Refining geodiversity variables for monitoring global mining

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Sharing Geoscience Online

Many thanks go to the EGU organization and our session conveners to facilitate this Sharing Geosciences Online session!

We here take the opportunity to briefly expose our ongoing project:
"*Refining geodiversity variables for monitoring global mining*".

- Global geodiversity is rapidly changing because many geodiversity components, such as mining, provide vital ecosystem services.
- Mining of geological, geomorphological, soil and hydrological resources is rapidly expanding due to increasing societal demands.
- Our aim is to refine existing essential geodiversity variables that can help measure /and monitor effects of mining on geodiversity and its services.

Here, we provide background information and preliminary results.

Enjoy!

The Geodiversity team of the University of Amsterdam

Ecosystem Services and Essential Geodiversity Variables

<u>Ecosystem Services</u>

Mining is a well-known example of how society benefits from goods and services obtained from ecosystems. Mining is strongly related to all geodiversity components (geology, landforms, soils and hydrology).

<u>Monitoring Global Mining</u>

We need to identify, develop and refine existing Essential Geodiversity Variables and their associated ecosystem services for monitoring purposes.

<u>Systematic Literature Review (meta-synthesis)</u>

We conducted a systematic literature review (meta-synthesis) with keyword searches in Scopus and the Web of Science to propose refined EGVs.

Geology			**Geo-morphology**
Hardrock/ fossils/minerals	**Unconsolidated deposits**	**Geophysical activity**	**Landform Distribution**

EGVs to be refined

Geological and geomorphological EGVs, recognized by Schrodt et al. (2019)

Mining is related to all **geodiversity components**

- Mining **geological** resources: e.g. gas, oil, (brown)*coal*, rare earth's, elements, minerals, metals, rocks etc.

- Mining **landforms** and its materials: **surface deposits**: e.g. sediments: *sand*, gravel, clay , silt etc.

- Mining **soils**: e.g. peat extraction, soil organic carbon extraction*, agricultural terrace construction,* soil translocation etc.

- Mining '**hydrology**' aquifers, *artificial lakes*, river training, estuary closures etc.

