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Sand and Sustainability: Finding new solutions for environmental governance of global sand resources

UN environment

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About this report

About this report

Environmental and social impacts of sand extraction and consumption is a new issue for the international community. United Nations Environment Programme / GRID Geneva and the University of Geneva held an expert roundtable event on 11 October 2018 in Geneva, Switzerland to produce an action-oriented starting point for a global conversation on how sand resources could be consumed and produced responsibly in future.

This report summarises the problem analysis, case studies and main messages suggested at this event by twenty primary participants. Expert perspectives were verified and supplemented with academic and grey literature reviews and an external review process.

This analysis contained in this report is not intended as prescriptive. Instead, the goal is to offer constructive overview of the sustainability challenge, governance gaps, available solutions and options for action for all stakeholders on sand resources and sustainability.

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Glossary

Definitions for terms as they are used in the following report are based on those available from: McMichael et al. (2003); Cash et al. (2006); International Resource Panel (2011); Lange et al. (2013); Bodin (2017); Baird (2018). They are presented in alphabetical order of primary terms defined.

Aggregates	A generic term for crushed rock, sand and gravels used in construction materials, water filtration.
Primary aggregates	Crushed rock, extracted in hard rock quarries by blasting, crushing; and sand and gravel extracted from pits by excavation and crushing, from lakes, rivers and from coastal beaches or dredged from the sea.
Recycled aggregates	A term for crushed rock, sand and gravel produced by sorting, crushing and screening of construction and demolition materials.
Manufactured aggregates	A term for substitutes to crushed rock, sand and gravel that are produced from wastes from other industries.
Avoidance	The avoidance of natural sand resources or its substitutes through alternative urban design, land use planning, infrastructure and building design, among other approaches.
Circular economy	The circular economy is one in which waste materials and products are reused and recycled within the production and consumption system. It is the better use of waste for new materials.
Consumption	The use of products and services for (domestic) final demand, i.e. for households, government and investments.
Efficiency	Efficiency is a broad concept that compares the inputs to a system with its outputs; it essentially means achieving —more with less. Efficiency includes activities to improve productivity (value added / input) and minimize intensity (input / value added).
Extraction	Extraction is the removal of primary (virgin, natural) sand resources from the natural environment (terrestrial, riverine, coastal or marine) for extracting valuable minerals, metals, crushed stone, sand and gravel for subsequent processing.
Extraction rates	The rate at which sand resources are removed from the natural environment by volume over time.
Governance	The on-going interaction between public and/or private entities with the purpose of realising a collective interest. This process can vary in its level of institutionalisation, collaboration and ability to adapt to change. The collective interest ,n the context of this report is sustainability in the sourcing and use of sand and its alternatives, so that human wellbeing, environmental quality and economic performance is maintained or enhanced equitably.
Green infrastructure	Green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of services such as water purification, flood management, recreation as either a complement or a substitute to built infrastructure.

Mineral sands	Mineral sands are part of a class of ore deposits that contain heavy minerals such as ilmenite, zircon, leucoxene, and rutile. Eroded materials from hard rock sources like granite or basalt accumulates on beaches within river systems and on coastlines. It is these beaches from which these valuable materials are extracted for end use in jewelry; as pigments in paints, plastics, paper, foods; in electronics.
Natural sand	A term used in this report to denote all sands extracted from natural environments.
Sand resources	A term used in this report to denote both mineral sands and aggregates. [Also used as: *Global sand resources*]
Scale / level *[Multi-scale Cross-level]*	"Scale" refers to spatial, temporal, jurisdictional, institutional, management, networks, knowledge scales. "Level" refers to the different units of analysis possible in each of these scales.
Substitution	The replacement of natural sand resources by other materials including manufactured aggregates.
Sustainability	Sustainability means transforming our ways of living to maximise the chances that environmental and social conditions will indefinitely support human security, well-being and health.
Sustainable development	Sustainable development refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Sustainable infrastructure	Infrastructure that is tailored to local social, economic and ecological environment and caters the need for infrastructure services in the most effective and efficient way. This requires both assessing and addressing environmental and social risks, assuring financial resources to maintain infrastructure over its entire lifespan, considering users' preferences and needs in the design, and understanding the institutional and political dynamics in order to guarantee a long term perspective.
Sustainable resource management	Sustainable resource management means both (a) ensuring that consumption does not exceed levels of sustainable supply and (b) ensuring that the earth's systems are able to perform their natural functions (i.e. sand and sediment materials flow processes in globally important river basins continue) to ensure the long-term material basis of societies in a way that resource extraction, use, and waste and emissions management do not surpass key thresholds for long-term environmental sustainability and human wellbeing.
Sustainable supply	Sustainable supply refers to the amount of resources that can be extracted and used for production and consumption before the threshold of a safe operating space is surpassed. At a global scale, (sustainable) levels of production equal (sustainable) levels of consumption. At a local scale, sustainable supply is aimed at by safe operating practises.

Foreword

Foreword

We give such little thought to sand, save perhaps when we are on the beach or our little ones are playing in sandpit. But sand and gravel build the foundations of our economies, finding uses in diverse sectors from construction to electronics to cosmetics.

As this report shows, demand for sand resources is rising. Shifting consumption patterns, growing populations, increasing urbanization and infrastructure development have increased demand three-fold over the last two decades. We now need 50 billion tonnes per year, an average of 18 kg per person per day.

The problem is that we have been exceeding easily available sand resources at a growing rate for decades. We are spending our sand "budget" faster than we can produce it responsibly. We now find ourselves in the position where the needs and expectations of our societies cannot be met without improved governance of global sand resources.

Even though these materials are the second largest resources extracted and traded by volume after water, they are one of the least regulated in many regions. Increasingly, sand is being produced through environmentally damaging extractive practices in sensitive terrestrial, riverine and ocean ecosystems. Complex questions on how to deliver on ecosystem and biodiversity conservation goals alongside necessary improvements in transport, infrastructure, housing and living standards are looming.

We need to reconcile relevant global policies and standards with local sand availability, development imperatives and standards and enforcement realities. We need to recognize the interdependence between countries and sectors and learn lessons on how to manage this critical resource sustainably. We need to rethink the relationship between infrastructure and the social and environmental outcomes for which we are striving.

This timely report looks at how we can cut consumption of sand and gravel and deliver this new reality by, for example, reducing over-building and over-design, and using recycled and alternative materials. It also looks at how to reduce impacts on ecosystems through implementing existing standards and best practices.

Fundamentally, improving governance of global sand resources means increasing the will to act, at all levels of government and industry. I encourage everybody involved in the sector to read this report and seriously consider its recommendations so we can create institutions that sustainably and equitably manage extraction and use of this vital resource.

Joyce Msuya
Acting Executive Director
United Nations Environment Programme

Executive Summary

Executive summary

Sand and gravels are the unrecognised foundational material of our economies. They are mined the world over, with aggregates accounting for the largest volume of solid material extracted globally (Peduzzi, 2014; Beiser, 2018). At the same time, these materials cannot be produced from our terrestrial, riverine and marine environments in quantities needed to meet demand from a world of 10 billion people without effective policy, planning, regulation and management.

Such actions remain largely unaddressed by decision makers in public or private sectors. It is time to challenge the paradigm of infinite sand resources through constructive dialogue and solution-finding. This report aims to be the starting point from which a productive global conversation on sand extraction can begin.

This synthesis was produced following a United Nations Environment Programme expert roundtable event held on 11 October 2018 in Geneva, Switzerland. The discussions emphasised potential solutions for mitigating mineral sands and aggregates extraction impacts and generating adequate support for responsible consumption pathways. Expert views were collated and complemented with additional research and consultation to distil key messages on an agenda for tackling this issue in 2019 and beyond.

Key messages

- **The needs and expectations of our societies are driving the demand for sand resources but a continued responsible supply cannot be assumed without improved governance of global sand resources.**

  The scale of the challenge inherent in sand and gravel extraction makes it one of the major sustainability challenges of the 21st century. These materials are one of the largest resources extracted and traded by volume, yet it is one of the least regulated activities in many regions. For one of the most traded commodities on the planet, there is very low general awareness about widespread extraction impacts. Local and international journalists are currently leading in uncovering the scale of the impacts while science and policies to support responsible consumption and extraction are lagging behind. Meanwhile, rivers, river deltas and coastlines are eroding, “sand mafias” are thriving and demand continues to grow.

- **Preventing or reducing damage to river, beach and marine ecosystems and social risks to workers and communities in sand extraction sites can be achieved through some already existing solutions:**

  Avoiding consumption through reducing over-building and over-design
  Society can make more efficient use of sourced aggregates through alterations to infrastructure and building designs so that sand and gravel demand and extraction is reduced to responsible levels.

  Using recycled and alternative materials to sand in the construction sector
  Society can make more efficient use of sourced aggregates through using substitutes to natural sand where feasible so that extraction is reduced to responsible levels.

  Reducing impacts through implementing existing standards and best practices
  Society can implement existing legal and voluntary standards and best practices in the extractives, environmental and other related sectors while analysing of sourced aggregates through use of substitutes to natural sand so that extraction is reduced to responsible levels.

- **International organisations, national governments, private sector companies, civil society groups and local communities all play critical roles in governance of sand resources. Three main options for joint action are recommended to these groups for faster and more widespread implementation of existing solutions:**

1. **Customise existing standards and best practices to national circumstances and extend where necessary to curb irresponsible and illegal extraction**
   Current legal frameworks are not sufficient considering the global outlook on aggregates demand and production. Existing international treaties, law, standards and best practices provide a foundation, but it is incomplete in places. Where addressed, sand extraction currently crosses extractives, water management, coastal zone management, biodiversity conservation legal systems and best practices. Without an integrated view on the governance, planning and management of these resources, sand extraction risks falling between the cracks into informal, or even illegal practices. Importantly, sand extraction is not regulated in some countries. Guidelines for governing, planning and managing sand extraction at the regional and international legal scale are needed. So is support to countries for customising these guidelines in national policy, law and regulation where these do not currently exist.

2. **Invest in sand production and consumption measurement, monitoring and planning**
   There is a lack of adequate information on sand extraction. We do not understand sand production and transport systems well in the context of current day geological and hydrological processes. Sand and gravel are a challenge to trace to their sources. Strategic monitoring for governance, planning and management of global sand resources is lacking. Coordination across established economic, social and environmental monitoring programmes could help quick start a global, regional and national sand resource monitoring programmes. International community organisations with mandates and access to relevant data need to collaborate on a rapid information synthesis, design a long-term monitoring programme and produce a rapid assessment tool in the context of existing processes in EIA, SEA, Responsible Mining and water governance.

3. **Establish dialogue between key players and stakeholders in the sand value chain based on transparency and accountability**
   The sand industry is fragmented and significantly informal in some parts of the world. Identifying existing sand extraction and trading companies requires peeling back many layers in a complex value chain– particularly in emerging economies. While improving legislative frameworks and regulation is critical, all actors from extraction sites to global levels, will need to be involved in next steps. International community, governments, industries, civil society including the media, nongovernmental organisations and the research and education sector have a role to play developing constructive policies and voluntary actions as an enabling conditions for real change.

Steering deep transformation in how we think about, plan for and manage sand resources. It will mean considering sectoral interdependence and a mix of solutions and actions with a long-term perspective. The impediments to change are not technical, but stem from poor awareness and governance. Building consensus through public awareness-raising and improved coordination across global, regional, national and sub-national levels on this critical sustainability challenge is the starting point. It will be a long road, but the key to a rapid yet smooth transition to more sustainable sand resource sourcing, while reducing the demand in parallel, lies in cooperation.

