Code of Sand

17 messages guiding a more sustainable use of marine sands

Final conference TILES project

Marine Sands as a Precious Resource

Brussels, Museum of Natural Sciences. June 1st, 2018

TILES partnership

Royal Belgian Institute of Natural Sciences
Operational Directorate Natural Environment

Ghent University
Department of Geology, Renard Centre of Marine Geology
Department Telecommunications and Information Processing,
Database, Document and Content Management

TNO
Geological Survey of the Netherlands

FPS Economy SMEs, Self-Employed and Energy
Continental Shelf Service

References

Code of Sand
Van Lancker V, Francken F, Kapel M, Kint L, Terseleer N, Van den Eynde D, Hademenos V, Missiaen T, De Mol R, De Tré G, van Heteren S, Stafleu J, Stam J, Degrendele K, Roche M., Baetens K, De Clercq M, Scory S, Stolk A, van der Voet E. ***Code of Sand: 17 messages guiding a more sustainable use of marine sands***. Proceedings TILES Final Conference on 'Marine Sands as a Precious Resource'. Brussels, Museum of Natural Sciences, June 1st 2018.

TILES Final report
Van Lancker V, Francken F, Kapel M, Kint L, Terseleer N, Van den Eynde D, Hademenos V, Missiaen T, De Mol R, De Tré G, Appleton R, van Heteren S, van Maanen PP, Stafleu J, Stam J, Degrendele K, Roche M. Transnational and Integrated Long-term Marine Exploitation Strategies (TILES). Final Report. Brussels: Belgian Science Policy 2018. (BRAIN-be - Belgian Research Action through Interdisciplinary Networks).

INTRODUCTION

With growing land-use constraints and depletion of terrestrial aggregate resources, **marine sand and gravel have gained considerable importance**. On a global scale, the stock for these widely demanded bulk resources are assumed infinite, though regionally, exploitation is limited by a diversity of interacting social, economic, technological, political, but also geological factors.

A four-years project (2014-2018) was dedicated to researching the **marine aggregate resource potential for the Belgian and southern Netherlands part of the North Sea**. TILES or "Transnational Integrated and Long-term marine Exploitation Strategies" had three main objectives: (1) Develop a resource decision support system containing tools that link 3D geological models, knowledge and concepts to 4D numerical environmental impact models; (2) Provide long-term adaptive resource management strategies; and (3) Propose legally binding measures to optimize and maximize long-term exploitation of aggregate resources within sustainable environmental limits.

A final conference on the TILES project was set-up in view of **bringing awareness on marine sand resources to a wider community**. In a logical flow 17 key messages were conveyed that should be known and understood by all involved in the exploitation of the seabed. They are structured under five themes: (1) **Sand**, dealing with nature, origin, formation and dynamics; (2) **Sand tools for better governance**, comprising of sand characterization, accounting and modelling; (3) **Sand as a resource**, bringing forward awareness on the finite nature, the unequal distribution, and the need for a more circular economy approach; (4) **Sand extraction**, highlighting good practice in monitoring and management, as well as the need for marine system knowledge; and (5) **Sand in a digital era**, stipulating the importance of open data portals, flexible visualization and querying tools, cooperative action and sand-resource comprehension. Altogether the messages combined into the **Code of Sand**, guiding a more sustainable use of marine sands. The Code of Sand was provided to the audience in the form of a unique portfolio ('fan') with pictures of different sand qualities and with the key messages at the back of each picture. In this document the presentations are included illustrating each of the messages.

All people contributing to the Code of Sand are listed at the back of this document. We thank warmly colleagues from outside the TILES consortium for adding their views on the different aspects of sand. Particularly, we acknowledge our keynote speaker Prof. dr. Ester van der Voet providing a view on global sustainability challenges and perspectives on how dealing with resources on the longer term. Via photography and virtual reality demonstrations the world of sand was imaged most attractively, for which we are most grateful to our TNO colleagues.

Finally, we thank the 125 conference participants coming from government, NGOs, academia and industry, and representing five countries: Belgium, The Netherlands, France, UK and Denmark. We hope to have stimulated the debate on sustainability challenges on marine sand use which is inevitably a multi- and interdisciplinary, as well as cross-sectoral endeavour!

Vera Van Lancker, *Coordinator TILES project*

Code of Sand

Sand as a resource

Sand is a basic component of our natural capital

Sand extraction

Sand exploitation thrives with a science-based fundament


Sand is a tiny miracle
of nature
aprenderamadeira.net

SAND

Sand is more than a grain size

Sand consists of particles between 1/16 and 2 mm in size. The composition and shape of these particles vary. Quartz and feldspars are common in North Sea sand, but plenty of other grains are mixed in. Shell fragments, mica flakes and fecal pellets are just a few examples. Silt and clay admixtures influence the quality of the sand.