coal

sand

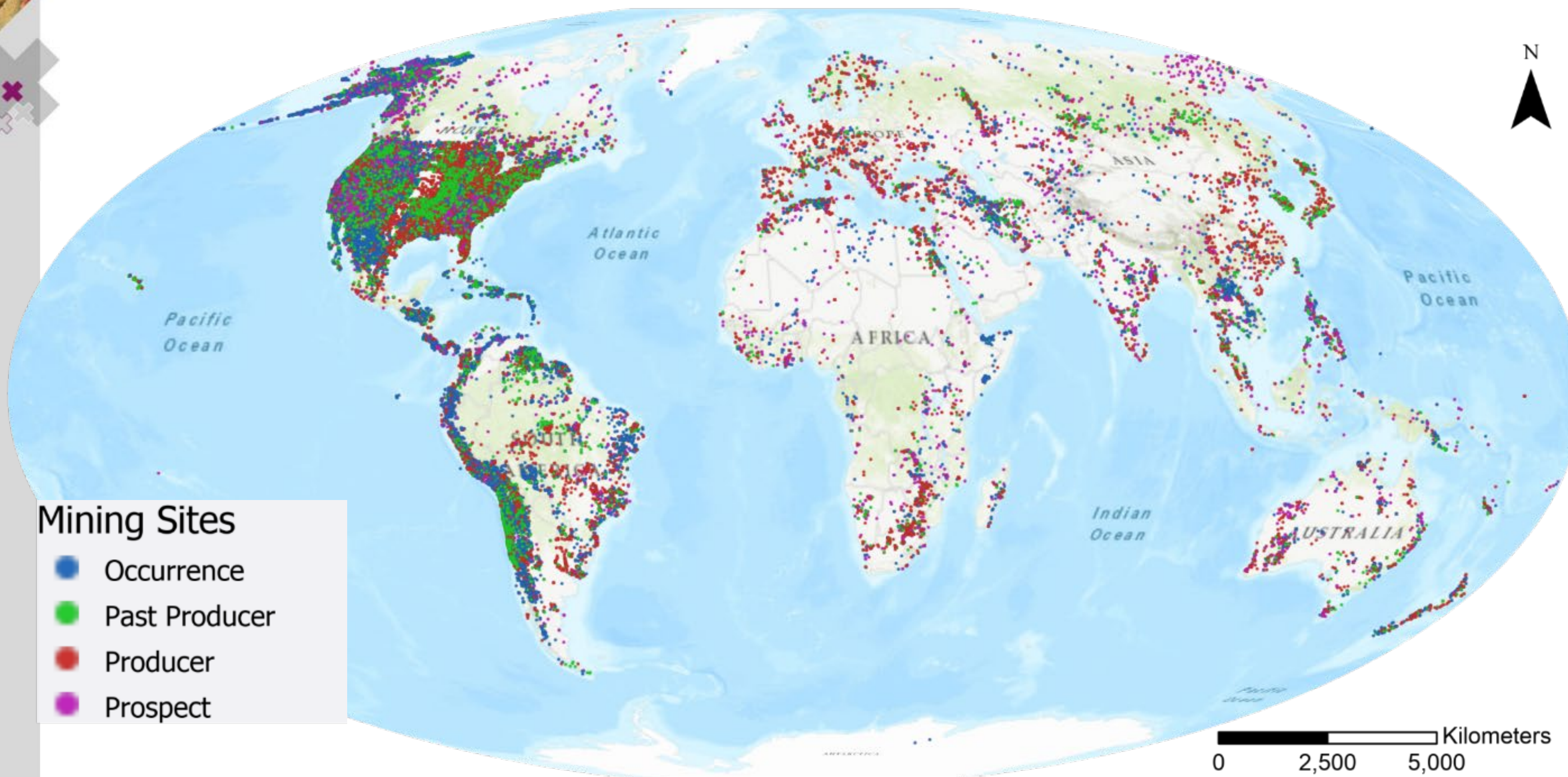
Agricultural terraces

artificial lakes

Photos 'mined' from: https://www.needpix.com/

Mining sites across the world

This combined dataset contains attributes on the location of: rare earth materials / elements, metals and minerals