1. Background

Riverbank at Cu Chi Tunnel

1. Background

Sand and gravels (hereafter aggregates) are the unrecognised foundational materials of economies. They are mined the world over, accounting for the largest volume of solid material extracted globally (Peduzzi, 2014). Without them, there is no concrete, no asphalt, no glass to build the necessary schools, hospitals, roads, solar panels and other necessary infrastructure under current construction and industrial production systems and methods.

Sand is ubiquitous in construction and industrial production because it is cheap, versatile and easy to acquire. Yet, all indications are that we are approaching a future where access to this resource is a critical barrier to sustainability, and the full costs of uncontrolled sand extraction come due.

Extraction rates are exceeding natural sand replenishment rates (John, 2009). The increasing volume of aggregates extracted, often illegally, from riverine and marine ecosystems results in river and coastal erosion, threats to freshwater and marine fisheries and biodiversity (World Wide Fund for Nature [WWF], 2018a). The people who work in unregulated extraction and those living in and around these sites risk their safety; even their lives when they seek to stop uncontrolled extraction (Awaaz Foundation, 2017).

The environmental and social impacts of sand extraction is an issue of global significance.

Despite our increasing dependence on these materials, the significant impact that their extraction has on the environment, and increasing media reportage, the issue is largely unaddressed by decision makers at the global level, in regional and national public agencies, or private firms. Sand exploitation is occurring with inadequate assessment of the wider environmental consequences of over-exploitation. Sand cannot be produced from our terrestrial, rivers and marine environments to meet the increasing demand from a world preparing for 10 billion people without effective policy, planning, regulation, management and functioning governance.

A paradigm of infinite sand resources dominates and this needs to be challenged through constructive dialogue and solution-finding. This report presents a synthesis of expert discussions at an United Nations Environment Programme / GRID-Geneva and University of Geneva co-hosted roundtable event on 11 October 2018 in Geneva, Switzerland. The discussions emphasised key issues and potential solutions for mitigating sand extraction impacts and supporting responsible consumption. The structure and main messages were verified and supplemented with academic and grey literature reviews. The aim is to provide a starting point for next steps on planning for production and consumption of global sand resources in the future.

Tropical beach, Bintan island (near Singapore), Indonesia

Photo credit: Delpixel. Shutterstock.com

2. The Challenge

Labourers using cement
© Iniabasi Udosen, October 2017

2. The Challenge

Crushed rock, sand and gravels are an essential element of urbanisation and infrastructure, water treatment, land reclamation, hydrological fracturing techniques (better known as gas fracking) and industrial production of electronics, cosmetics and glass production the world over. For this reason, sand consumption and production has implications for social and environmental management in infrastructure projects, sustainable cities planning, energy planning, biodiversity conservation, as well as both circular and green economy policy and planning. Sand and gravels resources are the second largest resource extracted and traded by volume after water. Yet it is one of the least regulated activities in many regions. A growing trend of irresponsible and illegal extraction in marine, coastal and freshwater ecosystems makes this a sustainability challenge of significant proportions

2.1 State of global sand resources

Sand can be classified by its properties, with each type used in different industries for different purposes (Gavriletea, 2017). Distinguishing between mineral sands and aggregates is a useful beginning since the materials and volumes involved, extraction impacts and solutions are quite different for these two sand resource types.

Mineral sand[1] contains metals and minerals such as Ilmenite, rutile and zircon that are used in industrial production of ceramics, pigments, plastics and other products. The original source is hard rock which is mined, or following long erosion processes, is deposited on and mined from river banks and coasts on beaches.

Aggregates is a generic term for crushed rock, sand and gravels, which can be sub-categorised by formation process (natural or manufactured), composition, and grain size distribution (Gavriletea, 2017). For the purposes of this report, three aggregates groups are defined:

- ***Primary Aggregates,*** *Crushed Rock,* extracted in hard rock quarries by blasting and crushing; and sand and gravels, extracted from pits by excavation, crushing, screening and washing (if required), dredged or pumped from lakes and rivers, removed from coastal beaches, or dredged from the sea bed (also termed Marine Aggregates).
- ***Recycled Aggregates,*** *Crushed rock, sand and gravels* produced by sorting, crushing and screening of construction and demolition materials.
- ***Manufactured Aggregates,*** *Crushed rock, sand and gravels substitutes* produced from wastes from other industries.

Crushed rock, sand and gravel account for the largest volume of solid material resources extracted from systems globally (Peduzzi, 2014; Beiser, 2018). An estimated 40-50 billion metric tonnes is extracted from quarries, pits, rivers, coastlines and the marine environment each year (Peduzzi, 2014; Beiser, 2018, See Box 1). The construction industry consumes over half of this volume annually (25.9 billion to 29.6 billion tonnes in 2012: UNEP, 2014) and could consume even more in future (Beiser, 2018).

Though little public data exists about extraction volumes, sources and uses we know that, with some exceptions, most sand and gravels extracted from natural environments are consumed regionally because of the high costs of transport. For example, two thirds of global cement production occurs in China (58.5%) and India (6.6%) (United States Geological Survey [USGS], 2017; Gavriletea, 2017). These two countries also lead in global infrastructure construction (Bagnasco et al., 2015; Global Construction 2030; World Economic Forum [WEF] 2019) as these nations look to rapidly transition their populations out of poverty.

The Global Aggregates Information Network [GAIN] suggests that at one end of the scale, least developed regions use 3-4 tonnes/capita per year and developed regions with slow growth, flat terrain use 4-8 tonnes/capita per year (based on 2016 data). Growing economies with rugged terrain and harsh climates can use between 8-16 tonnes/capita per year. China stands out for aggregates production at 14.3 tonnes/capita per year. In total, China, India and Asia represents 67% of global aggregates production.

The industry outlook to 2030 is one of strong growth in Asia, particularly India, Africa and Latin America (Gavriletea, 2017). GAIN estimates global aggregates demand will likely rise to 60 billion tonnes per annum by 2030 driven by increasing population, urbanisation and economic growth. However, mineral resources can only be worked where they lie – and their distribution is a consequence of the slow geological processes that created them. Often, access to sand is constrained by competing or conflicting land use (USGS, 2002). Desert sand, though plentiful, is unusable for most purposes because its wind-smoothed grains render it non-adherent for the purposes of industrial concrete (USGS, 2002; Gavriletea, 2017). Sand can be manufactured from gravel or crushed rock where not available. However, this does require

[1] See for example, Sibelco's websie.Available at:https://www.sibelco.com/materials/mineral-sands/, last accessed 28 January 2019

additional investment on extractives processing. It is extraction from rivers and sea shores, though often illegal where regulated, that is surging to meet growing demand for global sand resources (WWF, 2018a). Such sands are estimated to be 10-15% of the total global demand for aggregates currently (with the remaining 90% coming from terrestrial quarries and sand and gravel pits); but this relatively small part of aggregates consumption is causing severe concern due to negative environmental and social impacts.

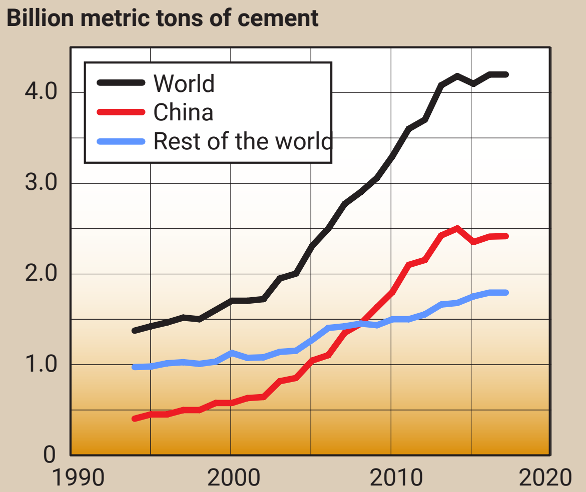
Box 1: A note on global sand extraction data

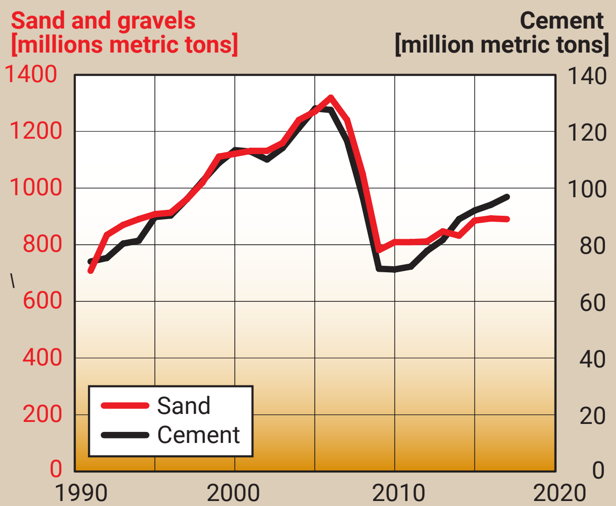
Although more aggregates are extracted from nature than any other material after water, reliable data on their extraction is only available in certain developed countries. Though sand, gravels and crushed rock are used in other 'bound' products, such as asphalt used to surface roads, and a variety of 'unbound' end-uses, such as sub-base for roads and railways, we can use the better data available on cement production for concrete to estimate global production of these materials.

Sand, aggregates and cement (and water) are mixed in standardised volumetric proportions to produce various concrete grades. The UK composition of concrete is generally defined as 1.5% air, 10% cement, 18.5% water, 25% fine aggregate (sand) and 45% coarse aggregate (crushed rock/gravel) by volume. The building industry uses between 6-10 tonnes gravel for each tonne of cement used. Given that annual cement production is reported by 150 countries as having reached 4.1 billion tonnes in 2017 the use of aggregates for concrete can be estimated at between 28.7-32.8 billion tonnes for 2017 alone.

China produces the most cement globally at an estimated 2.4 billion tonnes in 2017 (USGS, 2018), followed by India at 270 million tonnes and the USA at 86.3 million tonnes in the same year. In the USA, for every 1 ton of cement, 10 tons of aggregates are used. Using this ratio implies that as global annually cement production is expected to increase to 4.83 billion tonnes in 2030, aggregate use will likely reach close to 50 billion tonnes per year in 2030.

Figure 1: There are no global monitoring on the use of sand. However, cement is well reported. Tracking this data shows that the production of cement has tripled in the last two decades.





There is no global monitoring or reporting for sand. However, countries are reporting their cement production.

The statistics shows that the quantity of cement produced has tripled in two decades.

The use of sand and gravels is highly correlated with the cement production.

In USA, the amount of sand and gravels is almost exactly ten times the amount of cement.

If this was extrapolated to the rest of the world, the total sand and gravels used for construction only, would be 41 billion tons per year.

Data sources: Minerals commoditties, USGS, 2018.
Graphs: UNEP/GRID-Geneva, 2018

Sources: Krausmann et al. (2009); USGS (2013b); Peduzzi (2014); Mineral Products Association. (2018, July); USGS (2018)

2.2 Impacts

People working in sand extraction at the river Dibamba, Cameroon *© Minette Lontsie*

Many sand extraction operations in emerging and developing economies are not in line with extractives and environmental management regulations. Resulting social and environmental impacts have been reported in India, China, and other locations across Asia, Africa and South America (See Gavriletea, 2017:17).