Sytze van Heteren
TNO - Geological Survey of the Netherlands

TNO innovation for life

100 JAAR GEOLOGIE IN KAART

adoopla.com

different sizes

→

different applications

different compositions

→

different applications

pinterest.com

different shapes

→

different applications

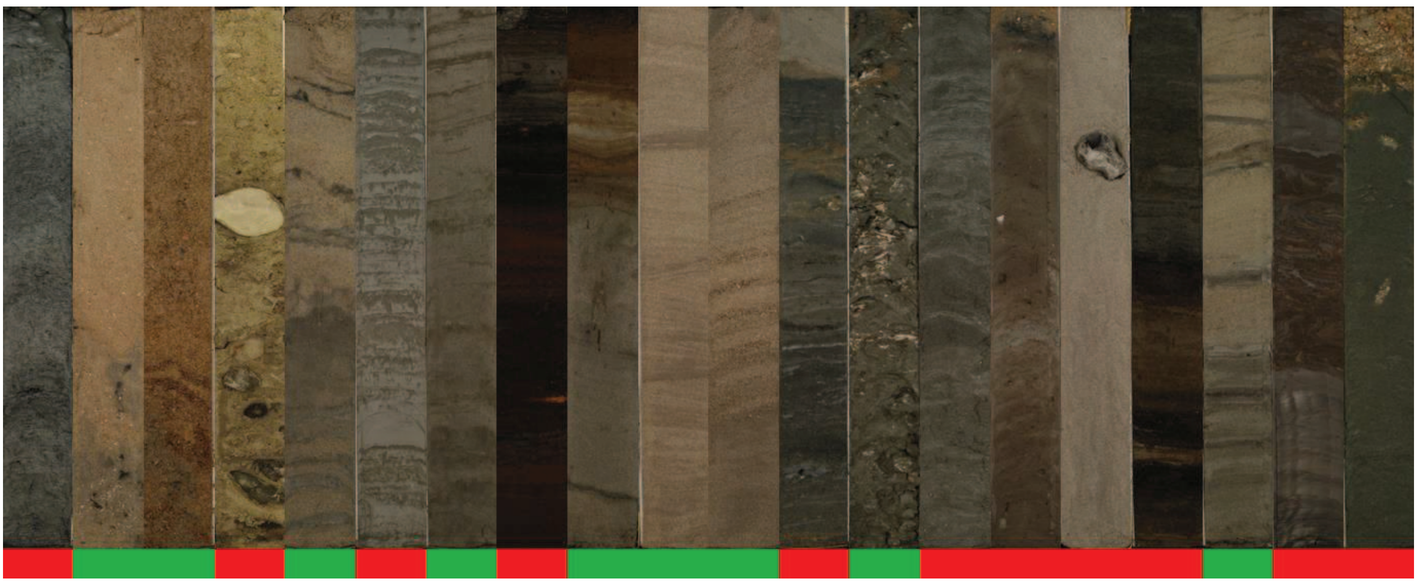
tassimo.nl demorgen.be

different admixtures

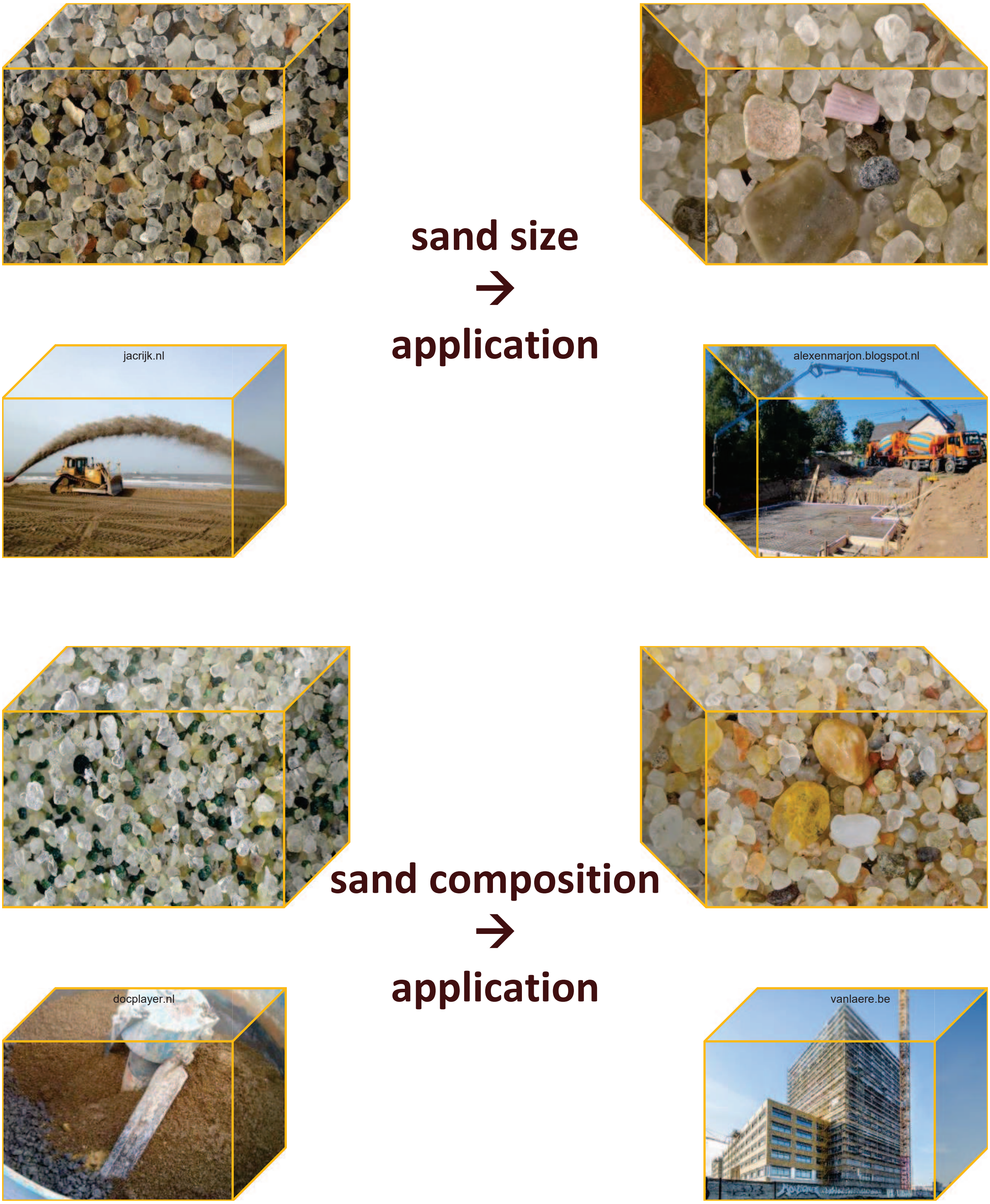
→

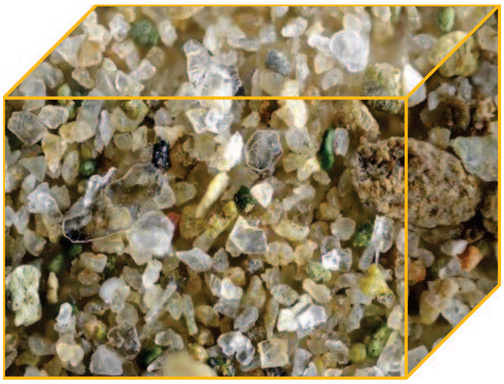
different applications

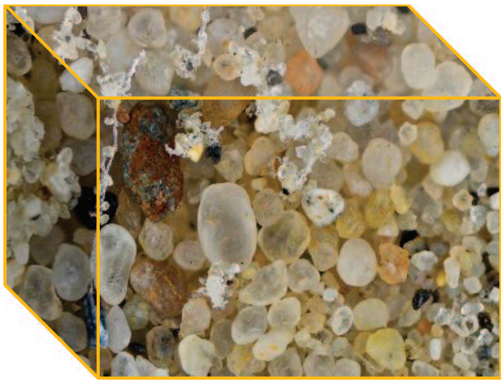
thewhiskyexchange.com



size, composition, shape, admixture → suitability


sand size
→
application
jacrijk.nl
alexenmarjon.blogspot.nl
sand composition
→
application
docplayer.nl
vanlaere.be

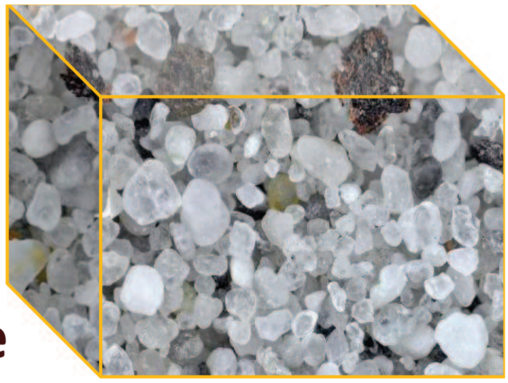




sand shape

→

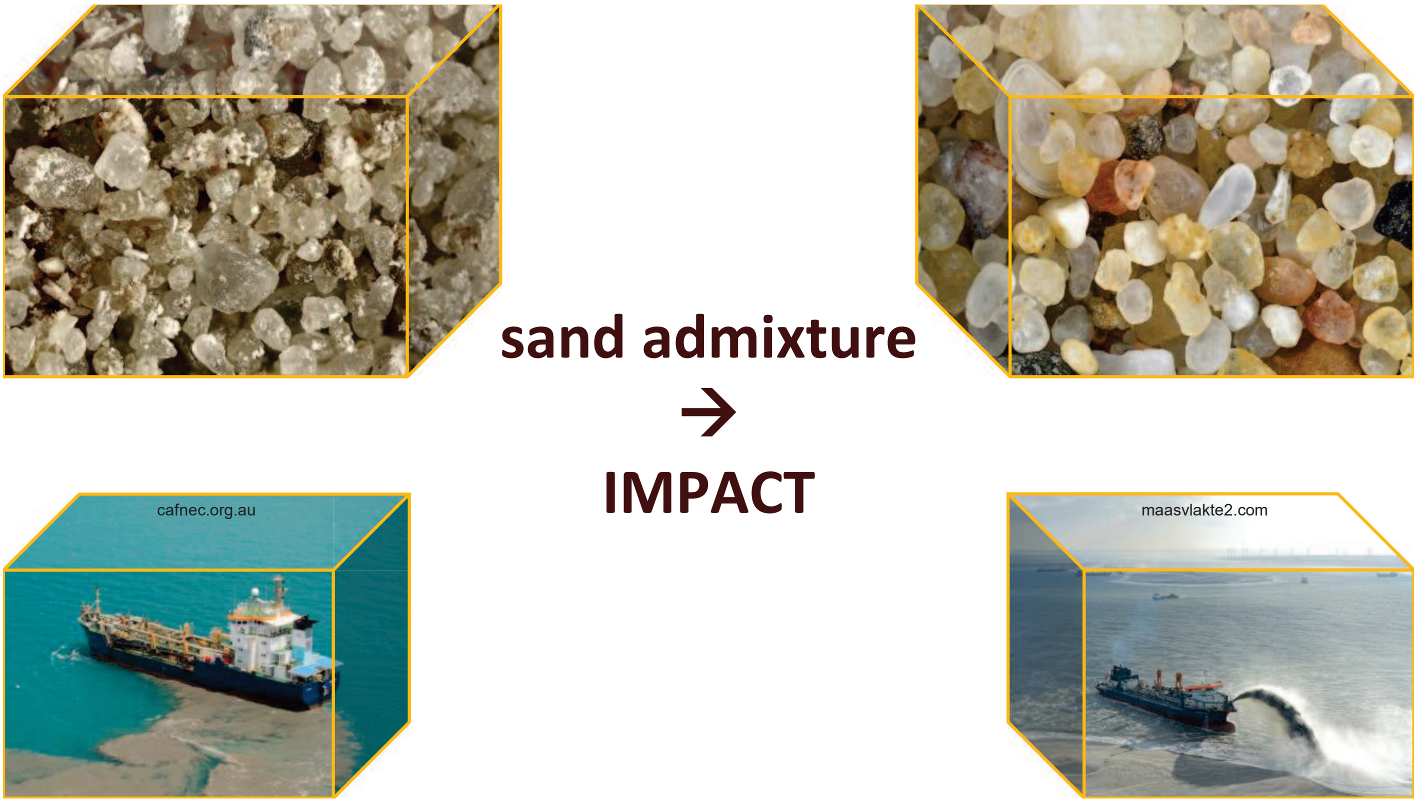
application



sand admixture

→

application


sand admixture
→
IMPACT
cafnec.org.au
maasvlakte2.com

Sand is abundantly present, though mostly relict in origin

Sand occupies vast areas of the North Sea. It was originally deposited by ever-shifting rivers and glaciers, tens to hundreds of thousands of years ago. A patchwork of sediments resulted. The coarsest sand is found where the rivers flowed. During the past ten thousand years, the sand has been reworked into sandbanks, sand waves, and sand sheets by the rising sea.