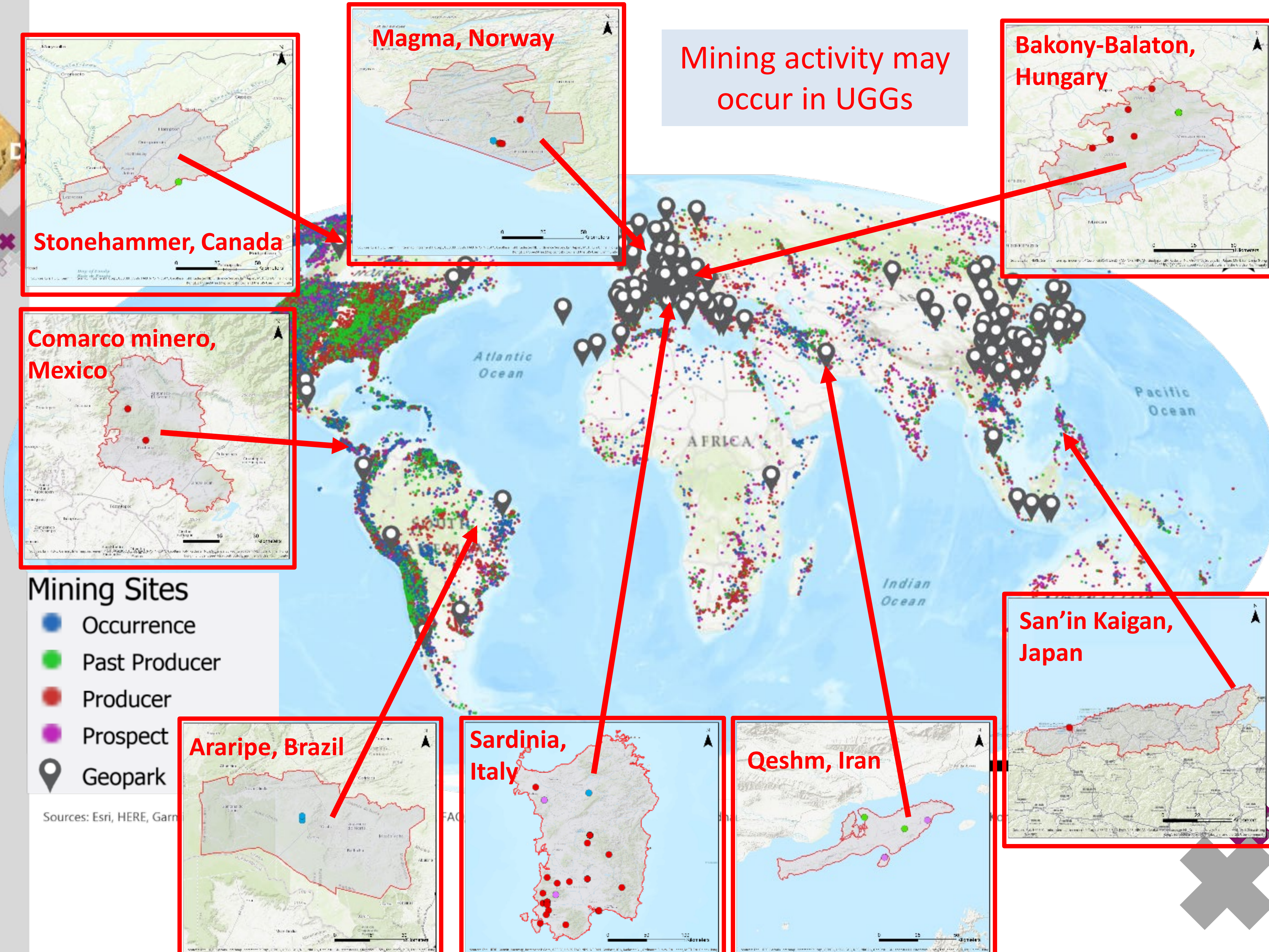


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

GIS data source: United States Geological Survey - https://mrdata.usgs.gov/

Mining and geoconservation: Unesco Global Geoparks

Mining activity may occur in UGGs



Preliminary refinements to **geological EGVs** and their link to associated ecosystem services