China and India head the list of critical hotspots[2] for sand extraction impacts in rivers, lakes and on coastlines (Sreebha & Padmalal, 2011), most likely because these countries also lead globally on infrastructure and construction. Other countries touched by regional and national construction booms exhibit similar trends. For example, Cambodia, Vietnam and Indonesia are the legal and illegal sources of aggregates materials for regional economic corridor development and land reclamation projects in Southeast Asia (Global Witness, 2010; WWF, 2018a). Sierra Leone, Kenya, Tanzania in Africa (Isaya, 2014; Shaghude et al., 2012) and Colombia in South America have been identified as places presenting sustainability challenges for the aggregates sector (Villas-Bôas & Barreto, 2000).

These cases, and others, demonstrate how uncontrolled extraction comes at the expense of other economic sectors, local livelihoods and biodiversity. Direct safety risks for those working in the sector and living in the communities where this takes place include drowning (of workers removing sand from river beds), subsidence and landslides in extraction areas (Awaaz Foundation, 2017).

Legal and illegal operations are increasingly reported adjacent to and inside established biodiversity reserves and protected areas (WWF, 2018a) – the unique places society has agreed are so ecologically and culturally significant that they cannot host economic activities that are not compatible with the biophysical integrity of these ecosystems. On site impacts on habitats for marine and freshwater fisheries and birdlife, and threatened species like turtles and freshwater dolphins have been reported in some cases (WWF, 2018a).

2 For current case studies, please see: http://www.sandstories.org/; http://coastalcare.org/sections/inform/sand-mining/ last accessed 28 January 2019

Indirectly, safety, livelihoods and other impacts can result from the widespread environmental change wrought by removing significant amounts of material from dynamic environments like rivers and coasts (as opposed to static environments like quarries).

Aggregate extraction in rivers has led to pollution and changes in pH levels (Saviour, 2012), instability of river banks leading to increased flood frequency and intensity (Sreebha & Padmalal, 2011), lowering of water aquifers (Myers et al., 2000) exacerbating drought occurrence and severity (John, 2009). Damming and extraction have reduced sediment delivery from rivers to many coastal areas, leading to reduced deposits in river deltas and accelerated beach erosion (Kondolf, 1997). This adds to effects of direct extraction in onshore sand extraction in coastal dune systems and near-shore marine dredging of aggregates, which may locally lead to long-term erosion impacts (US: Thornton et al., 2006; UK: Pye & Neal, 1994). Nearshore and offshore sand extraction in New Zealand continues despite considerable uncertainty of the environmental impacts (Hilton & Hesp, 1996) and the cumulative effects of mining, climate change and urbanisation of the coast.

Tourism is affected by loss of key species and beach erosion (Kondolf, 1997), while both freshwater and marine fishing — both traditional and commercial — has been shown to be affected through destruction of benthic fauna that accompanies dredging activities (Cooper, 2013; Desprez et al., 2010; Stelzenmueller et al, 2010). Agriculture land has been affected by river erosion in some cases (John, 2009) and the lowering of the water table (Kondolf, 1997). The insurance sector is affected through exacerbation of the impact of extreme events such as floods (Kondolf, 1997), droughts (John, 2009) and storm surges which can affect houses and infrastructure (Thornton et al., 2006; John, 2009). A decrease in bed load or channel shortening can cause downstream erosion including bank erosion and the undercutting or undermining of engineering structures such as bridges, side protection walls and structures for water supply (Padmalal et al., 2008; John, 2009).

Local and indigenous peoples living in communities where sand extraction takes place are rarely heard in the mix of informal and formal governance, illegal and criminal activities; though when riverine or coastal societies are in crisis, they participate in sand extraction processes because it is their only possibility to make a living in the short run (Anongos et al., 2012; Awaaz Foundation, 2017).

2.3 Gaps in the current governance system for global sand resources

Sand extraction and use is defined by its local geography and governance context and does not have the same rules, practices and ethics worldwide.

Sand extraction and use value chains are predominately governed at national and regional levels given the construction sector aims to reduce high transport costs by minimising distance between where material inputs are produced and used. Where sand extraction is regulated, national mining and environmental protection legislation provide the basic framework. Regulatory regimes may be devolved to often under-resourced sub-national level administrations. This formal governance structure can result in many small administrative entities having responsibility for policy implementation and enforcement without adequate human resources and financial capacity.

For example, production of crushed rock tends to be strictly permitted (some in the aggregates industry would argue over-regulated, depending on the jurisdiction). Illegal operations of any significant size are therefore relatively rare. However, production of sand and gravel in smaller pits sometimes operate knowingly and unknowingly outside regulations. Importantly, while many countries have banned sand extraction from lakes, rivers or beaches (de Leeuw et al., 2010), the legislation is either insufficient or not enforced adequately due to corruption, the absence of monitoring, or resources to prosecute offenders.

Part of the challenge is that the sand industry is fragmented and significantly informal in some parts of the world. It can be a complex value chain as artisanal and small-scale operations are legion in the sector – particularly in emerging economies (Gavriletea, 2017). Globally, there are a few significant commercial supply chains into which the majority of crushed rock, sand and aggregates flow. The top five companies for marine sand extraction are: Chinese Harbour & Construction Ltd; Boskalis (Dutch); Van Oord (Dutch); Deme (Belgium); Jan de Nul (Belgium – Luxembourg). In the United States of America, national legislation[3] only allows national company to operate in the marine sand extraction industry and the (large) domestic sector is dominated by Great Lakes Ltd. In the UK, for example, 80% of production is delivered by a small number of companies (See Section 3). Construction material businesses can be global multinationals with

[3] The Jones Act requires that all goods transported by water between U.S. ports be carried on U.S.-flag ships, constructed in the United States, owned by U.S. citizens, and crewed by U.S. citizens and U.S. permanent residents.2019

interests around the world. However crushed rock, sand and gravels are also extracted and traded illegally in large quantities in some regions of the world, at times by organised crime 'sand mafias' (See Box 2).

Box 2: Sand mafias, illegal sand extraction and smuggling in Morocco

In Morocco, half of the sand – 10 million cubic metres a year – comes from illegal coastal sand extraction. Sand smugglers have transformed a large beach into a rocky landscape between Safi and Essouira. Sand is often removed from beaches to build hotels, roads and other tourism-related infrastructure. In some locations, continued construction is likely to lead to an unsustainable situation and destruction of the main natural attraction for visitors — beaches themselves. Asilah, in Northern Morocco, has suffered severe erosion of its beaches, due to regulatory issues, and pressures relating to tourism. Many of the structures near the coast are now in danger from the erosion that created them.

Sources: The Economist (2005); Khardijamal (2011); Au fait (2011); Middle Eastern Eye (2016); Coastalcare (August 2016)

To add to this, sand extraction is fast becoming a transboundary issue due to sand extraction bans, international sourcing of sand for land reclamation projects and impacts of uncontrolled sand extraction beyond national borders.

International trade in sand and gravel is growing due to high demand in regions without local sand and gravel resources and is forecast to rise 5.5% a year with urbanisation and infrastructure development trends (Freedonia, 2014). There is also the question of how reclamation and infrastructure works are completed, resulting in security concerns and international diplomatic tensions. For example, the use of sand in reclamation practices is thought to have led to increased turbidity and coral reef decline in the South China Sea (Liu, 2019). In the Mekong basin, the impact of sand mining in Laos, Thailand, and Cambodia is felt on the Vietnam delta erosion (WWF, 2018a). Singapore demand for sand and gravel in land reclamation projects have triggered an increase in sand mining in Cambodia and Vietnam (See Box 3).

Degradation for development, Tanzania

Box 3: A growing international trade in sand?

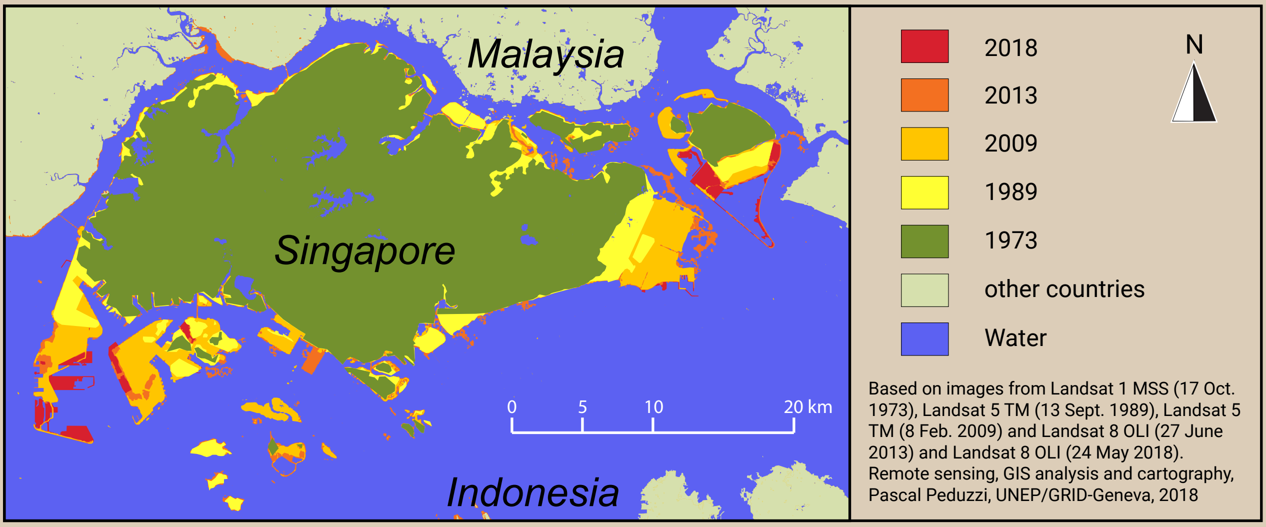
Singapore, the Southeast Asian city-state famous for its development miracle, continues to develop rapidly in size. Given its small area, Singapore needs more space for its growing population. To respond to this demand, the city has increased its land area by more than 20% in the last 40 years (an addition of 130 square kilometres), mostly by using aggregates to reclaim land from the sea (*See* Figure 2). Having imported a reported 517 million tonnes of sand over the last 20 years, Singapore is by far the largest importer of sand world-wide.

Sand was typically imported mostly from Indonesia, but also from the other neighbouring countries of Malaysia, Thailand and Cambodia. Export of sand to Singapore was reported to be responsible for the disappearance of some 24 Indonesian sand islands. It is reported that this triggered political tensions regarding maritime borders between the two countries.

The reported sand exported from Indonesia to Singapore declined sharply since a temporary ban declared in February 2002. Other neighbouring countries are now reporting few exports to Singapore. Overall, the reported total amount of sand imported by Singapore (517 million tonnes) and the sum of sand exports to Singapore from its four neighbouring countries (637 million tonnes) does not match, showing an underestimation of 120 million tonnes of sand imports. Obviously, these statistics do not include illegal imports and highlight the need for better monitoring. There is also an alleged illegal sand trade. As the price of sand increases, so does the traffic of sand by local mafias. The average price of sand imported by Singapore was US $3 per tonne from 1995 to 2001, but the price increased to US $190 per tonne from 2003 to 2005.

Though probably less than 5% of global aggregates production moves across borders, some countries and regions have less geological availability of these materials and so the need for national and international trading. Singapore is severely constrained in natural resources, but does that make it an early warning signal of a potential future trend for other resource-constrained countries? Dubai and Saudi Arabia have previously imported sand from Australia because of depleted marine sand resources in the region. What other countries might follow suit?