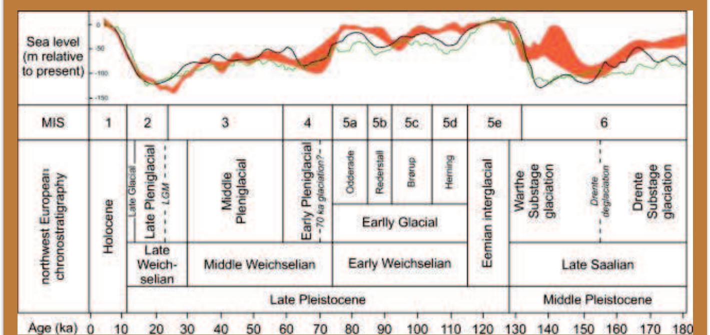
Maikel De Clercq

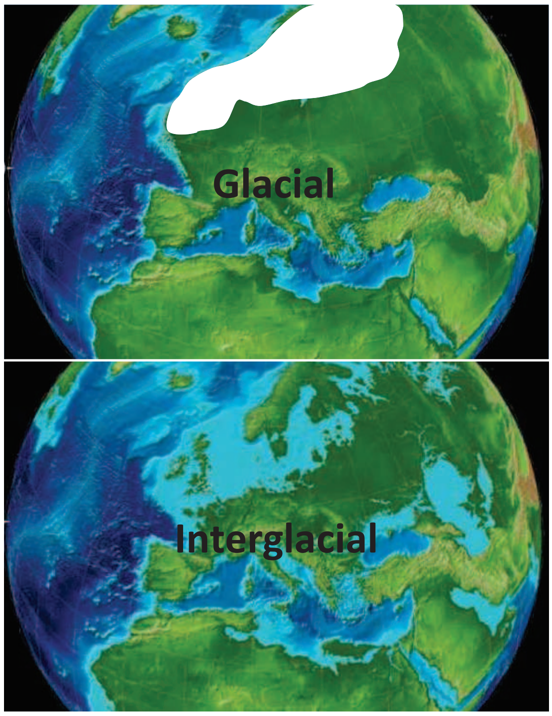
Ghent University – Renard Centre of Marine Geology

GHENT UNIVERSITY rcmg SEARCH IWT

Quaternary

- climate change
- glacial-interglacial cycles
- sea-level fluctuations





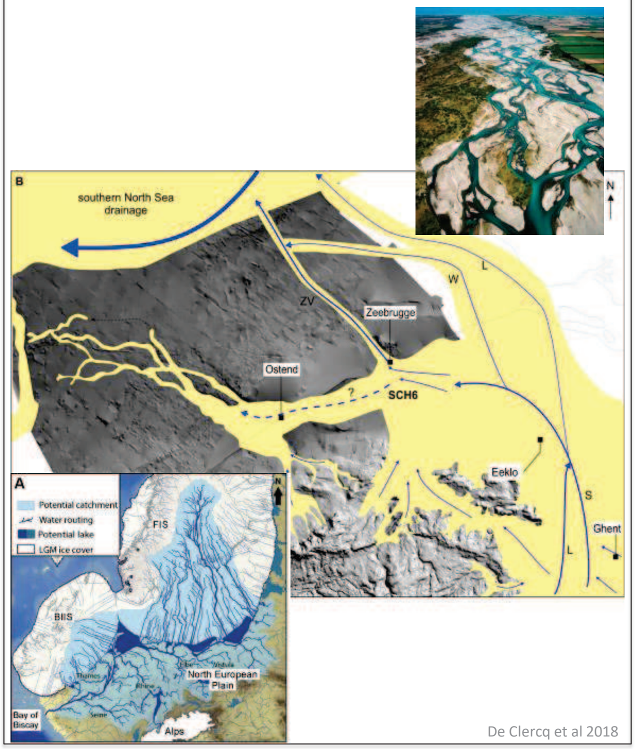
Flemming et al. 2014

Quaternary

Glacial periods:

- dry North Sea
- merged ice-sheets
- palaeolakes (outburst floods)
- tundra landscape
- large river systems

Deposition of sand and gravel



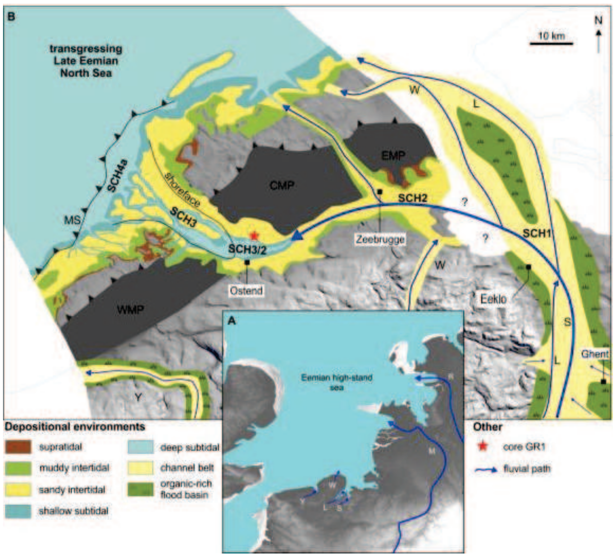
De Clercq et al 2018

Quaternary

Interglacial periods

- shallow sea
- large estuaries
- islands, intertidal flats
- lagoons & marshes

Deposition of sand, silt, clay, peat



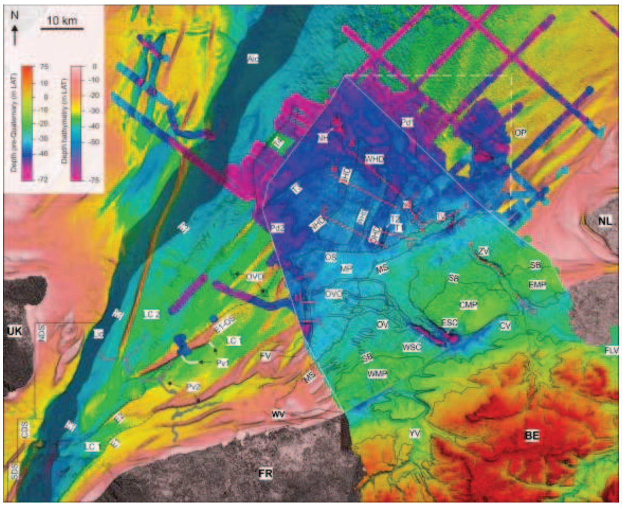
De Clercq et al. 2018

Base Quaternary surface

Complex surface dominated by erosional morphology

Composed of

- palaeodepressions
- incised-valleys
- escarpments
- river terraces



Modified from De Clercq et al. 2016

Quaternary deposits of BCS

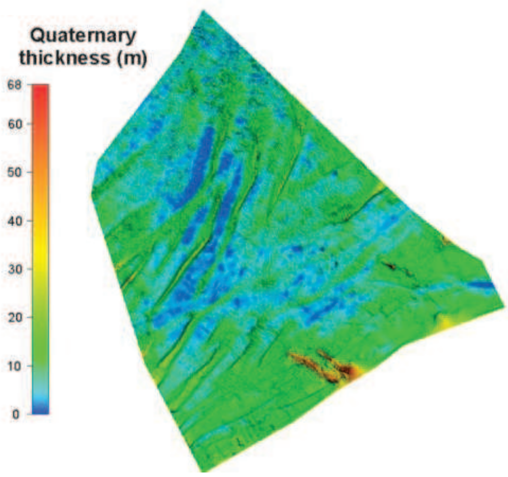
Patchy Quaternary record

Various depositional environments

- marine
- fluvial
- estuarine
- intertidal
- marsh

Preferential reworking or lack of deposition (relatively low accommodation space)

