This is the accepted manuscript of an article published as Nature 571, 29-31 (2019) at https://www.nature.com/articles/d41586-019-02042-4

Time is running out for sand

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What links the building you live in, the glass you drink from and the computer you work on? Sand. It is a key ingredient of modern life and yet, astonishingly, no-one knows how much sand there is or how much is being mined.

Sand and gravel are the most extracted group of materials, even exceeding fossil fuels[1]. Urbanization and global population growth are fueling an explosion in demand, especially in China, India and Africa[2]. Roughly 30-50 billion tonnes are used globally each year, mainly for making concrete, glass and electronics[3]. This pace exceeds that of natural renewal[4] and by mid-century demand may outstrip supply[2]. A lack of knowledge and oversight is allowing this unsustainable exploitation.

Desert sand grains are too smooth, so most of the angular sand that is suitable for industry comes from rivers (<1% of global land area)[8]. This extraction of sand and gravels has far-reaching impacts on ecology, infrastructure and the livelihoods of the 3 billion people who live along the world's rivers[3,5,6]. For example, sand mining on the Zhujiang (Pearl) River in China has lowered water tables, made it harder to extract drinking water and hastened riverbed scour, damaging bridges and embankments[6].

Most of the trade in sand is undocumented. For example, between 2006 and 2016, less than 4% of the 80 million tonnes of sediment Singapore reported having imported from Cambodia was confirmed as exported by the latter[7]. And illegal sand mining is rife in at least 70 countries[3]. Hundreds of people have reportedly been killed in battles over sand in countries including India and Kenya in the past decade, among them local citizens, police officers and government officials.

All these problems were highlighted in the May 2019 report on sand and sustainability by the United Nations Environmental Program (UNEP). The underlying reasons are too little data and a lack of policies supporting responsible consumption and extraction.

We now call upon UNEP and the World Trade Organization (WTO) to set up and oversee a global monitoring program for sand resources. Researchers need to establish accounting processes for sand flows and extraction – legal and illegal – from rivers, and bring the scale of the problem starkly to the attention of their peers, the public and policy makers. Local sand budgets and measures to promote responsible use must then be developed.

Scant data

Current global estimates of sand extraction undoubtedly far underestimate the actual total, and there are no reliable estimates of sand extraction, regionally or globally. Without such quantitative data, and knowledge of the rates of natural replenishment, it is impossible to plan a sustainable future for this vital resource. Most research on sediment starvation in rivers has focused on how dams block flows of sediment[10], and little academic attention has been given to sand mining[1,4]. For example, as of early 2019, only 38 of 443 scientific papers on "sand mining", identified in a search of the 'Web of Science' (wok.mimas.ac.uk), quantified sediment extraction.

There are few long term, basin-wide programs monitoring sediment. This is a product of technological limitations in quantifying sediment transport in river systems, the remoteness of many large river basins, and politically and industrially sensitive issues of data access and transparency.

Many large river basins also span several countries, making reporting and enforcing regulations and international laws difficult, such as the Mekong River that flows through China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam.

In many countries sand mining is unregulated, and may involve local 'sand mafias', with methods of extraction ranging from dredging boats and suction pumping, to digging with shovels and bare hands, both in daylight and during the night. In the developing world, where demand is greatest, it is mainly a small, informal industry, which is extremely difficult to monitor and control. Sand that is dredged from rivers using boats, also makes it hard to pinpoint the source, compared with material dug from shallow river beds and floodplain quarries.

International databases of the sand trade are too crude to track sustainability. The global UN Comtrade database, for example, collates the export and import values of sand and gravel in one or two categories, based around the quality and composition of material. It does not distinguish sand taken from rivers and deltas that are being replenished (active sources) from that removed from (passive) sources that are not, such as geological deposits where sand and gravel can be extracted with fewer environmental impacts.

Yet the former active sources cause greater environmental, social and economic harm. For example, in the Mekong delta, the Vietnamese government has estimated that nearly 500,000 people will need to be moved away from river banks that are collapsing as a result of sand mining in the channel. In the Ganges River in northern India, the removal of sand from river banks has destroyed the nesting and breeding habitats of fish-eating gharial crocodiles, of which just 250 are known in northern India and Nepal.

Global agenda

The following 7 components are essential to sustainable sand extraction.

1. Sources: Sustainable sources of sand — whose extraction is replaced naturally — must be sought and certified. The UN needs to develop a plan, perhaps along the lines of sustainable forestry management. New passive sources of sand should be identified, which do not damage rivers. These might include deposits locked up in floodplain sediments that can be quarried. Other targets are also worthy of exploration. Sand deposits emerging from beneath retreating glaciers, for example in Greenland[11]. Or sand trapped behind dams, which could be extracted with less ecological impact than mining downstream.

