India uncontrollably up to 2050, water table will drop to approximately 2537 square meters. A lowered water table due to mining leaves drinking water wells dry, and people starving. Suspended solids affect domestic water users downstream which increase treatment costs. Saviour (2012) also noted the deterioration of water quality due to dissolved suspended materials and solids from mining activities. Water 27 quality can also be compromised by oil spills and leakages from excavation machinery and transportation vehicles which may poison aquatic life

(Stebbins, 2006). Lawal (2011) supported Stebbins on that there are changes in channel morphology because of stream bank mining in Nigeria. Goddard (2007) indicated that gravel extraction and processing have significant negative effects on scenic landscapes. Too much mining intensifies coastal and exposed hillside erosion, accumulation of seawater up rivers, leaving coasts more vulnerable to extreme weather conditions. Pereira (2012) noted that there is decreased protection from sea water and shoreline erosion rates increases especially during ocean disasters when mining continues uncontrollably and unscientifically

Mitigation of Sand and Gravel Dredging on the Environment

The United Nations Conference on Environment and Development Report (2002), Agenda 21 advocates sustainable use of natural resources. Sustainable means ability to continue and be used for a long time. Goddard (2007) highlighted that man benefit from sand and gravel, as cheap and readily accessible resources for development, so there should be conservation and rehabilitation of these resources for future use. All governments worldwide should advocate for environmentally sustainable development. Kondolf (2007) discussed the importance of an environmental assessment management and monitoring program as part of extraction license in America. This is necessary to minimize negative impacts as mitigation and restoration strategy will be included. Monitoring regularly is important to ensure proper mining. Mitigation processes include minimizing extent of mining, repairing and rehabilitation of mines as well as replacement of resources. There is need for restoration and compensation of biotic integrity of ecosystems.

Most soil mining affect environment and India is inclusive as Savior (2012) noted that the country is 32 working hard to tackle negative impacts. The miners are supposed to draft an Environmental Management Plan (EMP) which ensures that potential impacts of projects are assessed and incorporated into early stages of development planning. The preparation of EMP had become a statutory requirement for granting permits in India. Clearance should be obtained from Department of Environment (DOE) and Ministry of Environment and Forests before permits are issued (Saviour, 2012). Kuttipuran (2006) suggested watershed restoration through replanting of riparian vegetation to replace large woody debris while conserving spawning gravel. This will re-establish ecological carrying capacity of the habitats, ecosystems and increase fish production.

Aromolaran (2012) recommended the planting of trees and shrubs that could help to regenerate degraded land and prevent erosion. People in rural areas must be educated on alternative resources to sand such as crushed stone as well as being involved in activities that are less degrading to agriculture land. Pereira (2012) also suggested use of crushed stone as alternative to conserve sand. The requirement of Environmental Management Authority (EMA) in Zimbabwe is to fill pits after mining, then plant trees and grass to minimize erosion. Land is leveled and growth of trees monitored until established as reclamation of land in Zimbabwe (Lupande, 2012). Stebbins (2006) noted that there is need to review potentially toxic sediment contaminants in or near streambed where gravel will be extracted while monitoring turbidity levels. There should be removal of in stream rough elements and sediments like debris, dumped far from rivers, streams and residential areas so that there is no filtration back into the water. Ekosse (2004) recommended reclamation of contaminated soils around all mining areas for resources to be used productively in future.

Bagchi (2010) suggested management of sand and gravel extraction operations to minimize damage to streams, rivers and riparian zone. 33 Since Kondolf (2007) had realized that gravel bar skimming significantly impacts aquatic habitats, the method can only be allowed under restricted conditions like during low flows with construction of buffer strips to control the flow. Hill and Kleynhans (1999) highlighted that if bar skimming is used as a method of mining, then there is need for close monitoring and refilling of pits on the riparian zone. Allow bar skimming only under restricted conditions but if the river or stream has a history of eroding bars then avoid this method. Kondolf (2007) supported this by suggesting that monitoring of all activities should be done to ensure that there is no gravel recruitment downstream. If a river has a recent history of rapidly eroding bars, then skimming should be avoided. In bar skimming, there is need for strictly limiting gravel removal quantities so that recruitment and accumulation rates are sufficient to avoid extended impacts on channel morphology and fish habitats (Kondolf, 2007).

According to Schaertzl (1990) there is generation of heavy vehicles on river banks and beds. He recommended that extraction should be done on one side of floodplain to eliminate crossing of active channels by heavy equipment. Generally, sand mining sites should be outside active floodplain. Hill and Kleynhans (1999) had also noted the need to apply dry pit mining method in sand mining project on one side of floodplain to avoid compacting active channels with heavy tipper trucks and front end loaders. Crossing active channels with trucks may lead to contamination of water with oil spills and leakages. Wachira (2009) recommended strict laws to be imposed on license holders as a prerequisite to miners in Kenya.