Total thickness between 0 and 68 m



De Clercq 2018

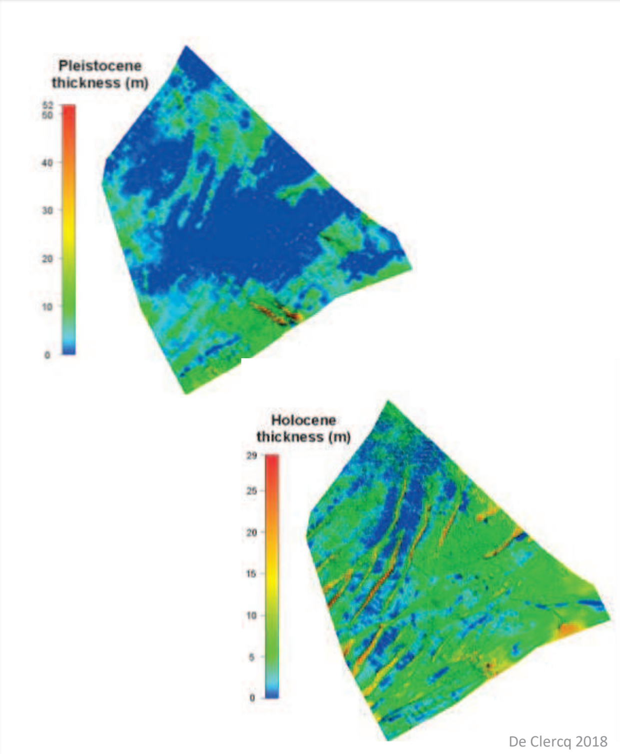
Quaternary deposits of BCS

Pleistocene:

- thickness up to 50 m
- concentrated in/near valleys
- base of sandbanks
- mainly fluvial and estuarine

Holocene:

- thickness up to 30 m
- concentrated in sand banks
- mainly marine and back-barrier



De Clercq 2018

Present seafloor

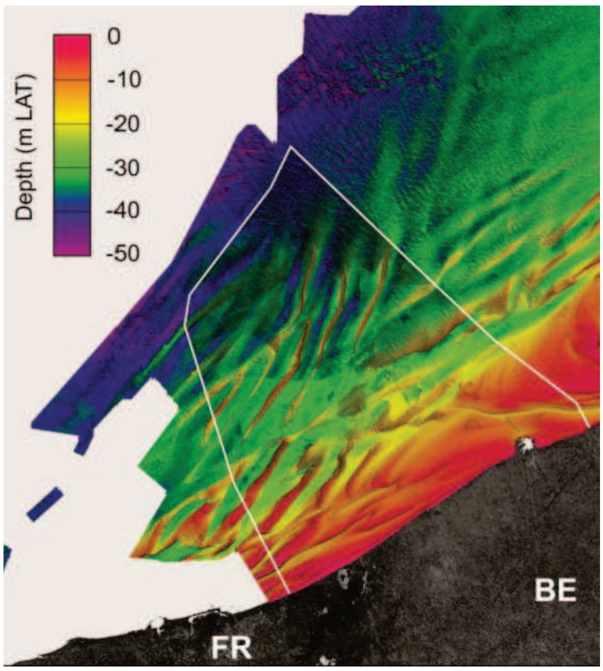
Amalgamation surface

Composed of old and recent sediments

Pre-Quaternary sediments outcrop

Geological events are still visible

Sand is scarce compared to neighbours



De Clercq 2018

Sandbanks are formed in successive phases

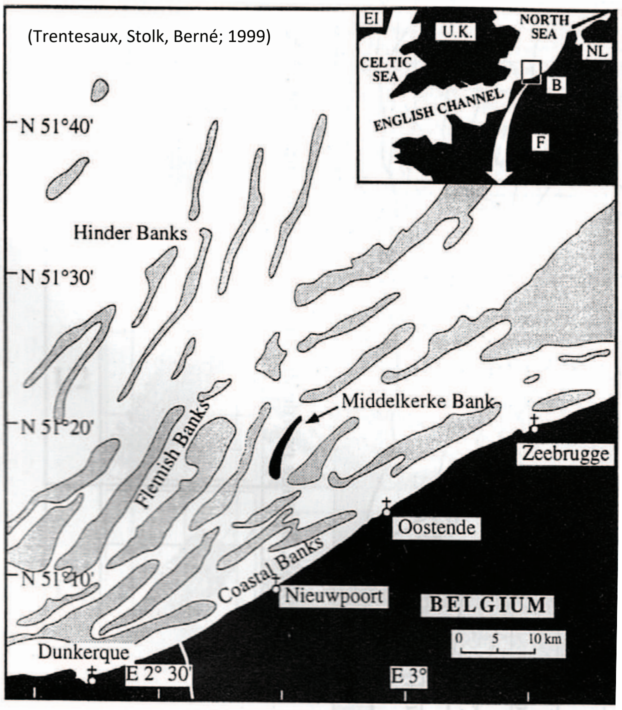
Sandbanks are often thought of as homogeneous stocks of sand. Internally, though, each one has unique characteristics. Some have very old fundaments of clay. Others consist of differing sand layers formed at different times. This compositional variability affects sand quality.

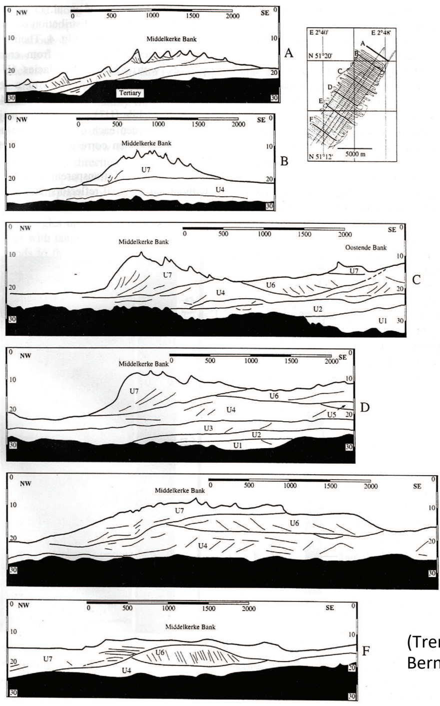
Ad Stolk
Rijkswaterstaat, The Netherlands

Ende de stroomen vallen t'meeste deel van ghetije d'weers over de bancken / soo wel bij ebbe als bij vloet.

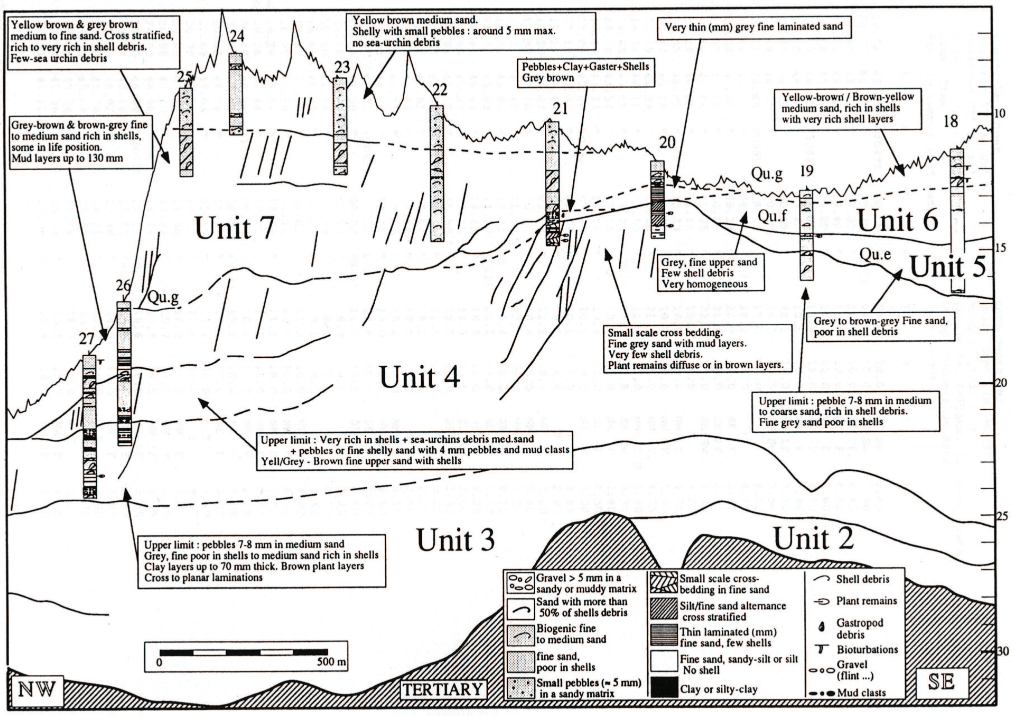
(Waghenaer, 1584)