Figure 2. Expansion of Singapore's territory since 1973 using sand from neighbouring countries, as observed by satellite imagery.



Sources: Remote sensing analysis (UNEP/GRID-Geneva); Hilton & Manning (1995); Guerin (2003); New York Times (27 March 2010); Milton (2010); Handron (2010); Peduzzi (2014); UN Comtrade (2014); Aquaknow (2014); Rayasam (2016); Gavriletea (2017). GAIN (Expert opinion given in writing in December 2018)

Some uncertainties and disagreements between experts on priority gaps are worth noting:

- While there was a general agreement that the market is a good intervention point for improved governance, there are different perspectives on how to coordinate public and private roles and interventions. What responsibilities lie where? For example, sand extraction and consumption is linked to regional economies but five major European companies are thought to be deeply involved in sand resource flows and use the world over, including Cemex, Heidelberg, Lafarge Holcim, CRH, Sibelco. These and other businesses produce annual reports and corporate documents which indicate the scope of their global aggregates businesses.
- While certification can be an important awareness raising and behaviour change incentive mechanism, we need to be aware of the challenges with certification before adopting it for addressing sand extraction and use challenges. For example, sand trading is not dealing with the public directly so sustainability premiums are not likely to be relevant, and traceability is going to be an issue. Would it really work for sand?
- Transparency and data go hand in hand. All actor should have access and capacity to use information – but how does this really work with proprietary data?

Five priority gaps were identified through the 11th October expert discussions and subsequent literature reviews and consultations for action in 2019 and beyond:

Awareness	National governments, producers across the sand value-chain, and the general public do not know why the state of the global sand resource and extraction impacts are relevant to them. The resource has been freely available, cheap and used widely, and so the general public has little perception of sand as a limited resource. Reconciling the image of endless deserts with this notion is a challenge without understanding that desert sand has been unusable in construction and land reclamation projects to date because it is too finely polished by desert winds. Continued supply is simply assumed.
Knowledge and science	Basic information about sand resource flows and extraction impacts is in short supply. Yet basic data is essential to effective planning and management. Priority questions to be answered include: • How much sand is required for the future under different demand scenarios, acknowledging different forms of development and the rate of population growth? • What could future demand imply for future sand extraction and consumption impacts? These impacts happen over large temporal and spatial scales that need a systems view to be understood. • What is the real cost of unsustainable sand resource extraction and consumption, including externalities associated with its extraction and use? What is the value of sand in our economies and societies? Can we value the ecosystem value of sand in fluvial and coastal systems? • Sand is not equally distributed around the world or within states. Where is it in relation to projected demand? What does that mean for future sand needs and flows? How will it affect future trade and price-setting? • Who is involved? What can they do? How will they be affected? Who owns the rights to sand resources and the land, rivers or marine areas from which they are extracted? This is a crucial question for governance and management.
Transparency and accountability	There is currently no level playing field across governments, companies, contractors, subcontractors in the sand value-chain. Accountability is something that needs to cross boundaries and borders, right down the value chain. While we may know how much sand is being extracted from a location, we rarely know where it goes. Similarly, we can estimate how much sand is being consumed but we cannot say where it comes from. Transparency and information sharing by, and between, companies and governments is extremely limited along the sand value change. Nor do we know who holds relevant existing data or mandates for relevant data collection. This is a common issue for the extractives industry.
Stakeholder relationships and platforms	Relationships between stakeholders are key to building transparency and accountability. Yet there is currently no international body with a mandate to mediate differing interests on sand resources to reach a broad consensus on what is the best interests of all stakeholders, and where possible, on the standards and best practices, recommended policies and effective procedures to help realise the collective interest.
Fragmented participation by key actors	A focus on the players who need to adjust their practices is needed. That implies working within existing or creating new interfaces that include companies, local communities and impacted stakeholders. We need to bring governments, local and indigenous communities, and industry players of all related sectors together to co-produce constructive governance.

Key messages

The scale of the challenge inherent in sand and gravels extraction makes it one of the major sustainability challenges of the 21st century. For one of the most traded commodities on the planet, there is very low general awareness about widespread extraction impacts. Local and international journalists are currently leading in uncovering the scale of the impacts while science and policies to support responsible consumption and extraction are lagging behind. Meanwhile, rivers, river deltas and coastlines are eroding, “Sand mafias” are thriving and demand continues to grow.

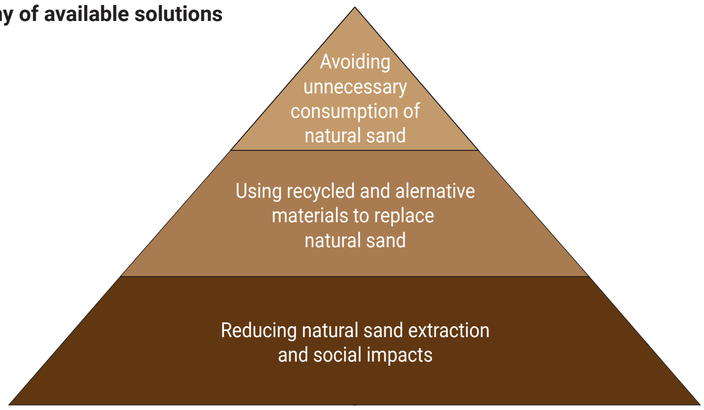
3. Available solutions

3. Available Solutions

Improving sustainable consumption and production of sand resources does not imply waiting for new global laws or rules to enable international cooperation. Avoidance strategies, alternative materials, standards and best practices already exist on which to build for action at regional, national and site levels. The 11th October 2018 roundtable discussion focussed on solutions in the construction sector – the largest consumer of global sand resources. A hierarchy of three major strategies emerged that could lay new foundations for improved governance of sand resources in 2019 and thereafter:
1) Avoiding unnecessary natural sand consumption in construction;
2) Using alternative materials to replace natural sand in construction; and
3) Reducing sand extraction impacts with existing standards and best practices.

At current infrastructure production rates, avoidance is a challenge and alternatives cannot yet substitute a significant share of the 2.7 billion tonnes of aggregates demand in Europe, let alone the 20 billion tonnes in China. The emphasis must be on reducing natural sand extraction and its impacts in the near term.

Figure 3. Suggested hierarchy of available solutions



3.1 Avoiding unnecessary consumption

Society can make more efficient use of sourced aggregates through land use planning, and pursuing alternative infrastructure and building design and construction methods. The goal of this strategy is reducing unnecessary construction. The second is avoided use of cement and concrete where possible, so that demand for natural sand is reduced to responsible levels. Available solutions identified for avoiding unnecessary expansion of built environments or use of concrete in construction include but are not limited to:

- **Spatial planning for compact urban growth** where total resource requirements are reduced. One example of how this is achieved is compact city policies and performance indicators (OECD, 2012).
- **Avoiding surplus construction projects,** such as those for speculation or prestige. The Republic of Ireland is a clear example. Ireland experienced a period of economic growth from 1992 to 2007 which led to, among other outcomes, an unprecedented speculative investment in the domestic housing market. Years after the 2007 recession, 'ghost estate' residential developments were left empty and often unfinished (O'Callaghan et al., 2014). These are wide spread practices. In Dubai, the Burj Khalifa tower dominates at 828 metres, but this is clearly for prestige as 31% of office space was vacant in the centre of Dubai in 2014 (Peduzzi, 2014).
- **Employing green infrastructure in place of built infrastructure** where possible. The US EPA (2010) illustrates ten municipal-level examples of green infrastructure approaches to managing stormwater events across the United States (also, See Box 4: Case Study – Scaling the use of permeable pavements).
- **Substituting traditional concrete where possible** in building design with traditional materials like timber, and non-traditional options emerging from materials sciences innovation (Brownell, 2019).
- **Optimising concrete mixes to increase resource efficiency and lifespan** of concrete materials (Saha et al., 2018) (noting CO_2 emission concerns with cement production).
- **Investing in infrastructure maintenance and retrofitting** rather than demolishing old buildings to extend the lifetime of the current built environment. Some studies suggest adaptive reuse is attractive to investors and urban planners because it is profitable and effective at reducing abandoned or neglected urban areas (Bullen, 2007; Stas, 2007).
- **Reviewing and verifying technical standards for construction projects** to ensure appropriate quality of sand is being used in building projects (known as "over-design" in the engineering sector) (Orr et al., 2019).

Avoidance of irresponsible sand consumption must be designed-in to our infrastructure projects, construction projects and industrial products from the beginning. In some cases, this requires crossing some new frontiers in infrastructure design and engineering. In others, we already have long experience to draw from, like land use and spatial planning have which is well established in European countries (Albrechts & Balducci, 2013) and the exciting focus on green building design and construction emerging in architectural sectors in recent years (Kibert, 2016).

One caveat needs to be considered. As construction design is altered, new environmental and social risks are created. For example, for example replacing concrete construction with timber construction increases pressure on forested regions. For this reason, sustainable compact urban planning is the preferred solution. A key priority is to mainstream sand resource policy, planning and management into on-going sustainable cities and sustainable infrastructure initiatives, though the time horizon for impact on the ground is a long-term one.

Box 4: Case study - Scaling the use of permeable pavements

Ever-expanding paved surfaces accompany ever-growing cities. When rain falls on impervious paving, that water flows across the surface of the land. With large volumes of rainfall, urban floods become more likely and more severe. Even moderate rainfalls can result in significant erosion and water pollution as any fuel, oil or chemical substances are washed into rivers, lakes, and coastal waters.

Permeable pavement (sometimes called porous pavement) is one example of green infrastructure that replaces traditional concrete and asphalt to allow for absorption and infiltration of rainwater and snow melt in urban environments. It is used in cities around the world, particularly in new cities projects in China and India to reduce surface water runoff volumes and rates by allowing water to infiltrate soil rapidly, helping to reduce flooding while replenishing groundwater reserves.

In many cases, permeable roadways, pedestrian walkways, playgrounds, parking zones can also act as water retention structures, reducing or eliminating the need for traditional stormwater management systems. Vegetated surfaces in cities are also allowing water absorption, store CO2 and have esthetical value. Additional proven benefits include improved water quality, reduced pollutant runoff into local waterbodies, reduced urban heat island effects (great advantage for adaptation to climate change), lower cost of road salting (in cold environments), among others. Less noted is the indirect contribution to reduced demand for natural sand both in constructing these permeable surfaces, and in reducing the need for built drainage systems.

Most permeable pavement designs – porous (or pervious) concrete, interlocking pavement slabs, crushed rock and gravels, or clay, amongst other materials – do not use fine aggregates (sand). For example, pervious concrete is 15-25% porous space made by mixing coarse aggregate materials, cement or cement-like additives (i.e. bottom ash or fly ash) and water with little or no sand, depending upon the strength of concrete required. Recent experimentation has shown that introducing end-of-life tyre aggregates can increase flexibility of rigid permeable pavement systems, and with that their capacity to cope with ground movement or tree root systems. New compositions are being developed to improve strength and allow for heavier weight loads. And as each design issue is resolved, the opportunities for scaling increase

Sources: Scholz & Grabowiecki (2007); Center for Neighborhood Technology (2010); Admute et al. (2017) ; Disfani et al. (2018); Wang et al., (2018); Yuan et al., (2018).