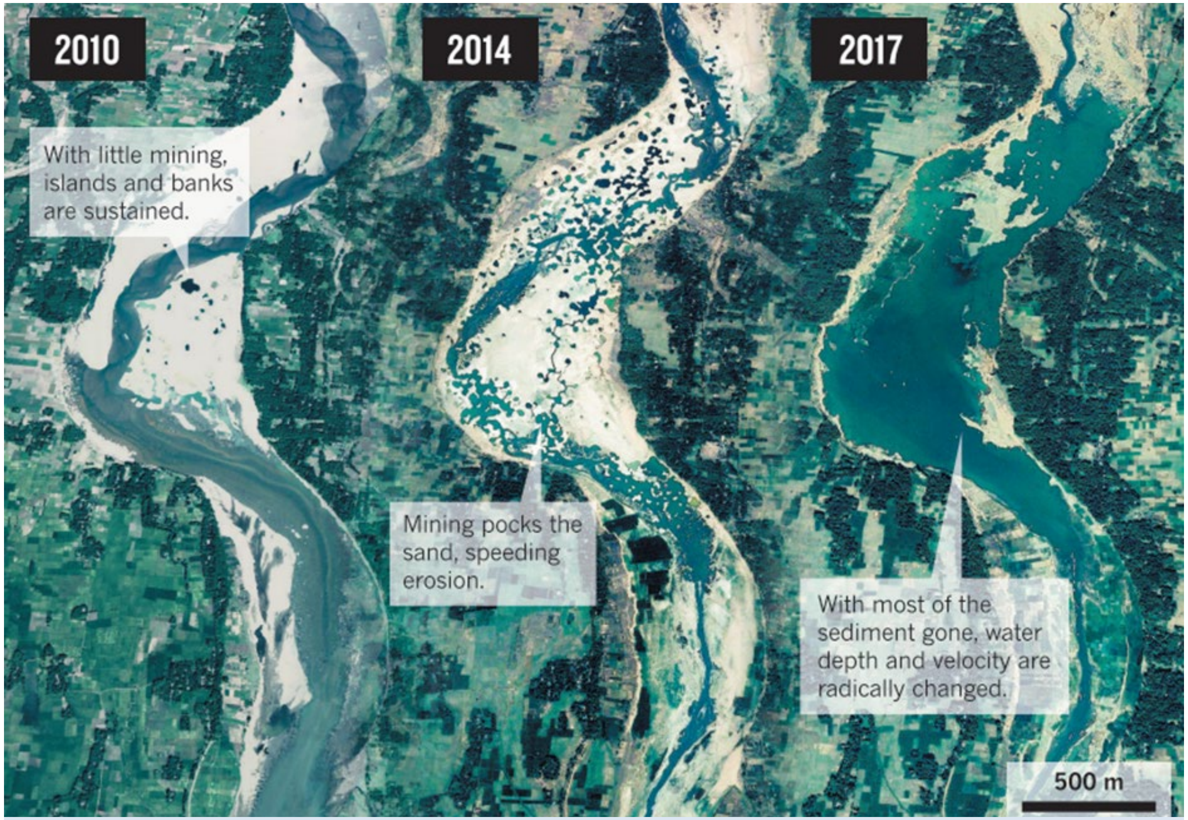
Essential Geodiversity Variables				Related Ecosystem Services			
Class	**Original EGV** (Schrodt et al., 2019)	**Proposed EGV Refinement**	**Examples**	**Provisioning**	**Supporting**	**Regulating**	**Cultural**
Geological	Hardrock, fossil & mineral distribution	**Distribution of minerals and rocks**	Industrial minerals and rocks: Granite; Phosphate; Limestone; Salt; Sand	• Building material (e.g. granite, limestone and sand) (Brilha et al., 2018; Ruban, Tiess, Sallam, Ponedelnik, & Yashalova, 2018) • Raw materials for manufacture of many products (e.g. plastics, pharmaceuticals, ceramics) (Brilha et al., 2018) • Food (e.g. salt) (Brilha et al., 2018) • Phosphate rock is a raw material for fertilizer (Ruban et al., 2018)	• Limestone pavements can support grasslands which support specialized species (Hjort et al., 2015)		• Mining sites can allow for scientific, educational and recreational activities (Ruban et al., 2018)
			Metallic minerals: Base metals: Copper, Lead; Precious metals: Gold, Silver, Platinum; Light metals: Aluminum, Magnesium; Iron and steel metals: Manganese, Chromium, Nickel	• Precious metals (e.g. gold, silver and platinum) provide ornamental products and jewelry (Brilha et al., 2018). • Can be a source of income for local communities (e.g. in the Geopark Colca, Peru) (Gałaś et al., 2018) • Raw materials (for e.g. wires, vehicles, computers, smartphones, machines etc.) (Brilha et al., 2018)			• Precious metals have aesthetic value (Brilha et al., 2018)
			Other Surface and underground rocks	• Food supply via habitat provision for edible species (e.g. South Brazil Shelf) (Garcia, 2019) • Nutrient, mineral and ion supply via weathering and biogeochemical processes (Brilha et al., 2018). • Construction material (Brilha et al., 2018)	• Habitat provision (e.g. place for anchorage on the rocky shore of Sau Paulo, Brazil) (Garcia, 2019) • Rock weathering releases minerals and nutrients, increases porosity and allows incorporation of organic matter (important for plant growth) (Brilha et al., 2018). • Burial and storage (e.g. radioactive waste, municipal landfill, cemeteries (Brilha et al., 2018). • Construction and infrastructure platform (Brilha et al., 2018)	• Sedimentary rocks store large amounts of carbon (Brilha et al., 2018) • Chemical weathering of silicate rock regulates long-term carbon cycle (Garcia, 2019) • Regulation of water quality (Brilha et al., 2018) • Regulation of natural hazards (Gray et al., 2013)	• Geotourism (e.g. rock climbing, caving) (Gray et al., 2013) • Provide knowledge on Earth history (Gray et al., 2013)