(Trentesaux, Stolk, Berné; 1999)





(Trentesaux, Stolk, Berné; 1999)

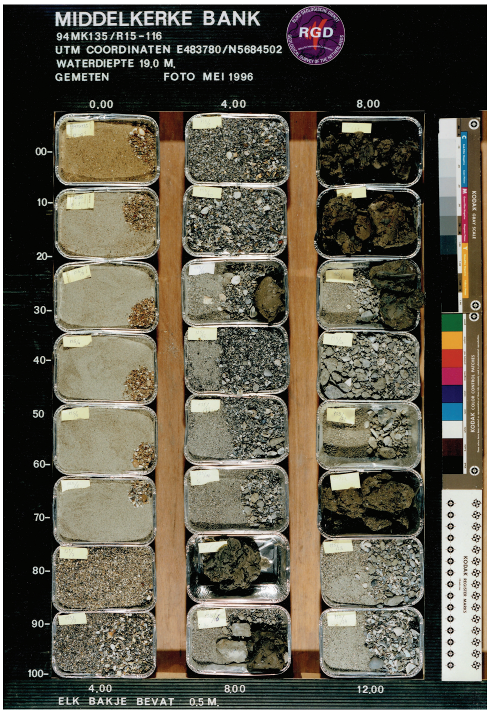


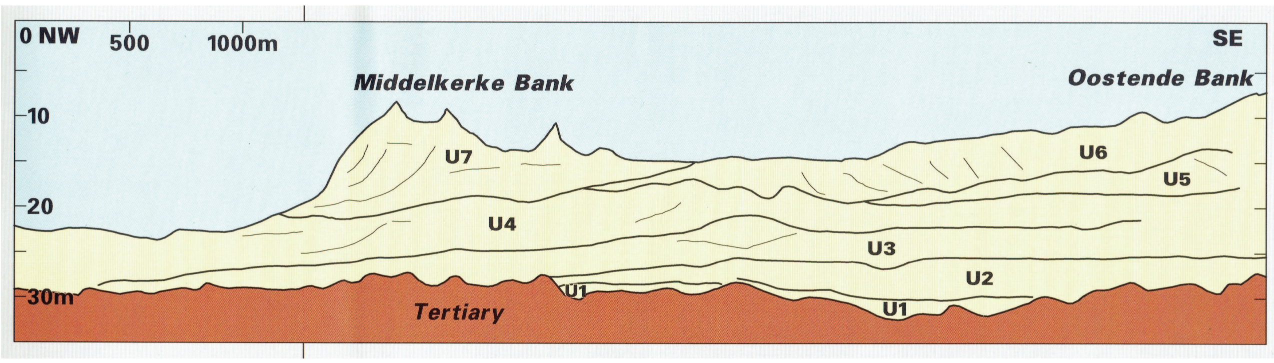
(Stolk , Trentesaux; 1993)


MV91023


MV91020


MV91027


MIDDELKERKE BANK
94MK135/R15-116
UTM COORDINATEN E483780/N5684502
WATERDIEPTE 19,0 M.
GEMETEN FOTO MEI 1996
RGD
0,00
4,00
8,00
4,00
8,00
12,00
ELK BAKJE BEVAT 0,5 M.


0 NW
500
1000m
SE
Middelkerke Bank
Oostende Bank
10
20
30m
U7
U6
U5
U4
U3
U2
U1
U1
Tertiary

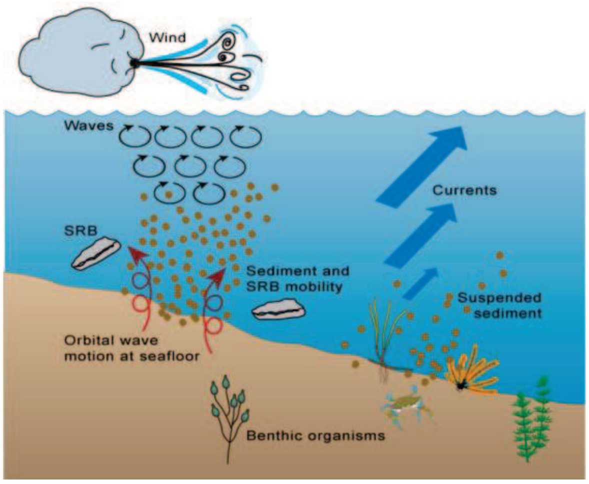
SAND

Sand in the sea is swept by tidal and wave action

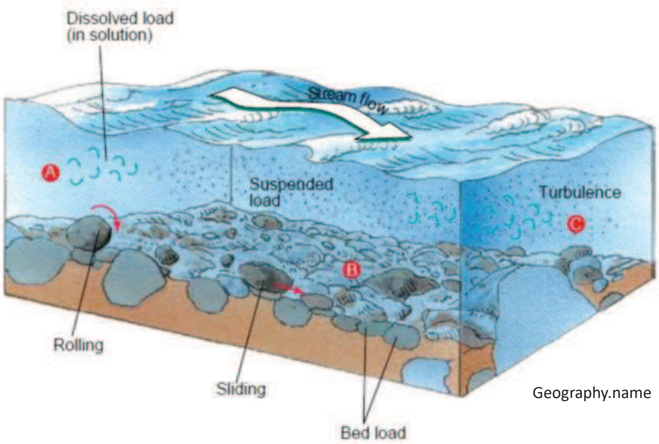
Sand is easily eroded, transported and deposited. Tides and waves sort the grains, depending on coarseness and water depth. The natural variability of this process is important when assessing environmental impacts and estimating the recovery of the seabed after human disturbance. Climate change may induce shifts in the natural sand dynamics.

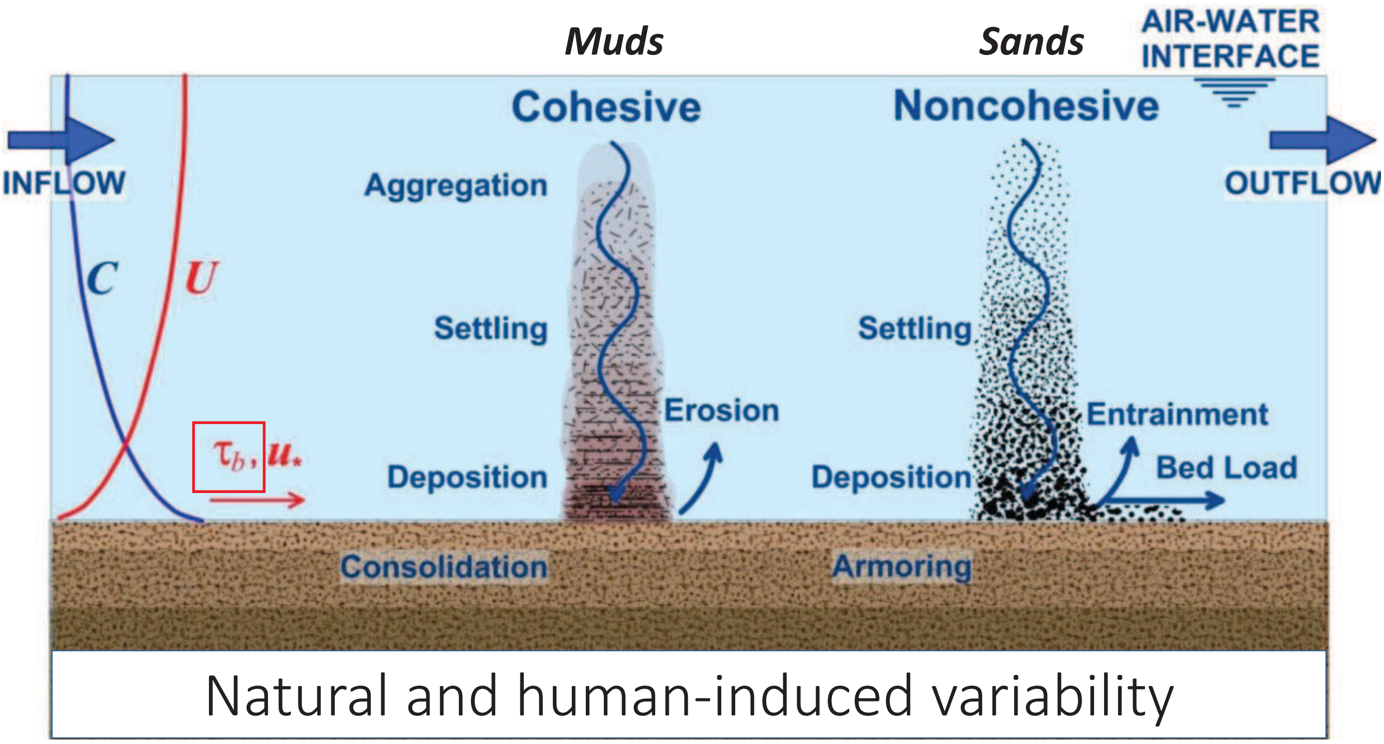
Katrijn Baetens
Royal Belgian Institute of Natural Sciences