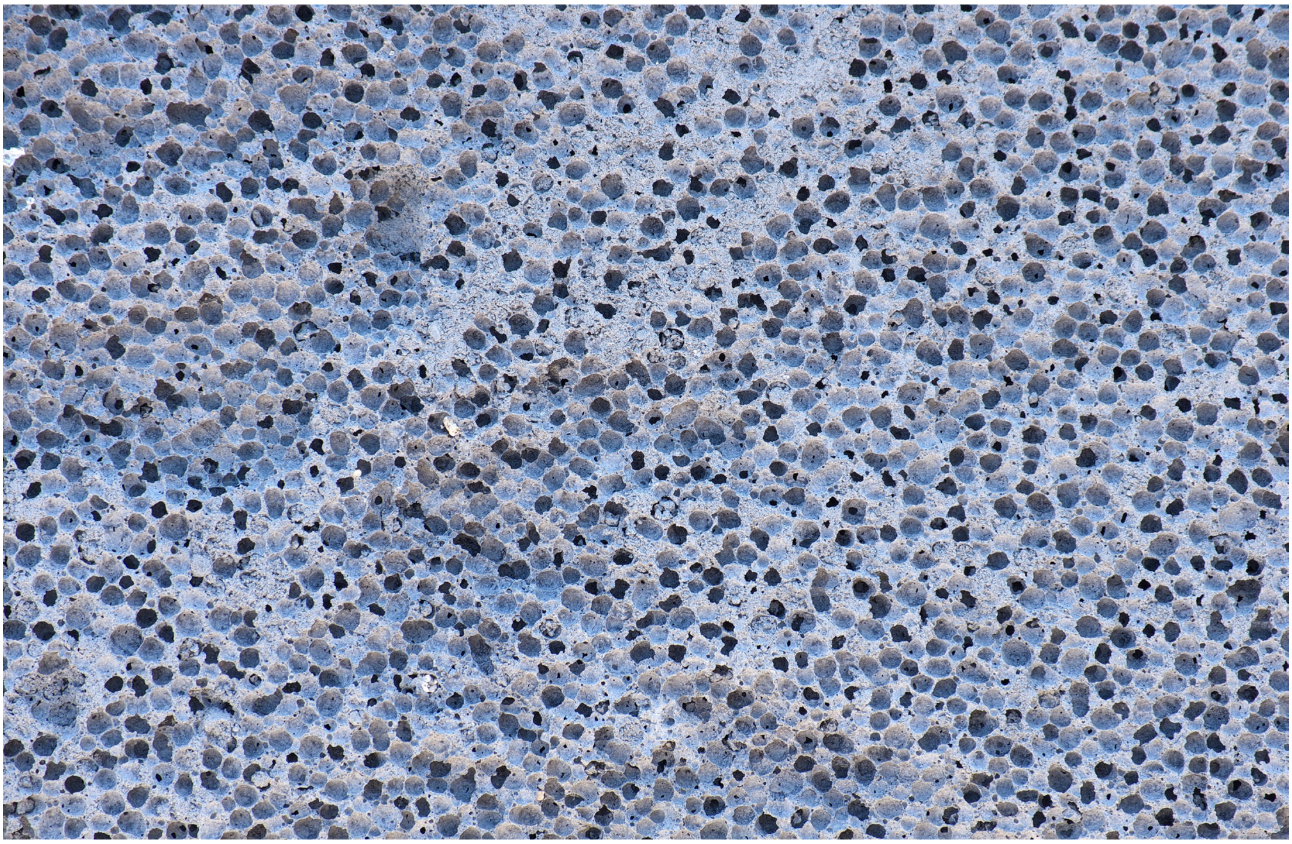
3.2 Using recycled and alternative materials to replace natural sand in construction

Where construction or traditional cement cannot be avoided, reduction of natural sand use can be achieved through some tried and tested, as well as new emerging technologies and materials. Experimentation has led to a wide variety of "green concrete" forms such as bottom ash or fly ash concrete, ultrahigh performance concrete, geopolymer concrete, lightweight concrete (Liew et al., 2017). Table 1 provides some recent examples of available solutions which can be summarised as:

- **Reusing waste aggregates** on construction sites.
- **Recycling concrete** from waste asphalt.
- **Substituting fine aggregates (sand) and coarse aggregates (gravel) in concrete production** with materials like:
  - Waste by-products of other processes, for example, fly ash left over after waste incineration, waste foundry sand;
  - Waste by-products of other processes, for example stainless steel slag, coconut shells, sawdust;
  - Desert sand fine sand aggregate in concrete.
- Manufacturing fine and coarse aggregates by recycling construction and demolition waste material.
- Innovating on concrete designs to increase materials efficiency and environmental performance, with:
  - Foamed concrete
  - Geopolymer concrete

Table 1: Some recent examples of studies on substitute materials to traditional concrete

Authors	Year	Document Title	Country
Gökçe et al.	2019	Effect of fly ash and silica fume on hardened properties of foam concrete	Turkey
Doğan-Sağlamtimur	2018	Waste Foundry Sand Usage for Building Material Production: A First Geopolymer Record in Material Reuse	Turkey
Mohammadinia et al.	2018	Mechanical behaviour and load bearing mechanism of high porosity permeable pavements utilizing recycled tire aggregates	Australia
Swamynadh & Muthumani	2018	Properties of structural lightweight concrete containing treated oil palm shell as coarse aggregate	India
Yuan et al.	2018	Environmental and economic impacts assessment of concrete pavement brick and permeable brick production process - A case study in China	China
Shi et al.	2018	Sustainability assessment for portland cement concrete pavement containing reclaimed asphalt pavement aggregates	United States
Bhardwaj & Kumar	2017	Waste foundry sand in concrete: A review	India
Shi et al.	2017	Mix design formulation and evaluation of portland cement concrete paving mixtures containing reclaimed asphalt pavement	United States
Aslam et al.	2016	Benefits of using blended waste coarse lightweight aggregates in structural lightweight aggregate concrete	Malaysia
Prasad et al.	2016	Partial Replacement of Coarse aggregate by Crushed Tiles and Fine aggregate by Granite Powder to improve the Concrete Properties	India
Shreekant et al.	2016	Utilisation of Mine Waste in the Construction Industry – A Critical Review	India
Salman et al.	2015	Construction Materials from Stainless Steel Slags: Technical Aspects, Environmental Benefits, and Economic Opportunities	Belgium
Siddique et al.	2015	Comparative investigation on the influence of spent foundry sand as partial replacement of fine aggregates on the properties of two grades of concrete	India
Aggarwal & Siddique	2014	Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates	India
Meddah et al.	2014	Use of shredded rubber tire aggregates for roller compacted concrete pavement	Algeria
Singh and Singla	2014	Utilization Of Waste Ceramic Tiles As Coarse Aggregate In Concrete	India
Shafigh et al.	2014	Structural lightweight aggregate concrete using two types of waste from the palm oil industry as aggregate	Malaysia
Thomas et al.	2014	Strength, abrasion and permeation characteristics of cement concrete containing discarded rubber fine aggregates	India
Note: This table is not a product of a systematic review.			



Lightweight foamed concrete is a substitute material for traditional concrete in building construction

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Green concrete innovations are being driven by a variety of factors including the drive to reduce green-house gas emissions by nation states and private actors, resource costs and, at times, the search for economic uses of waste by-products (Liew et al., 2017).

Some countries already have high aggregate recycling rates because of virgin aggregates costs (Germany recycles 87% of its waste aggregates[4]). However, it is the intersection of materials cost minimisation pressures in construction projects and locally-available waste streams that seems to create some key enabling conditions for substitution away from primary aggregates. For example, in India there are cases of used non-toxic municipal waste as a replacement for aggregates in road-building, as well as the use of waste foundry sand used (Siddique et al. 2004, 2015), waste rubber (Gupta et al., 2014), waste tiles (Singha & Singla, 2014) to produce concrete. Iraqi researchers have experimented with waste plastic in concrete mixtures (Ismail & Al-Hashmi, 2008). Oil palm kernel and coconut production waste has been tested as replacement coarse aggregate in Malaysia (Shafigh et al., 2014) and Nigeria (Emiero & Oyedepo, 2006). The spread of waste-to-energy solutions in response to growing waste production around the world, shrinking landfill space availability and, in some countries, landfill quotas or taxes, offers opportunities at perhaps an even greater scale (See Box 5, Case study : Manufactured aggregates from municipal Solid Waste Incineration bottom and fly ash by-products). Where the cost of sand and aggregates is low, extraction taxes have been put in place to incentivise reduction of primary aggregates and support increased use of recycled aggregates (EEA, 2008). It is worth noting that such economic instruments can have perverse consequences like creating or supporting illegal aggregates extraction and trade, as has been seen in waste management in Europe following introduction of landfill levy schemes (Dunne et al., 2008; United Nations, 2012; Europol, 2018).

Box 5: Case study – Manufactured aggregates from Municipal Solid Waste Incineration bottom and fly ash by-products

Municipal solid waste is classified in various ways in different jurisdictions but typically refers to the mixed waste stream produced everyday by households, businesses and schools. It contains paper, plastic, metal, glass, clothing, furniture, end-of-life electrical appliances and food waste. Best practice is to reduce, reuse, compost and recycle this waste, ensuring that as much waste as possible is diverted from landfill sites. (When unmanaged, landfill sites are a source of environmental pollution and human health risks. It is an uneconomic use of land in urban areas, and can generate strong protests from people living in close proximity because of environmental, human health and social concerns).

Municipal waste incineration is considered a form of recovery called Waste-to-Energy when it used to generate energy. Controlled burning of municipal solid waste converts waste into heat, ash and flue gas. The heat is used to generate steam for electricity production, as a process steam in nearby industrial zones, or in some cases to provide district heating services. The ash by-product is either collected in the flue (fly ash) or at the bottom of the furnace (bottom ash). Fly ash is composed of fine particles captured by filtration technologies before flue gas exits incinerator chimneys. Bottom ash is the coarse residue left on the grate of waste incinerators in a mix of ash, ceramics, slags, glassy material, ferrous metal – elements that did not burn thoroughly in the combustion process.

There are both economic and environmental incentives to commercialise this waste stream. Depending on combustion control system design and efficiency, incineration residues can be as high as 15% of the original municipal solid waste volume treated and still requires disposal. Moreover, bottom and fly ash can contain heavy metals and dioxins res (again depending on combustion system efficiency) that can cause serious environmental and human health risks if disposed off improperly. Some options for good disposal include bottom ash as an aggregate for road base, asphalt and in cement for construction. Fly ash, and hybrid mixtures of bottom and fly ash, can be used in producing glass, ceramic and as an additive in mortar.

It is the scale of the Waste-to-Energy market that makes these waste by-products interesting as a manufactured aggregate alternative to primary sand and gravel use. The global Waste-to-Energy market is expected to maintain its steady growth to 2023, when it is estimated it would be worth US$40 billion. Europe and Japan have long used this technology, and it is expanding in the United States. However, the fastest market growth has been witnessed in China, which doubled its Waste-to-Energy capacity in the period 2011-2015. In fact, the world's largest waste-to-energy plant is to be built in Shenzen, China to treat up to 5,000 tonnes of waste per day.

[4] German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Retrieved from: https://www.bmu.de/en/topics/water-waste-soil/waste-management/types-of-waste-waste-flows/construction-waste/, last accessed 28 January 2019.