Mwangi (2007) recommended restriction of heavy front end loader equipment on mining areas and instead encouraged use of shovels which have less impact on the ground. Kuttipuran (2006) suggested that mining of river sand should strictly be done on larger rivers such as Bharathapuzha and Pamba in India containing a lot of sand avoiding smaller rivers and streams which may easily be destroyed. Braided river systems are recommended instead of straight, meandering and split rivers. Strictly, operators should never be allowed to divert streams and rivers creating inactive channels. Lawal (2011) recommended the use of abandoned stream channels on terraces, inactive floodplains and deltas as the best sources of gravel and sand. He noted that gravel pits on floodplain should not go deeper than water. He recommended that pit excavations on adjacent floodplain or terraces should be separated from active channel for two to three decades by constructing buffers or levees to reduce long term flooding. Stebbins (2006) researched on co-existence of gravel sand mines and water supply wells and revealed that continuous removal of the resources harm ground water quality. He suggested regulators to assess changes in ground water and develop a methodology on management of both resources effectively. Hill and Kleynhans (1999)’s research included recommendations to decision makers who are involved in reviewing sand mining and gravel extraction to make informed decisions when issuing licenses.

Lawal (2011) encouraged Nigerian authorities to discourage indiscriminate opening up of plots for sand and gravel mining. The government should evolve a policy compelling miners to reinvest and repair old disused mine sites so as to reduce occurrences of landslides or earth tremors in the locality. Government should consider changes in market prices of sand and gravel so as to charge according to economic value of environment. Ekosse (2004) recommended remedial measures for reclamation of the contaminated soil to appropriate land use. After reviewing the National Marine Fisheries Service (NMFS), Kondolf (2007) suggested that the government of USA should use modern technology and field sampling prior to extraction to establish and document baseline data and evaluate ways of minimizing negative impacts. This can be done through calculating sediment and hydraulic flow budgets, then find possible changes in water quality and channel morphology. There is need to address cumulative impacts and propose possible mitigation and restoration strategies. Close monitoring permitted operations and verifying environmental safeguards by regulating extraction rates and volume is important. Channel cross sections should be benchmarked and documented using aerial photographs taken at regular intervals (Kondolf, 2007). The NMFS Policy highlights the need to give permits with five-year limits subjected to annual review and revision if fishery management objectives are met. This will ensure establishment and implementation of long term monitoring and restoration program in American States. 35 In Kenya, Mwangi (2007) discussed the establishment of the National Environmental Watchdog of Kenya with a list of guidelines to soil harvesters and traders in the Eastern Province. He gave mitigation measures to sand mining and gravel extraction as refilling and growing appropriate vegetation on eroded areas by licensed miners as a prerequisite.

The National Environmental Management Authority (NEMA) was drafted by the Kenyan government to apply to all mining activities including soil. NEMA officials work with District Sand Harvesting Committees to ensure sustainable mining is done. Hill and Kleynrans (1999) gave fundamental considerations and recommendations on how to reduce negative impacts in all sand and gravel extraction operations. There is need for strict laws to govern sand mining and gravel extraction activities both in rivers and on land. Standard conditions should be part of mining operations. Mitigation and restoration must occur concurrently with extraction activities thus restoration becomes part of mitigation. This is done to restore biotic integrity of riverine ecosystems. Dry pit mining was recommended instead of bar skimming or wet pit mining in most activities because the depth of extraction can easily be controlled. The Mines and Minerals Act (1999) of Botswana gave guidelines on mitigation measures against negative impacts on mining. The distance of mining from banks of meandering rivers should be 2.5 to 5.0 meters but this depends on height of river bank and thickness of sand to be extracted. The Act prohibits digging of river banks within 500 meters for pit sand and gravel. At least 0.5 meters of sand bed should be left in situ while harvesting sand. No permits are issued to prospective miners who wish to mine near schools, villages, clinics or any other major human activities. The Department of Mine gave an example of intended reclamation/rehabilitation plan to be followed by the licensed miners soon after mining.

Conclusion

Sand and gravel dredging is an essential activity that supports global development by providing materials for construction, land reclamation, and industrial applications. However, its environmental impacts are profound and often irreversible when extraction is poorly managed or unregulated. These include ecosystem disruption, biodiversity loss, water pollution, land degradation, and alterations in hydrological cycles. While the activity offers economic benefits such as job creation and infrastructure development, the environmental and social costs often outweigh these gains in the absence of sustainable practices. Sand and gravel represent the highest volume of raw material used on earth after water. Their use greatly exceeds natural renewal rates. Moreover, the amount being mined is increasing exponentially, mainly as a result of rapid economic growth in Asia (UNEP and CSIRO, 2011). Negative effects on the environment are unequivocal and are occurring around the world.