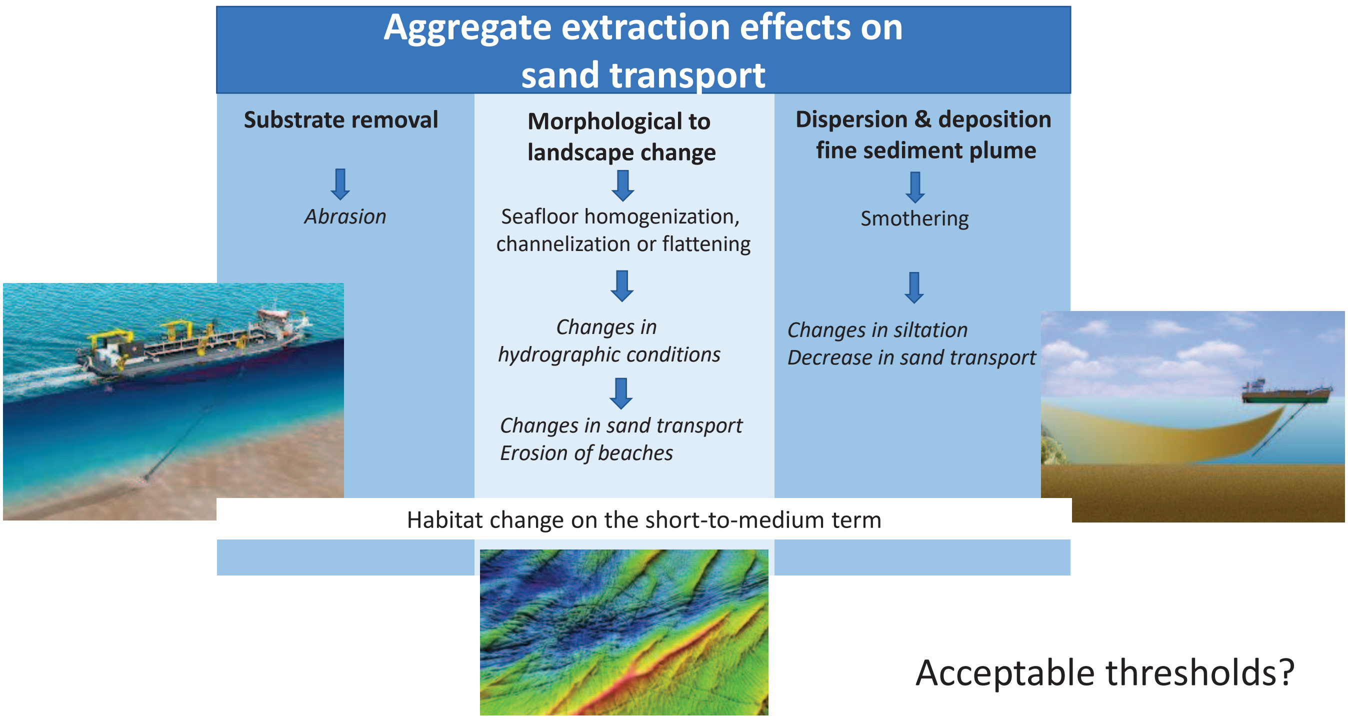
Main Forcing



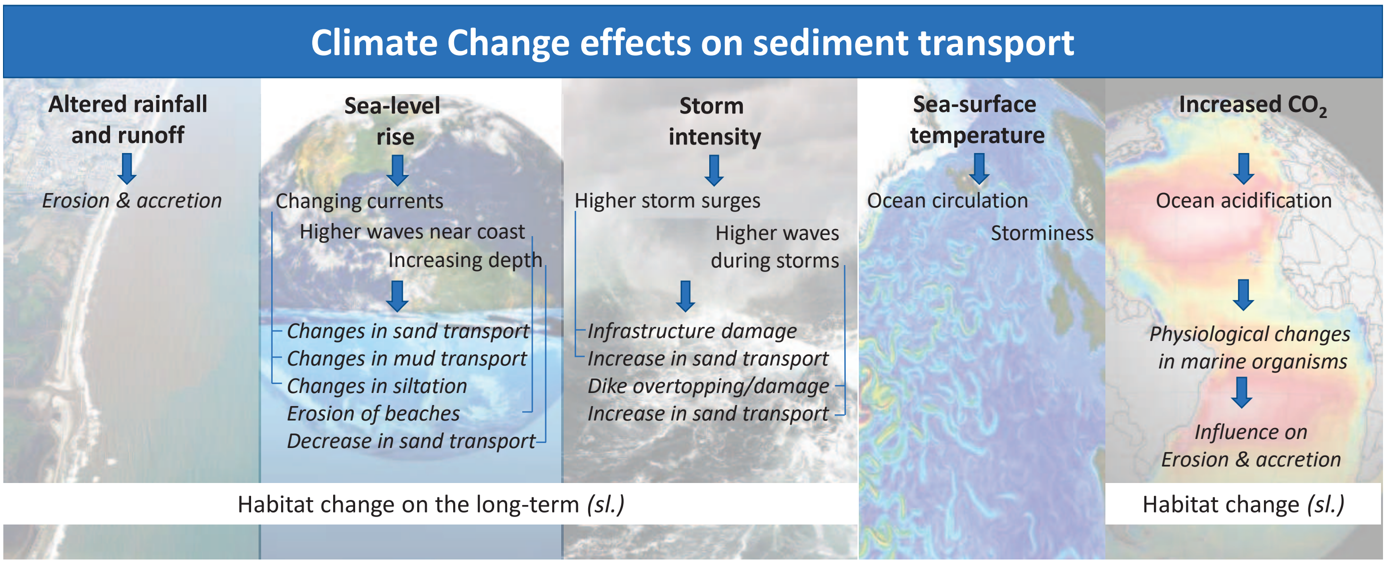
Sand → seabed → **habitat**!







Acceptable thresholds?

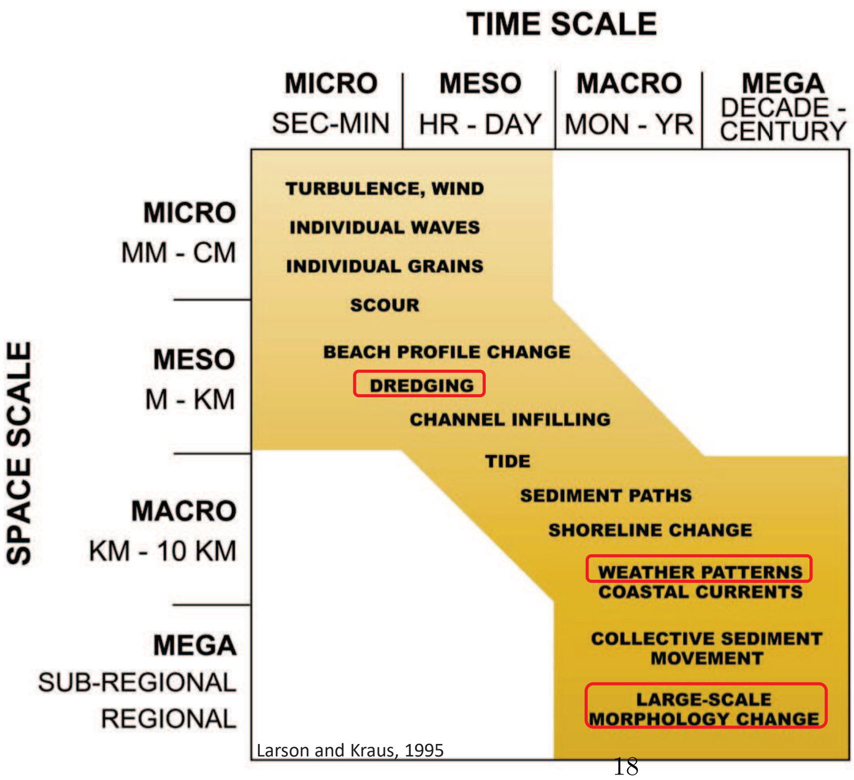


Ongoing research Belspo CORDEX.be & IWT-SBO CREST

Conclusions

- Tides and waves mobilize the seabed at varying spatial and temporal scales
- Acceptable thresholds for alterations to the seabed need defining to maximize **seabed recovery** after disturbance