		Distribution of fossils and fuels	Fossil fuels: Crude oil; Coal; Natural Gas	• Energy resources • Raw materials for products (e.g. oil used for gasoline, jet fuel, diesel, asphalt, lubricants (Brilha et al., 2018) • By-products useful for making plastic, fertilizers, perfume and tyres (Brilha et al., 2018) • Sources of income for local communities (e.g. Santos Basin, Brazil) (Garcia, 2019).		• Store carbon and therefore regulate carbon cycle (Brilha et al., 2018)	
			Fossils				• Leisure (fossil collecting) (Gray et al., 2013) • Knowledge on evolution of life (Gray et al., 2013)
		Distribution of rare earth elements	Uranium	• Energy resource (Gray, 2013)			
			Rare earth metals: Lithium; Beryllium; Uranium	• Important raw materials for the manufacture of products such as windmills, solar panels and batteries (Brilha et al., 2018)			
	Unconsolidated deposits	**Distribution of unconsolidated deposits**	Sand; Gravel; Clay	• Building and construction materials (Everard & Quinn, 2015; Garcia, 2019)	• Important for water retention and dissolving basic elements for plant growth (e.g. clay) (Brilha et al., 2018)		
	Geophysical Processes	**Variability in the intensity of geophysical processes**	Volcanism	• Can provide suitable topography for human settlements (Szepesi et al., 2017) • Can produce a range of raw materials (Szepesi et al., 2017)	• Volcanic activity increases the productivity of soil, supporting plant growth and therefore food production (e.g. in Hungary) (Szepesi et al., 2017)		• Geotourism – volcanoes can enhance the tourism of an area (Szepesi et al., 2017). • Symbolic, religious or symbolic value (e.g. The Boca do Inferno geosite, São Tomé island.) (Gordon, 2018; Henriques & Neto, 2015)
			Geothermal activity	• Energy resource (Gray et al., 2013)	• Habitat provision (hot springs / hydrothermal vents) (Brilha et al., 2018)		• Health benefits via hydrotherapy (spas) (Brilha et al., 2018). • Geoutourism (e.g. Iceland) (Ólafsdóttir & Dowling, 2014)