The problem is now so serious that the existence of river ecosystems is threatened in a number of locations (Kondolf, 1997; Sreebha and Padmalal, 2011). Damage is more severe in small river catchments. The same applies to threats to benthic ecosystems from marine extraction (Krause et al., 2010; Desprez et al., 2010; Boyd et al., 2005). A large discrepancy exists between the magnitude of the problem and public awareness of it. The absence of global monitoring of aggregates extraction undoubtedly contributes to the gap in knowledge, which translates into a lack of action. As this issue is truly a major emerging one, there is a need for in-depth research. The implementation of a monitoring mechanism regarding global aggregate extractions and trade would shed light on the magnitude of this issue and bridge the current data and knowledge gap (Velegrakis et al., 2010). This would also raise this issue on the political agenda and perhaps lead to an international framework to improve extraction governance, as the current level of political concern clearly does not match the urgency of the situation at hand.

Recommendations

To mitigate the negative impacts of sand and gravel dredging while maximizing its socio-economic benefits, the following recommendations are proposed:

1. Strengthen Regulatory Frameworks

Governments should establish and enforce strict regulations governing sand and gravel extraction, including licensing, environmental assessments, and monitoring of dredging activities. Policies should address extraction limits, designated dredging zones, and compliance with sustainable practices.

2. Promote Sustainable Dredging Practices

Adopting eco-friendly dredging techniques, such as controlled sediment removal and selective mining, can minimize environmental damage. Restoration of mined areas through replanting vegetation and rehabilitating aquatic habitats is essential.

3. Encourage Use of Alternative Materials

Invest in research and development of alternative construction materials, such as recycled aggregates and manufactured sand, to reduce reliance on natural sand and gravel resources.

4. Implement Community Engagement and Awareness Campaigns.

Engage local communities in decision-making processes to ensure their needs and concerns are addressed. Awareness campaigns can educate stakeholders about the environmental and social consequences of unregulated dredging and promote community-driven conservation initiatives.

5. Enhance Monitoring and Data Collection

Develop systems for monitoring dredging activities using satellite imagery, drones, and field inspections. Accurate data collection can inform sustainable resource management and identify illegal mining operations.

6. Promote International Collaboration

Since sand and gravel dredging often affects trans-boundary rivers and coastal areas, fostering international cooperation and sharing best practices can help address shared environmental and socio-economic challenges.

7. Encourage Private Sector Responsibility

Incorporate corporate social responsibility (CSR) policies into the operations of companies involved in dredging. These policies should prioritize sustainable practices, invest in local development, and ensure accountability for environmental impacts.

8. Support Research and Innovation

Funding academic and industrial research on sustainable dredging technologies, sediment management, and environmental restoration can pave the way for more effective and less harmful extraction methods.

By implementing these recommendations, stakeholders can balance the growing demand for sand and gravel with the need to protect ecosystems, preserve biodiversity, and sustain livelihoods, ensuring a more sustainable future.

REFERENCES

Apitz, S. E., & Brils, J. M. (2004). Contaminated sediments in European river basins. Journal of Soils and Sediments, 4(4), 241-246.

Ericson, J. P., Vörösmarty, C. J., Dingman, S. L., Ward, L. G., & Meybeck, M. (2006). Effective sea-level rise and deltas: Causes of change and human dimension implications. Global and Planetary Change, 50(1-2), 63-82.

Green, A. (2017). Sand mining impacts on South Africa's estuarine ecosystems: A review. African Journal of Aquatic Science, 42(3), 229-239.

Kondolf, G. M. (1997). Hungry water: Effects of dams and gravel mining on river channels. Environmental Management, 21(4), 533-551.

Kondolf, G. M., Smutko, L. S., & Kimball, K. (2018). Freshwater gravel mining and dredging issues. Center for Environmental Design Research.

Mensah, J. V. (1997). Causes and effects of coastal sand mining in Ghana. Singapore Journal of Tropical Geography, 18(1), 69-88.

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology, 36, 127-178.

Nigeria. African Journal of Environmental Science and Technology, 12(6), 199-208.

Omolu, B., & Adebayo, O. (2018). Environmental impacts of sand mining in the Niger Delta region of Nigeria.

Peduzzi, P. (2014). Sand, rarer than one thinks. Environmental Development, 11, 208-218.

Syvitski, J. P. M., Kettner, A. J., Overeem, I., Hutton, E. W. H., Hannon, M. T., Brakenridge, G. R., & Nicholls, R. J. (2009). Sinking deltas due to human activities. Nature Geo science, 2(10), 681-686.

Tubb, K. N. (2003). An evaluation of the effectiveness of interpretation within Dartmoor National Park in reaching the goals of sustainable tourism development. Journal of Sustainable Tourism, 11(6), 476-498.

Wright, I. A., & Phillips, N. (2016). Urban storm water quality and eco toxicology: The challenge of source versus effect-based monitoring. Water, 8(11), 530.