Bartholdy et al., 2015



Larson and Kraus, 1995


Sand is material
that flows

SAND TOOLS

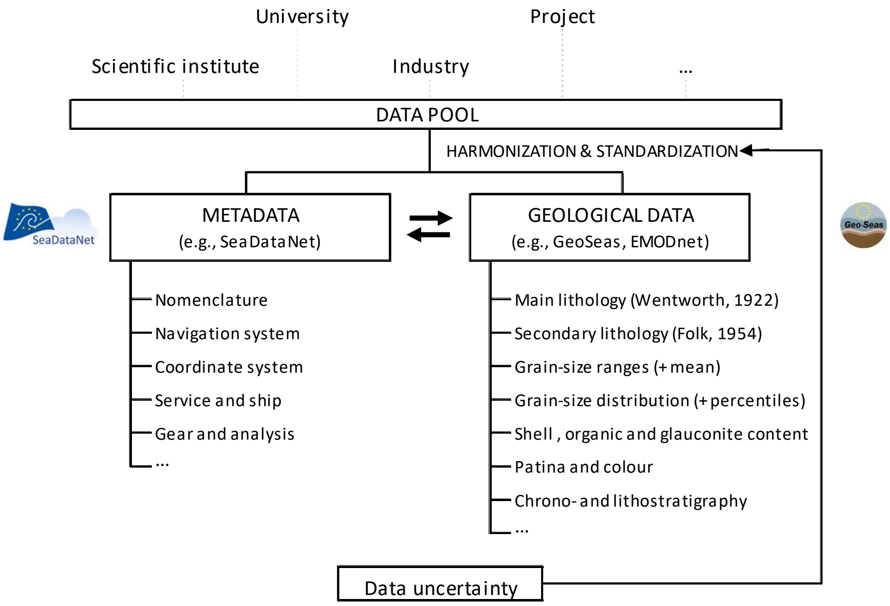
Sand characterization relies on diverse databases

Sand-quality estimation requires **standardized** data for **harmonized** mapping across borders. Each end user has unique questions; hence, databases should be **versatile** enough to accommodate the various demands of government, industry and science. Not all data are equally reliable. **Uncertainties** should be quantified and propagated in decision making.

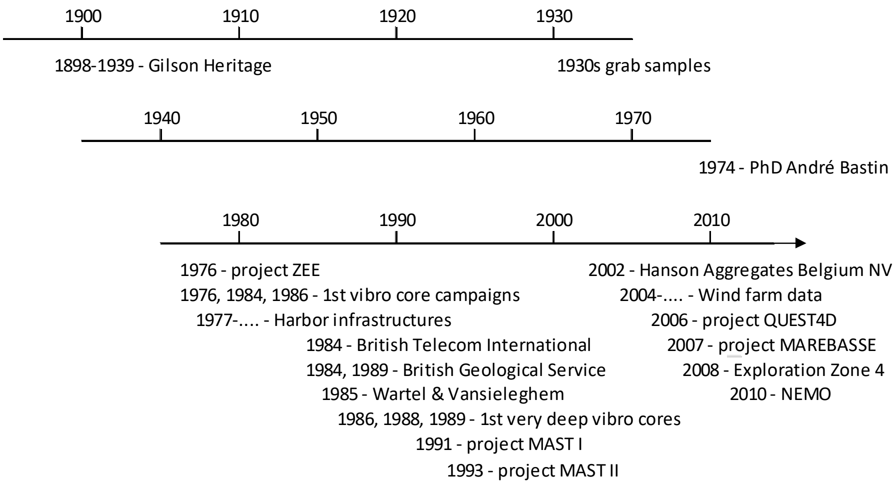
Lars Kint
Royal Belgian Institute of Natural Sciences

museum

What do we do with (y)our geological data?



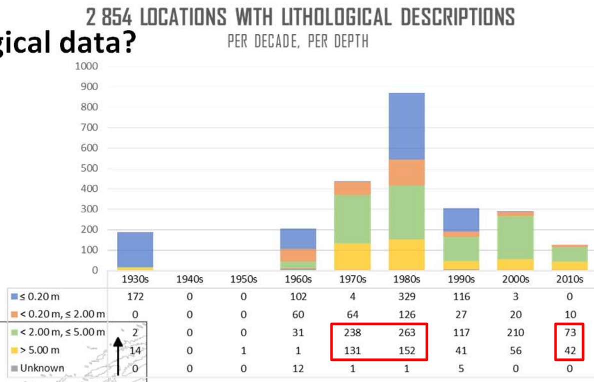
How diverse is (y)our geological data?



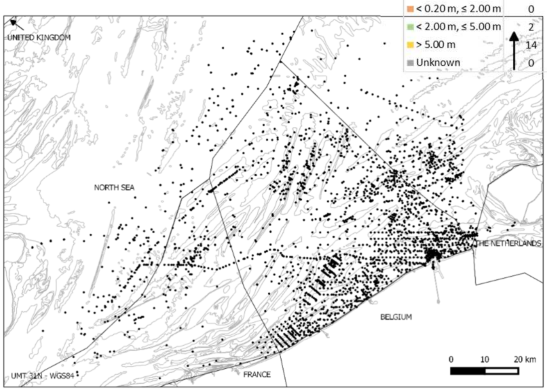
museum

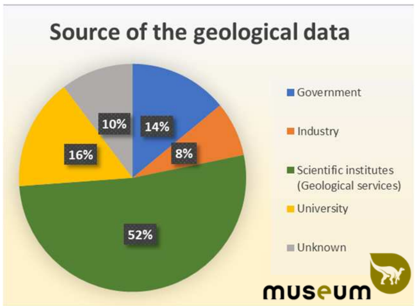
How diverse is (y)our geological data?

- 2 854 locations with lithological descriptions coming from boreholes, samples, …
- 15 680 subsamples or lithological descriptions



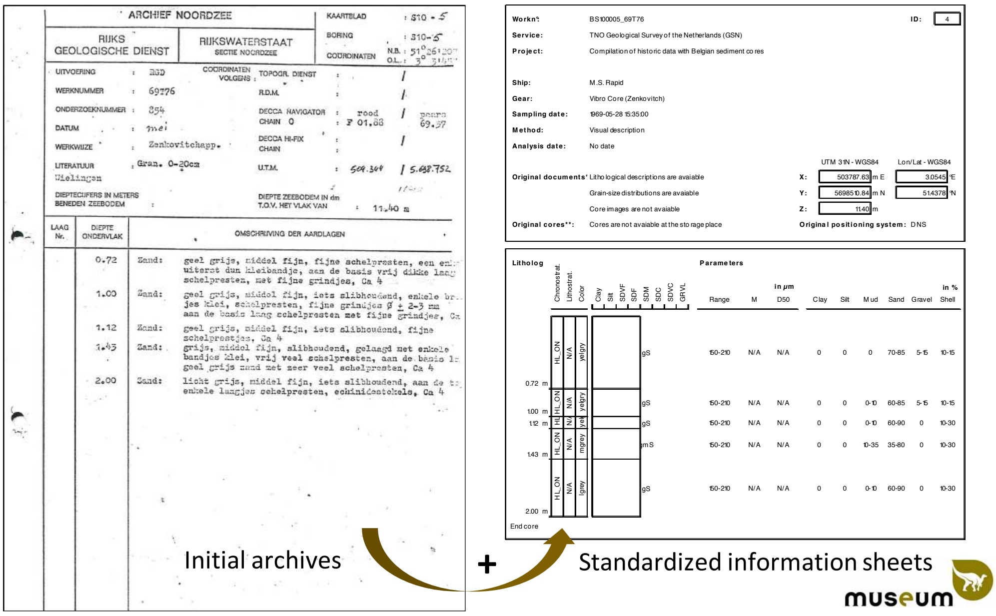
	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	2010s
≤ 0.20 m	172	0	0	102	4	329	116	3	0
< 0.20 m, ≤ 2.00 m	0	0	0	60	64	126	27	20	10
< 2.00 m, ≤ 5.00 m	2	0	0	31	238	263	117	210	73
> 5.00 m	14	0	1	1	131	152	41	56	42
Unknown	0	0	0	12	1	1	5	0	0