Workers on a road construction site

3.3 Reducing extraction impacts through implementing existing standards and best practices

Many existing standards and best practices already exist that do not include sand extraction and consumption currently, but could provide the basis of a coherent framework for improved global sand governance if adjusted. The following available solutions are relevant, to varying degrees, in global sand resources governance and management:

<table>
<tr>
<td>Normative / legal environmental and social standards at global level</td>
<td>The Sustainable Development Goals: These are not legally binding and do not explicitly address sand sustainability challenges, but the Goals are setting new norms relevant to addressing these issues.

International conventions: These are legally binding international law for signatory countries and spur these national governments to create national legal frameworks and regulation, economic instruments and voluntary mechanisms. An initial list (non-exhaustive) produced through expert discussions and further desktop research identified the following international laws as potentially relevant to a) identifying ‘no-go’ zones for sand resource extraction, b) minimum practices for sand extraction or c) legal rights and/or best practices for sand extraction impact assessment. In order of date of entry into force:
• Convention for the International Council for the Exploration of the Sea (ICES), 1964
• Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar), 1971
• Protection of the World Cultural and Natural Heritage (World Heritage Convention), 1972
• Environmental Impact Assessment in a Transboundary Context (Espoo), 1991
• Law of the Sea (UNCLOS),1992
• Convention on Biological Diversity (CBD), 1992
• Protection and Use of Transboundary Watercourses and International Lakes (International Watercourses Convention),1992
    ◦ Berlin Rules on Water Resources, 2004
• Convention to Combat Desertification (CCD),1994
• Convention on the Law of the Non-Navigational Uses of International Watercourses, 1997
• Protocol on Strategic Environmental Assessment (SEA Protocol), 2003</td>
</tr>
</table>

Normative / legal environmental and social standards at regional level	**Regional conventions:** These are legally binding international law for signatory countries and provide frameworks for these national governments to create national policies, laws and regulations, economic instruments and voluntary mechanisms. An initial list produced through expert discussions and further desktop research identified the following (non-exhaustive) list of international agreements relevant for standards and best practices for sand extraction covering transboundary seas, rivers and some terrestrial landscapes. Transboundary freshwater and marine zone governance and management mechanisms overlap significantly with sand extraction geographies and impacts. **Regional cooperation on development, security issues** • Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, 1986 • Sanya Declaration (for peace, security, development and cooperation between BRICS countries), 2011 **Marine ecosystems** • Protection and Development of the Marine Environment and Coastal Region of the Mediterranean Sea Barcelona Convention, Barcelona, 1976 • Convention for Co-operation on the Protection of the Marine Environment from Pollution, Kuwait, 1978 • Protection of the Marine Environment and Coastal Area of the South-east Pacific, Lima, 1981 • Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, Abidjan, 1981 • Conservation of the Red Sea and the Gulf of Aden Environment, Jeddah, 1982 • Protection and Development of the Marine Environment of the Wider Caribbean Region, Cartagena de Indias, 1983 • Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region, Nairobi, 1985 • The Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (WCR) (Cartagena Convention), 1986 ◦ Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region, 2000 • Protection of the Marine Environment of the North-east Atlantic OSPAR Convention, Paris, 1992 • Protection of the Marine Environment of the Baltic Sea Area 1992 Helsinki Convention, Helsinki, 1992 • Protection of the Marine Environment of the Caspian Sea, 2003 **Freshwater Ecosystems** UN-Water states there are over 3,600 treaties related to international water resource governance and management.[5] For sand extraction, some relevant examples include: • Indus Water Treaty (India and Pakistan), 1960 • Mekong River Agreement (Laos, Thailand, Cambodia, Viet Nam), 1995 • Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) region, 1995 • Nile Basin Initiative (Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, The Sudan, Tanzania and Uganda. Eritrea participates as an observer), 1999

[5] See UN Water (nd), Available at: http://www.un.org/waterforlifedecade/transboundary_waters.shtml, last accessed 28 January 2019.

In addition to the global and regional instruments listed above, sectoral-based global initiatives, national legislation and voluntary schemes contribute to a starting point for sand-extraction standards and best practices:

Extractives sector	Existing extractives sector regulations, standards and best practices can be adapted to sand extraction activities. IISD (2018) identifies the Initiative for Responsible Mining Assurance as a top performer encompassing pre-existing global and regional standards covering worker health and safety, social and environmental domains.[6] Lessons can be learned from the extensive experience already developed on improving environmental and social performance in mining activities (*See* Case study 3). UEPG (Europe) members run several projects on responsible aggregates extraction.[7] Going one step further, environmental enhancement after mining activities cease is currently being explored in Europe. The Belgian project "Life In Quarries", co-financed by the European Commission, promotes dynamic biodiversity management in aggregates mines with some good results: 90% of all eagle owls and 94% of sand martins in Wallonia nest in active sites.[8]
Engineering & Construction sector	Best practices in the engineering sector may be a part of the problem because at times they result in over design and waste in construction (Orr et al., 2019). Engineering requirements can be too strict for the final purpose to which sand resources are being used. Or can be applied in a risk-averse behaviour that is a barrier to alternatives becoming mainstream in engineering and construction practices. Addressing over-design issues through voluntary standards and certification schemes can be part of the solution, though success depends on careful design of such schemes. One example in operation is the Cement Sustainability Initiative (Previously under the World Business Council for Sustainable Development, transferred to the Global Cement and Concrete Association in early January 2019[9]). Another is the BES 6001 Responsible Sourcing of Construction Products certification system in the United Kingdom.[10]
Water, Conservation, Environmental management sectors	Domestic regulations for coastal zone management, water management, freshwater and marine fisheries management and land use planning are relevant to informing extraction permits (where such system are in place), to controlling illegal sand extraction and to determining sustainable sediment removal limits. In addition, nationally-legislated Key Biodiversity Areas, World Heritage Sites, National Parks, biodiversity reserves, terrestrial and marine Protected Areas identify regions where extraction should be avoided. Some conservation projects offer opportunities for better defining if sand extraction can ever be sustainable or just responsible. For example, sediment dredged to prevent river blockages has been recycled to support new wetland creation in the Mississippi river (Powers & Duffy, 2018). Wetlands International are pioneering in this field of sustainable dredging with the Benin Ramsar site also[11].

Sea turtle hatchling crawls to the sea

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6 See Initiative for Responsible Mining Assurance (n.d.): https://responsiblemining.net/.
7 See Safequarry.com (n.d.): http://www.safequarry.com
8 See Life in Quarries (n.d.): www.lifeinquarries.eu
9 See Global Cement and Concrete Association (n.d.): https://gccassociation.org/,
10 See BSI Group (n.d.): http://www.bsigroup.com/en-GB/bes-6001-responsible-sourcing-of-construction-products/
11 See Ramsar Benin Information Site (n.d.):https://www.ramsar.org/wetland/benin.

Box 6: Case study 3 – Learning lessons for mitigating sand extraction impacts in Suriname

Braamspunt is a biodiverse coastal area 15 km from the capital of Suriname, Paramaribo, on the Northeastern Coast of South America. This sandy beach on the eastern shore at the mouth of the Suriname river is in a Multiple Use Management Area (MUMA) designated under the 2010 Integrated Coastal Zone Management plan. This plan aims for balanced economic development while preserving ecological values in this landscape of pristine mangrove forest. Among fishing, tourism and other uses, Braamspunt is a critical coastal defense against flooding and erosion for Paramaribo North at a time when natural defenses have been undermined by removal of mangroves. It is also home to nesting grounds of leatherback sea turtles and green sea turtles, considered vulnerable and endangered by the IUCN Red List of Threatened Species respectively. Yet, until recently active sand extraction took place on the beach, accelerating the erosion of this already vulnerable sand spit.

Despite a previous temporary ban in 2015 and protests from environmental groups and citizens, the Ministry of Natural Resources gave concessions for sand extraction to four Surinamese construction companies in February 2017. This coincided with the beginning of turtle nesting season. These concessions were given out without the knowledge or consultation of the line ministry overseeing the MUMA, the Ministry of Ministry of Spatial Planning, Land and Forest Management. As Environmental and Social Impact . As Environmental and Social Impact Assessments are voluntary in Suriname, the local companies legally extracting sand were not required to evaluate their impact on the beach. Moreover, as part of the MUMA, the beach is not a legal protected area designated for conservation of biodiversity alone. Even though the turtle species themselves are protected, their nesting grounds at Braamspunt are not. Between 2015 and 2017, environmental groups sought an immediate halt to excavation at Braamspuntso so that protected species are not just protected on paper. The result would be that turtle nesting sites are automatically protected irrespective of where they are located (inside or outside a protected area). This will take time. Environmental and social impact assessments seen as a barrier to development, an additional cost burden on the private sector, and there are a lack of funds for enforcement.

With that in mind, local NGO Green Heritage Fund Suriname is aiming to learn lessons from what has worked on other legal and illegal extraction sectors such as forestry and gold and accelerate voluntary action while legislation, safeguards and enforcement catches up. One successful strategy in other responsible mining efforts outside of Suriname has been to get illegal extractors organised to request concessions that have already undergone environmental and social impact assessments financed by government agencies.

Sources: WWF (2016); Fritz (2017); Deltares (n.d.); Green Heritage Fund Suriname (n.d.); Nadine McCormick (IUCN), personal communication in writing December 2018.

Aerial image of a deep blue gravel lake in which sand is mined for the construction industry. *© Geogif /Shutterstock*

Key messages

A quick start for sand resource governance is possible if we work with the many available solutions and adjust existing legal frameworks, standards and regulations. However, some new standards and best practices are likely to be required in the near term to tackle sand extraction impacts.

Current legal frameworks are not sufficient considering the global outlook on aggregates demand and production. Existing international treaties, law, standards and best practices provide a foundation, but it is an incomplete.

Where addressed, sand extraction currently crosses extractives, water management, coastal zone management, biodiversity conservation legal systems and best practices. Importantly, sand extraction is not regulated in some countries. In other countries, sand extraction is regulated but trade-offs are made given other priorities such as the need for new infrastructure.

For example, in marine ecosystems, existing models predict the outer limit of beach-nearshore sand exchange. An agreed standard might advise against extraction inside this limit or advise appropriate assessment criteria if extraction is proposed within these limits. In a similar vein, the existing legal frameworks in freshwater systems focus on water allocation, water quality and security, cooperation, and development of the basin for energy and other economic purposes. A major gap related to sand resources and extraction impacts is sediment flow management.

Without an integrated view on the governance, planning and management of these resources, sand extraction risks falling between the cracks into informal, or even illegal practices.

4. Options for Action

4. Options for Action

Actions can be taken today by all stakeholders to achieve responsible extraction, reduced consumption and normalisation of alternatives. International organisations, national and local governments, private sector companies, civil society groups and local communities all play critical roles in governance of sand resources. Three main actions for faster implementation of available solutions were identified in the 11th October roundtable discussion and subsequent consultations:

1. Strengthen standards and best practices to curb irresponsible extraction
2. Invest in sand production and consumption measurement, monitoring and planning
3. Establish dialogue based on transparency and accountability

The options are not prescriptive, nor comprehensive – but they are critical next steps that can be taken.

4.1 Strengthen standards and best practices to curb irresponsible extraction

Ideally, each country should have appropriate legal frameworks and regulations through which either a permit or a license is required for sand extraction activities, and seek to reduce irresponsible and illegal extraction activities. Every case is different, however.

Firstly, sand extraction occurs in a range of geological (sand supply) situations. 'Go' zones that are appropriate for extractive practices are context-specific and so-called "produce and use locally" principles can only work where sand is locally available.