Preliminary refinements to **geomorphological EGVs** and their link to associated ecosystem services

Essential Geodiversity Variables					Related Ecosystem Services			
Class	**Original EGV** (Schrodt et al., 2019)	**Proposed EGV Refinement**	**Examples**		**Provisioning**	**Supporting**	**Regulating**	**Cultural**
Geomorphological	Landform distribution	**Distribution and variability of surface landforms and processes**	Coastal landforms	Cliffs Beaches Sand dunes	• Food supply (fishing from beaches and edible species on coastal landforms) (e.g. South Brazil Shelf) (Garcia, 2019) • Aggregate extraction (Gray et al., 2013)	• Habitat provision (e.g. cliffs for seabirds and sand dunes for certain grasses) (Brilha et al., 2018; Hjort et al., 2015) • Habitat provision for edible species (Garcia, 2019) • Can support mosaics of species-rich habitats (e.g. Morrich More, Scotland (Figure 3)) (Gordon, Brazier, Hansom, & Werritty, 2019)	• Can regulate coastal flooding (Everard & Quinn, 2015) • Absorb wave energy (e.g. sand dunes) (Gray et al., 2013)	• Tourism (beach visits) (Gray et al., 2013) • Aesthetic (e.g. White cliffs of Dover, UK) (Gray et al., 2013) • Scientific / educational value (e.g. stratigraphic record of shoreline change at Morrich More, Scotland) (Gordon et al., 2019)
			Glacial landforms	Glacial valleys Moraine ridges Knob and kettles Glacial till	• Till plains and glacial valleys provide sites for livestock grazing (e.g. Las Lagunas, Peru) (Seijmonsbergen et al., 2010)	• Can support water sources (e.g. reservoirs for drinking water, or knob and kettle morphology for irrigation) (Seijmonsbergen et al., 2010) • Habitat provision via landform mosaics (Hjort et al., 2015)	• Knob and kettle morphology can allow for formation of peat bogs which are important for carbon storage (Seijmonsbergen et al., 2010)	• Knowledge - knob and kettle morphology and moraine ridges can act as a climate proxy (Seijmonsbergen et al., 2010)
			Fluvial landforms	Sediment bars River terraces Floodplains Potholes	• River terraces and floodplains provide a platform for buildings (Everard & Quinn, 2015) • Source for building and industrial materials (sand, gravel, clay) (Everard & Quinn, 2015)	• Sediment bars along rivers can support species which use them for resting sites (Hjort et al., 2015) • Floodplains provide riparian zones which support vegetation and tree growth (Testa, Aldighieri, D'Alberto, Lucianetti, & Mazza, 2019) • Riparian vegetation on fluvial landforms provides habitat for various pollinating insects, supporting pollination (Everard & Quinn, 2015) • River bars provide habitats for various insects and successional plants (Hjort et al., 2015) • Processes such as sediment supply and erosion can assist with habitat maintenance (Hjort et al., 2015)	• Regulate channel flow and therefore water supply (Everard & Quinn, 2015) • Regulate flow and therefore increase resilience against flooding (Everard & Quinn, 2015) • Can regulate erosion, protecting infrastructure (Everard & Quinn, 2015)	• Education – study of landforms and geomorphic processes (e.g. Colca Canyon in Peru) (Gałaś et al., 2018) • Aesthetic and recreational values (e.g. potholes on the Miño river in Spain (Álvarez-Vázquez & De Uña-Álvarez, 2017) • Tourism (Everard & Quinn, 2015) • Spiritual and religious values (Everard & Quinn, 2015)
		Distribution of underground landforms	Caves			• Unique habitats which can support unique lifeforms (Hjort et al., 2015)	• Can contribute to regulation of water quality (Hjort et al., 2015)	• Geotourism (Gray et al., 2013) • Legends / folktales (e.g. Grotta di San Lucano in the San Lucano Valley, Italy) (Testa et al., 2019) • Source of inspiration for music and art (e.g. Fingal's Cave, Scotland) (Gordon, 2018)
		Topographic diversity	Mountain ranges		• Building stone and aggregate provision (Gray et al., 2013)	• Can determine delivery of water (e.g. Huambo river valley, Peru) (Gałaś et al., 2018) • Can provide unique habitats (e.g. cliffs offer protection from some predators and competitors) (Hjort et al., 2015)	• Mountains are a common site for peatlands which are important for carbon storage and therefore climate regulation (Gray et al., 2013)	• Geotourism (Gałaś et al., 2018; Thomas, 2012) • Aesthetic value (Gray et al., 2013) • Artistic inspiration (Brilha et al., 2018) • Educational opportunities (Gray et al., 2013; Brandolini et al., 2011) • Sport and leisure (e.g. rock climbing and hiking in the Ponci valley) (Brandolini et al., 2011; Gray et al., 2013) • Scientific value (e.g. San Lucano Valley in the Dolomites, Italy) (Gordon, 2018; Testa et al., 2019)
			Lowlands		• Provide a platform for buildings (Everard & Quinn, 2015)	• Relief and rock resistance essential for urban planning, bridges, dams, airports, road networks and railways (Brilha et al., 2018; Ilić, Stojković, Rundić, Ćalić, & Sandić, 2016)		