2. Replace: Local and national governments and planning authorities should encourage greater use of alternatives to sand, such as crushed rock[12], industrial slags and wastes (such as copper, fly-ash and foundry sand[3,5]) and recycled plastic. For example, roads, car parks and driveways made from plastic waste within asphalt can lessen demands for bitumen and aggregate.

3. Reuse: Sand-based materials should be reused when possible. For example, demolition waste and concrete can be crushed and mixed into cement. Rubble may be used as a base aggregate for building foundations and roads, filling holes and as gravels for walkways and gardens, noise barriers and embankments. Legislation and controls on the disposal of concrete, and financial incentives to reuse old concrete, will be needed.

4. Reduce: Cutting the amount of concrete required in new structures, by using more efficient materials such as concrete blocks with hollow cores and porous roofs, roads and printed construction panels, would also lessen demand for sand[3]. Industry standards will be needed for material qualities and should be backed up by regulations to enforce usage.

5. Governance: An international or multilateral framework[5] to govern sand extraction should be forged between local stakeholders, non-governmental organisations, industry, law enforcers and government. UNEP and the World Trade Organization should establish global good practice guidelines for sand extraction as a first step. These should identify where extraction is sustainable and where it is not.

6. Educate: governments, scientists and industry must disseminate information on the nature, extent and solutions to the issues raised by sand mining, including those related to social equity, inclusivity and gender. Such information has to span all sectors – from schools to policy advice and media coverage.

7. Monitor: a global program to gather and share data is imperative to quantify the location and extent of sediment mining, as well as the natural variations in sand flux in the world's rivers. Remote sensing technologies hold promise. For example, satellite data from the Gravity Recovery and Climate Experiment (GRACE) can reveal sediment discharge rates at river outlets and material exported to the ocean from ice sheets and glaciers[13,14]. NASA's Surface-Water Ocean Topography (SWOT) Mission, due to launch in 2021, will offer unprecedented coverage of water discharge in large rivers over 100 m wide. Small satellites, such as CubeSats and SmallSats, can also deliver high-resolution images repeatedly and cheaply for monitoring mining. As an example, the European Union's Raw Materials and Copernicus Earth observation project (RawMatCop) fosters the use of space imagery for managing resources. Ground-truthing tools will be needed, including gauge stations, acoustic technologies for measuring river bed morphology and suspended and bed-load fluxes of sediment, as well as airborne LIDAR. Many boats now routinely carry sonar or echo sounders, which offer a vast, untapped resource of topographic data about the world's rivers and estuaries. Better models will also need to be developed to predict and assess sediment flows and their changes.

UNEP's report is the first footprint in the sand. Now it must be followed up with global action and regulation.

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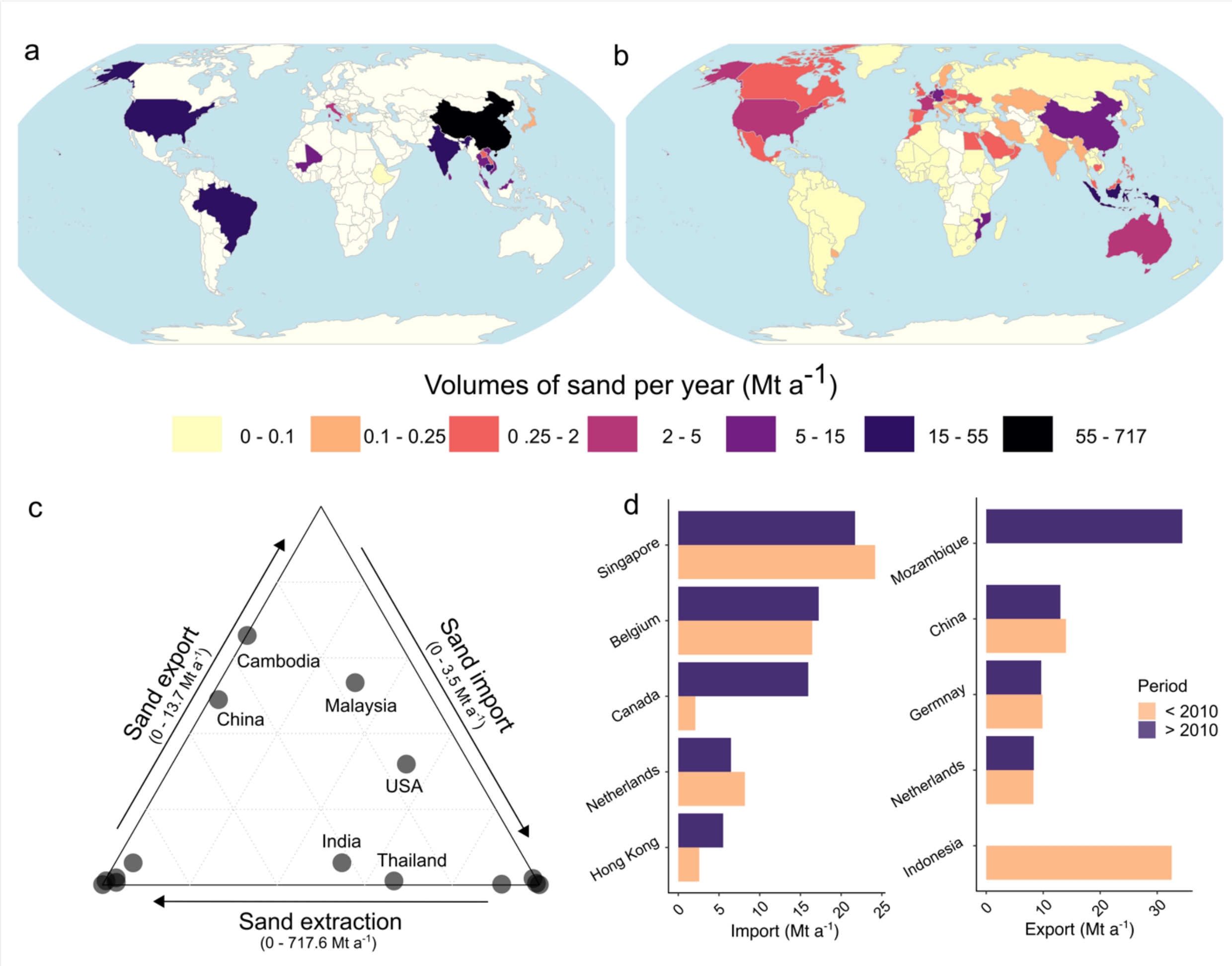