Secondly, the results of preventative and protective measures proposed by responsible extraction depend upon the significance of the impacts that may arise from extraction in these locations. A developed, indigenous regulatory regime will be able to determine the acceptability (or otherwise) of extraction – and there are good examples of this working in both UK and Europe.

Thirdly, local governance differences present a challenge to replicating legal frameworks across in countries. For example, Europe is very rich in sand and gravel and has developed effective management systems over 40 years of exploitation that is not comparable to circumstances in other global regions. However, there are opportunities to learn from these experiences, which may accelerate the transition towards robust policy, planning and regulatory regimes.

National laws are needed, but there are limitations to be dealt with involving enforcement and transboundary regulation. Providing guidance on good practice to existing industry is a clear starting point, but to implement well localised economic, political, social and cultural factors must be taken into consideration. These include transfers of legislative frameworks; voluntary standards; skills; knowledge; established customs and traditions, and best practices. The practical solution will be to work within international standards, but localise recommended rules, legislation, and voluntary efforts appropriately.

Recommendations:

Prepare guidelines for governing, planning and managing sand extraction at the regional and international legal scale and support countries to customise these for national policy, law and regulation where these do not currently exist. The principle aim should be to build enabling conditions for the introduction of responsible sand extraction and use of alternative options to natural sand as rapidly as possible. A first step may be to build consensus on classification of global sand resources and impacts. The UN Economic Commission for Europe (UNECE) Committee on Sustainable Energy and its subsidiary bodies on anthropogenic resources classification for sustainable resource management under the 2030 Sustainable Development Agenda may provide some early momentum for such an initiative (United Nations, 2018).

Commission review and analysis of existing law and voluntary initiatives at global, regional and national levels to identify critical regulatory gaps and 'low hanging fruit' opportunities for integrating sand into established frameworks and programmes. This list provided in Section 3: Available Solutions provides a starting point for this activity.

Raise awareness through commissioning rapid scenario analyses identifying the role of sand and gravels in building and sustaining particular regional and national ecosystems, societies and economies, including potential futures and thresholds of natural sand extraction and use beyond risks are increased. Existing methods, data and collaborative research efforts on systems analysis for aggregates analysis in manufacturing systems (See Tesfamariam & Lindberg (2005) as one example) and green economy and circular economy analyses are directly applicable to this effort[12].

4.2 Invest in sand production and consumption measurement, monitoring and planning.

Countries and rivers for which there are high quality studies of sand extraction impacts are not, in fact, the countries where extensive illegal sand extraction is increasingly reported by domestic and international media (WWF, 2018a). While we do not have to wait for perfect data before making choices, improving available knowledge is a fundamental contribution to sand resource governance, planning and management. We need some basic information flows on sand extraction, its impacts and consumption that are specifically geared to support decision-making.

We have a poor understanding of sand production and transport processes in particular. The geological context for sand resources is important – not just knowing the origins of deposits but also understanding the current physical processes that act upon them. Sediment transport pathways are often largely ignored in research and decision support information. The result is that downstream and cross-boundary impacts of disrupting sediment flows are not considered where formal environmental impact assessments are undertaken.

Secondly, traceability of sand in supply chains within the construction sector is extremely weak. How can we have responsible consumption without tracing and differentiating responsible and irresponsible sand sources? The Roundtable on Sustainable Palm Oil (RSPO) example for palm oil tracing might be a source of lessons. In addition, data sharing between international agencies, national governments and national and multinational companies is critical but difficult given the lack of accurate reporting.

Thirdly, environmental monitoring programmes often focus on state and input- output monitoring and reporting, but have more difficulty monitoring outcomes in such a way that creates feedback for organisational leaders in their decision-making. This is especially true for environmental and social outcomes with time horizons greater than standard project or programme cycles, or impacts that are experienced far from the source of the problem.

The best measurement, monitoring and data visualisation systems cannot replace good governance and leadership; but they can be designed to help these behaviours emerge however (See Table 2).

12 Some useful entry points on Green Economy and Circular Economy scenario analysis are the Green Growth Knowledge Platform (http://www.greengrowthknowledge.org/about-us); the EU-funded Circular Impacts project (Woltjer, 2018)

Table 2: Why undertake sand resource measurement, monitoring and evaluation?

Purpose	Relevance
Benchmarking and monitoring	Indicators provide a quantitative baseline of the state of the environment and related socioeconomic factors that are integral to sand resource production and consumption, or are impacted by these processes. Baseline and thresholds offer a means of monitoring changes or progress towards set goals.
Problem identification & goal-setting	Data on sand consumption at project and national levels is needed to set appropriate goals for replenishment, extraction rates and consumption at appropriate scales and levels. Monitor replenishment rates, extraction rates (and associated morphological evolution of the rivers and coasts), and materials supply flows and costs can help identify problems and opportunities to improve governance and management.
Prioritising interventions & planning	Choices in priority-setting can include short or long-term interventions, as well as real-time decisions on resource allocation and management, responding to emerging or pressing issues. Data and related analysis supports future planning and policy-setting.
Facilitating cross-sectoral & cross-scale dialogue	Measurement and monitoring in sustainability encourages, if not requires, integrating knowledge from different related sectors. In this case, the process is just as important as the resulting datasets and analysis. Data collection and synthesis is an opportunity for dialogue among different stakeholders, helping them to jointly establish goals, identify problems, and negotiate the trade-offs that are implicit in balancing competing uses and priorities within ecosystems. Eventual monitoring results may help to renegotiate and change institutions to improve ecosystem management and local communities' wellbeing.
Increasing public awareness	Indicators summarise a substantial amount of data and information into a coherent narrative are often useful as a public communication tool to raise awareness on progress towards or threats to overall welfare.
Facilitating Transparency & Accountability	To measure the effectiveness of chosen policies, providing transparency and accountability, particularly if the public has been involved in the goal-setting process. Building open knowledge bases on sand availability and property rights may also help assess claims to extract sand resources. In many cases sand extraction locations are politically decided and not necessarily underpinned by geology or responsible sourcing.
Revenue raising	In some contexts, accurate accounting is a precursor to recovering local or regional mining royalties.

Sources: 11 October 2018, Expert Roundtable discussions; Reviewers' input

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Recommendations:

Commission basin-wide and coastal region studies to determine quotas for sand and sediment inflows to river deltas and coastal beaches so that replenishment is adequate for river forms, deltas and beaches to be maintained. This implies understanding the geological origins of the resources in question, where these resources occur, and how they relate to modern geological processes to establish baselines. This requires a) basin-wide and coastal sediment budgets (identifying natural sources by grains size, and natural and human-made sinks b) a quota for how much each specific river can produce and where extraction sites should be located c) monitor extraction rates and their impacts.

International community organisations with mandates and access to relevant data could collaborate to create a rapid information synthesis, design a long-term monitoring programme and produced a rapid assessment tool in the context of existing processes in EIA, SEA, Responsible Mining and water governance. Coordination across established economic, social and environmental monitoring programmes could help quick start a global, regional and national sand resource monitoring programmes. UN agencies, in collaboration with private sector partners and national governments, are well-placed to design a cost-effective global monitoring programme for sand resources. Global level programmes with linkages to sand resources include:

- HydroSHEDS (WWF, USGS)[13]
- Protected Planet (United Nations Environment Programme, WCMC, IUCN)[14]
- Ramsar Site Information Service (Ramsar)[15]
- Transboundary Waters Assessment Programme (United Nations Environment Programme, GEF)[16]
- UN Comtrade (UNTAD)[17]
- Water Risk Filter (WWF) [18]
- World Environment Situation Room (United Nations Environment Programme, GRID Geneva)[19]
- WRI Resource Watch Database[20]
- WWF Sight[21]
- Some national reporting regimes for production and use of sand and gravel already exist. For example:
    - An Aggregates Monitoring Survey is undertaken by the British Geological Survey on behalf of British Government.[22]
    - For marine production, the marine mineral owner (The Crown Estate) publishes annual reports detailing total tonnage dredged and to where this was supplied. Where marine extraction activities occur, 'black box' Electronic Monitoring Systems are a common requirement.[23]

Review and evaluate implementation of established social and environmental safeguards and impact assessment procedures and identify key performance indicators to be included for the treatment of sand sustainability issues. Such a review could include global, regional and key national Environmental Impact Assessment and Strategic Environmental Assessment and responsible extractives standards to understand if these are being applied at the right scale, (i.e. landscape vs. project vs. site-specific scales) and whether they have included sand appropriately.

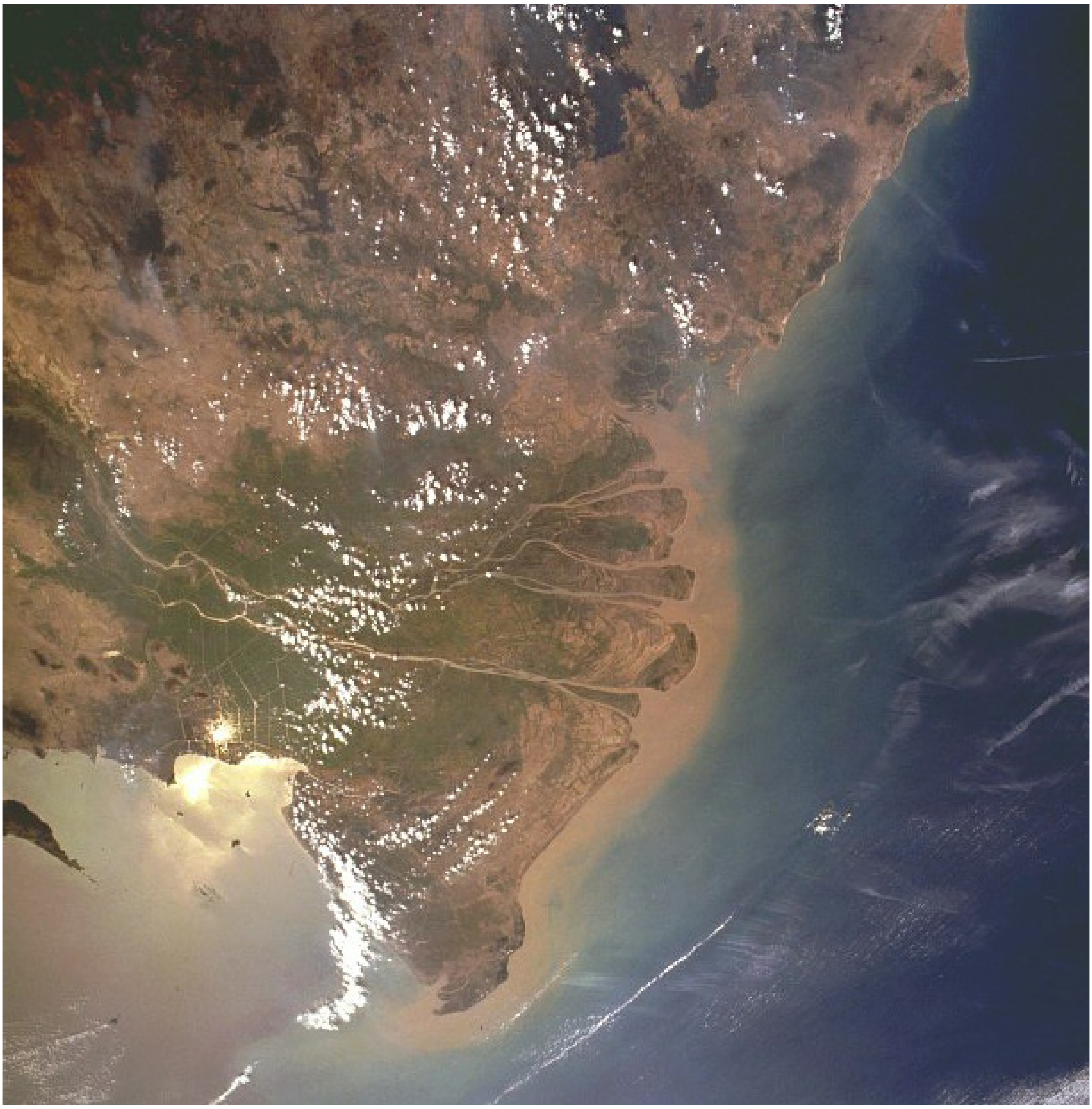
4.3 Establish dialogue based on transparency and accountability

A focus on constructive dialogue and rapid lesson learning is needed to create awareness and voluntary action today. We have an opportunity to act early to prevent avoidable environmental damage and biodiversity loss while transitioning to a new pathway of responsible sand extraction and consumption. We have the experience and existing international environmental treaties, industry standards and best practices, and international, regional and local civil society communities to make a start in the right direction. International community, governments, industries, civil society – all relevant stakeholders (See Table 3: Stakeholders in sand and sustainability issues) – need to participate in developing constructive policies, regulation and voluntary actions.