The need for sand and its potential impacts

- Sand is mined across the world in rivers and along beaches and shelfs for growing demand of concrete in an urbanizing environment
- Sand mining may lead to icreased erosion rates, morphological changes, loss of fishery, interference with shipping etc.
- Similar overexploitation is seen in other mining resources, such as phosphate

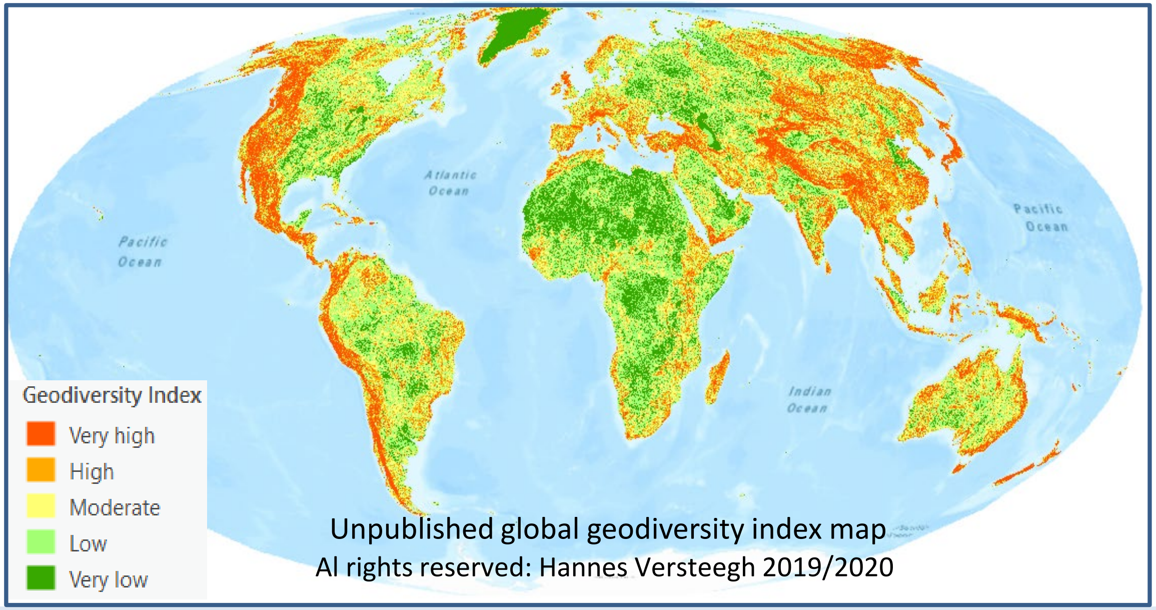


Impacts of sand extraction represented in satellite images of the Umngi River in northern Bangladesh (Bendixen, Best, et al., 2019)

Sand mining simply cannot remain as unregulated as it is now, or future conflict and environmental crises will become inevitable. Monitoring using EGVs may identify/quantify (negative) effects on the environment.

Remarks / outlook

- Essential Geodiversity Variables provide opportunities to monitor global landscape change, e.g. due to mining; they need, however, additional input
- Spatial analysis is needed to analyze mining activity versus geodiversity: a global geodiversity map can be used as input – see below
- Monitoring geodiversity change can support landscape management, conservation, restoration, biodiversity research and help to preserve ecosystem services



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Many thanks for participating and “listening” to this online presentation

We appreciate any feedback, remarks and / or suggestions to improve this project or to start cooperation

On behalf of the UvA Geodiversity Team,

Harry Seijmonsbergen