Figure 1: The global sand market. **a**) Volumes of sand mining at a country level based on values reported in the scientific literature returned from the Web of Science search for “sand mining”. **b**) Global sand export values reported by the UN Comtrade International Trade Statistics Database (www.comtrade.un.org) for the period 1984 – 2018. **c)** The balance between reported sand extraction, export and import across the 15 countries in panel a). **d)** Changes in sand volumes for the top five importing (left) and exporting (right) countries.

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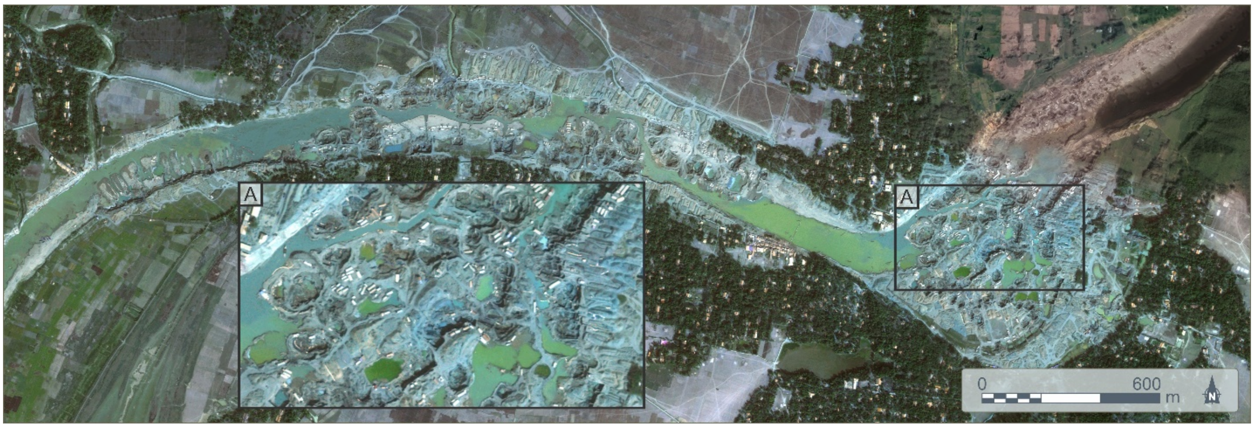
Images (high resolution photos available):



A river channel decimated by gravel and sand mining pits, Lubha River, northern Bangladesh, February 2017. SmallSat image courtesy Planet Labs Inc.

Labourers offload buckets of sand from a dredge boat to a waiting truck, Dhaleshwari River, Bangladesh.

A flotilla of suction dredging boats, Meghna River, Bangladesh

Sand mining by small boats and manual labour, Boro Gang River, near Tamabil, northern Bangladesh.

Suction dredgers mining sand in the Mekong River near Phnom Penh, Cambodia


Gravel and sand mining in the Goyain River, a tributary to the Shari River, Meghna River basin, northern Bangladesh

Animation: The rapidity of the effects of alluvial gravel and sand mining: timelapse imagery of part of the Wah Umngi River, northern Bangladesh. Images courtesy Google Earth.

Animation available via the following link:
https://www.dropbox.com/s/ycatzuwxzz2zcc0/Gravel%20and%20sand%20mining%20Wah%20Umngi%20River%20Bangladesh.mp4?dl=0

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