13 http://www.hydrosheds.org/
14 https://www.protectedplanet.net/
15 https://www.ramsar.org/document/using-the-ramsar-sites-information-service
16 http://twap-rivers.org/
17 https://comtrade.un.org/
18 http://waterriskfilter.panda.org/
19 http://www.uneplive.org/situation
20 https://www.wri.org/resource-watch
21 https://www.wwf.org.uk/updates/wwf-sight-conservation-intelligence
22 https://www.thecrownestate.co.uk/media/2484/marine-aggregates-statistics-2017.pdf.
23 https://www.gov.uk/government/collections/minerals.

Responsible industry players are committed to phasing out illegal extraction and use of river and beach sand; and they have significant power to drive good practices on sand resource consumption and production. While the number of small and informal operations in sand extraction are large, there are thought to be around 10 large multinational players that are significant "pinch points" for influential action in the sand value chain:

- Sibelco Group, Belgium
- Heidelberg Cement, Germany
- CRH, Ireland
- Holcim, Switzerland
- Chinese Harbour & Construction Ltd., China
- Boskalis, Netherlands
- Van Oord, Netherlands
- Deme, Belgium
- Jan De Nul, Belgium & Luxembourg
- Great Lakes Dredge & Dock Company (GLDD), United States of America



The Mekong Delta and surrounding coastal areas in Viet Nam depend on sand inputs from the Mekong River. *Photo credit: NASA satellite image, taken February 1996*
https://commons.wikimedia.org/wiki/File:Mekong_delta.jpg

Box 7: Private sector voluntary action on sand and sustainability standards in the United Kingdom

The United Kingdom has some interesting examples of private sector voluntary action on sand. The UK mineral industry published a Minerals Strategy in 2018 which sets out the social, environmental and economic issues that will need to be addressed to ensure sustainable supplies of minerals to 2050. The UK marine industry published a good practice guidance for marine aggregate extraction in 2017, endorsed by the national government. The industry has also been reporting on seabed dredging for 20 years as part of its commitment to transparency. The Aggregates Levy, a tax placed on sales of primary aggregates in the UK (sand, gravels & crushed rock – both land and marine), was used to fund research to develop understanding and improve practices to minimise environmental effects of extraction.
In terms of terrestrial operations, an awards scheme is in operation to champion and showcase restoration and biodiversity opportunities following extraction projects.

Sources: Newell & Woodcock (2013); British Marine Aggregate Producers Association (2017; 2018); Mineral Products Association (2018); Mineral Products Association (n.d.); UEPG Biodiversity (n.d.)

Table 3: Stakeholders in sand and sustainability issues

Stakeholder group	Relevance
Local communities	Individuals and communities living close to extraction sites live with the impacts of irresponsible sand extraction; they may also be engaged in the sector as owners or employees.
Local sand extraction companies	Directly engaged in extractive activities in rivers, on beaches, in quarries; where pursued legally, this implies engaging with permitting authorities to identify preferred sites for extraction.
Transporter, Trading companies	Middle men in the sand supply chain.
Engineering & construction firms	Directly engaged in sourcing crushed rock, sand, gravels and using these materials in construction activities.
Municipal / sub-national governments	In some cases, local government entities have the authority to issue permits for extraction activities; also the responsibility to implement regulations and plans for local spatial planning, economic development, water management, fisheries management, environmental management. Sub-national administration procurement for public infrastructure and buildings may play a role in driving demand for local sand resources. They may also play a role in local monitoring and reporting.
National governments	Line ministries with responsibilities for natural resources, mining and extractive industries may be the authority to issue concessions or permits or bans for extraction activities. Other national line ministries hold the responsibility to determine development pathways, support equitable development and local livelihoods under which sand extraction livelihoods may fall; uphold and implement environmental and social protection laws. National governments also play significant roles in public infrastructure procurement, national monitoring and reporting.
Transboundary cooperation platforms	These entities facilitate regional transboundary cooperation on economic development, joint management of ecological zones like shared water bodies (lakes, river basins, seas). In some cases, they may hold the authority for management decision-making on resource use, such as is the case for some river authorities. More generally, they may play a role on data monitoring
Multinational firms	Major consumers of crushed rock, sand and gravels in the sand value chain include cement firms and construction firms; a wide range of producers use industrial grade sand for manufacturing glass, pigments, engineered stone, etc.
Education & research institutions	Engineering and materials sciences experimentation and innovation for alternatives to concrete, cement. Capacity for socioeconomic, policy, management analysis to support decision-making on sand extraction legal and voluntary standards and best practices. These institutions also lead on education for future government policy makers, land use planners, engineers and architects.
Nongovernmental Organisations	International NGOs engaged in environmental and social issue-based advocacy globally, regionally and nationally; Peer support and capacity development for local and regional civil society groups; global awareness raising. Local NGOs lead on awareness raising and early-warning of irresponsible and illegal activities on the ground. They also lead on supporting local communities to defend their rights.
Inter-Governmental Organisations	Norm-setting, knowledge transfer, convening, consensus-building, synthesis research, global monitoring programmes.

Societies' demand for construction materials, and the need for this to be met in the most sustainable manner possible,

[24] WWF: Dr. Marc Goichot, personal communication in writing December 2018

is relevant to every nation. However, two nation states are likely to be pivotal for any positive action: India and China. China increased its concrete use by 540% in the last 20 years, exceeding the use of all the other countries combined (See Figure 4). Even as domestic consumption rates begin to stabilise, China-overseas investment in infrastructure development through the Belt and Road Initiative will drive demand for aggregates in approximately 70 countries. Furthermore, domestic demand in India is expected to drive strong future growth in Asia (Gavriletea, 2017). These countries are also the source of solutions when it comes to alternative materials (See Table 1 in Section 3. Available Solutions) and new building strategies. The Mining Engineers Association of India held a major national conference on urgent replacement of illegally-sourced sands by manufactured sands in August 2018.

Finally, local communities and civil society groups have a critical role to play through awareness raising, empowerment and organisation of citizens in extraction sites or affected by extraction (Anongos et al., 2012). In Cambodia, villagers living on the Mekong river started chasing away sand extractors when they saw the direct link between this activity and loss of agriculture land to river bank erosion.[24] As a second example, Awaaz Foundation campaigns against 'sand mafias' and their support to local communities seeking justice has resulted in real policy change in India (Awaaz Foundation, 2017).

Recommendations:

One key barrier on which to focus is the transparency of the extractives supply chain for aggregates. A positive step forward would be to integrate crushed rock, sand and gravels sourcing into the Extractive Industries Transparency Initiative (EITI) standard for published information on the oil, gas and mining industries25 At a minimum, a lessons learning analysis could reveal some key guidelines on how to establish transparency initiatives for the aggregates sector specifically.

The sand value chain needs to be better understood – including all stakeholders – to implement avoidance and reduction strategies well. What is the structure of sand value chains? How formal, informal and mixed are they? What are the financing structures underpinning sand demand and supply? These are some priority questions that need to be answered for assessing the business case, including full cost analyses and risk assessments, for alternative sources.

Cross-sector collective action platforms are needed. One suggested priority is exploration of cooperation mechanisms for managing water and sediments as a shared resources in a responsible manner for the long term. A second is collaborative design of processes to encourage financing of bankable sand for sustainable urban planning and infrastructure projects.

5. Conclusions

5. Conclusions

Sand production is not rocket science. At its most basic, it needs boats and pumps, shovels and trucks, hammers and rocks. The main limitation to responsible sand extraction is not technical; it is an awareness and governance issue. A paradigm of infinite sand resources still dominates. Challenging this is the difficult task ahead as we aim for a rapid yet smooth transition to more sustainable sourcing, while reducing consumption and demand in parallel.

To do this, we must first acknowledge the scale of the issue as one of the major sustainability challenges of the century. Most large rivers of the world have lost between half and 95% of their natural sand and gravel delivery to ocean. The damming of rivers for hydro-electricity production or irrigation is reducing the amount of sediment flowing downstream. This broken replenishment system exacerbates pressures on beaches already threatened by sea level rise and intensity of storm-waves induced by climate change, as well as coastal developments. "Sand mafias' are thriving, with activists against their activities being threatened and even killed. Sand and gravel is one of the largest extracted resources by volume, possibly one of the most profitable illegal traded while also being one of the least regulated. Yet awareness is very low, with media uncovering the scale of the impacts while science and policies are lagging behind

Large-scale multipronged actions are urgently needed to implement technical and institutional innovations designed at the scale of regional infrastructure projects, large river basins and their downstream connections to deltas and coasts and global construction materials markets. This will need to involve a wide range of players – public, private and civil society organisations – from local to global levels. A new frame for collaborative action is needed. Together, we can:

Build consensus through improved coordination and public awareness-raising at the global, regional and national levels on how much our current development trajectory is dependent on sand supply and the sustainability challenges this poses. This will involve developing understanding from many perspectives, as well as a vocabulary to define aggregates characteristics and their extraction impacts. We do not yet know the appropriate language and definitions to use in discussing this topic across the stakeholder groups. These definitions are needed for transboundary, cross-sectoral and cross-scale dialogues, institutionalising new technical standards and best practices, and establishing regulation.

Define what success looks like for sand production and consumption in sustainable development. As long as it is planned, regulated and managed appropriately, sand extraction can be responsible. It is about being aware of its resource potential and making the right choices from the very beginning in a knowledge-based resource management. It is about the right resources being worked in the right place and in the right way. This will involve identifying sand sources that might be harvested at a sustainable level and according to guidelines, and with the support of agreed standards, best practices and decision support tools, that are developed with inputs from all stakeholders.

Reconcile globally-relevant policies and standards with the local realities of domestic sand resource availability, local development imperatives and standards and enforcement realities. There are a wide range of experiences in the management and use of sand globally, reflecting the wide range of maturity in the regulations, controls and awareness of individual nations to these issues. Consequently, the principles of good practice derived from practical experiences and hard lessons are available and should be readily shared for customisation to new contexts.

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