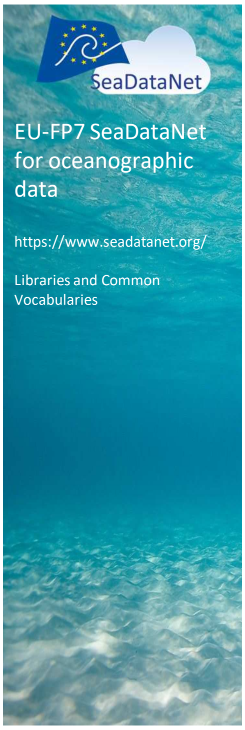




What will be publically available?

+ Photographic images





Which metadata do we provide?

PAN-EUROPEAN INFRASTRUCTURE FOR OCEAN & MARINE DATA MANAGEMENT

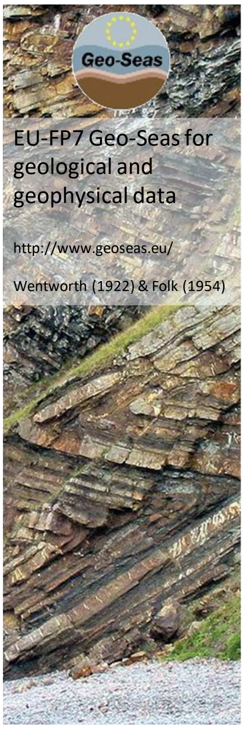
BODC WEBSERVICES V2 (LIBRARIES) CL12

Library	Thesaurus	Title	Alt Title
C16		SeaDataNet sea areas	SDN sea areas
C17		ICES Platform Codes	ICES Platforms
C32		International Standards Organisation countries	ISO countries
GS3		Geo-Seas adjusted Folk sediment lithology classes	Adjusted Folk classes
GS4		Geo-Seas geological sample colours	Geo-Seas colours
L05		SeaDataNet device categories	SDN devices
L11		SeaDataNet depth measurement reference planes	SeaDataNet datum origins
L22		SeaVoX Device Catalogue	SeaVoX Device Catalogue

- Nomenclature
- Service — EDMO
- Project — EDMERP

- Ship
- Gear
- Analysis
- Date

- Coordinate system — WGS84
- Positioning system



What geological information will you gain?

Descriptive tekst ⇄ Numerical values

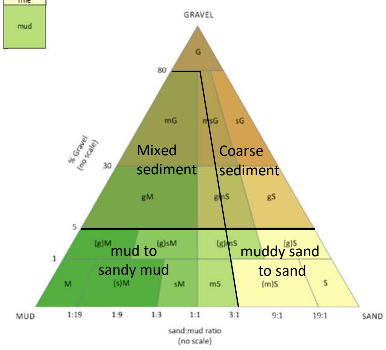
- Shell , organic and glauconite content
- Patina and color
- Chrono- and lithostratigraphy

Wentworth (1922)

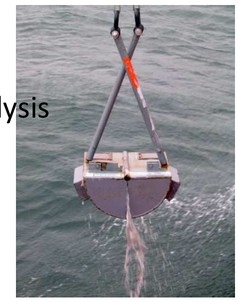
- Ranges
- Mean
- Median (D50)
- Percentiles

Folk (1954)

- Percentages (mud, sand, gravel)
- Grain-size distributions



How do we deal with data uncertainty?

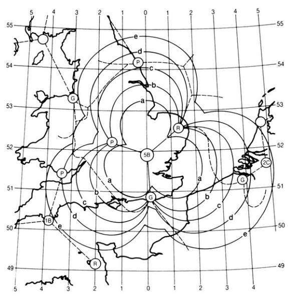


Sampling and Analysis

- Device
- Lithology

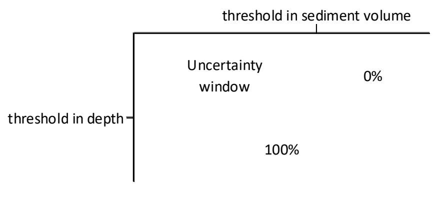
Positioning

- Accuracy of navigation system
- Resolution of the (voxel) model



Vintage

- Vintage of the sample
- Regional sediment dynamics and transport



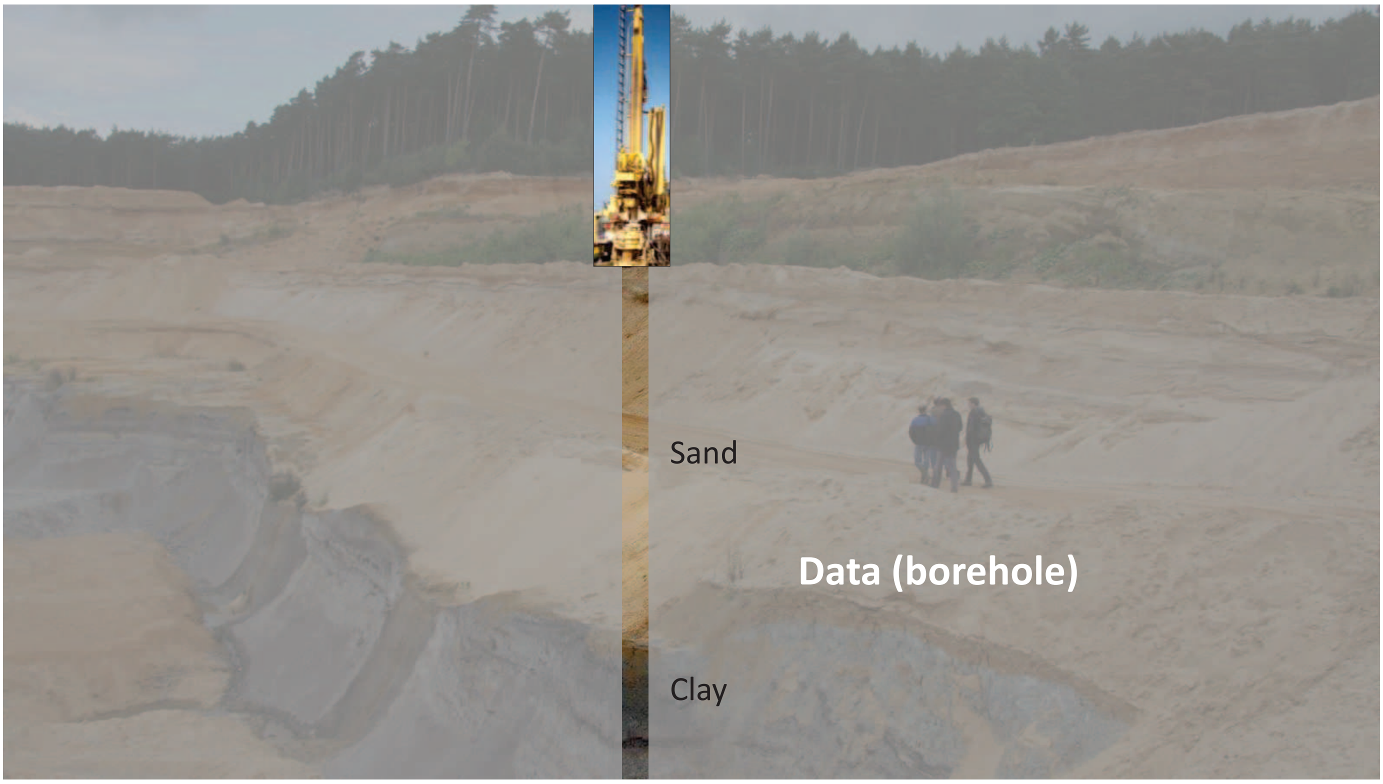
SAND TOOLS

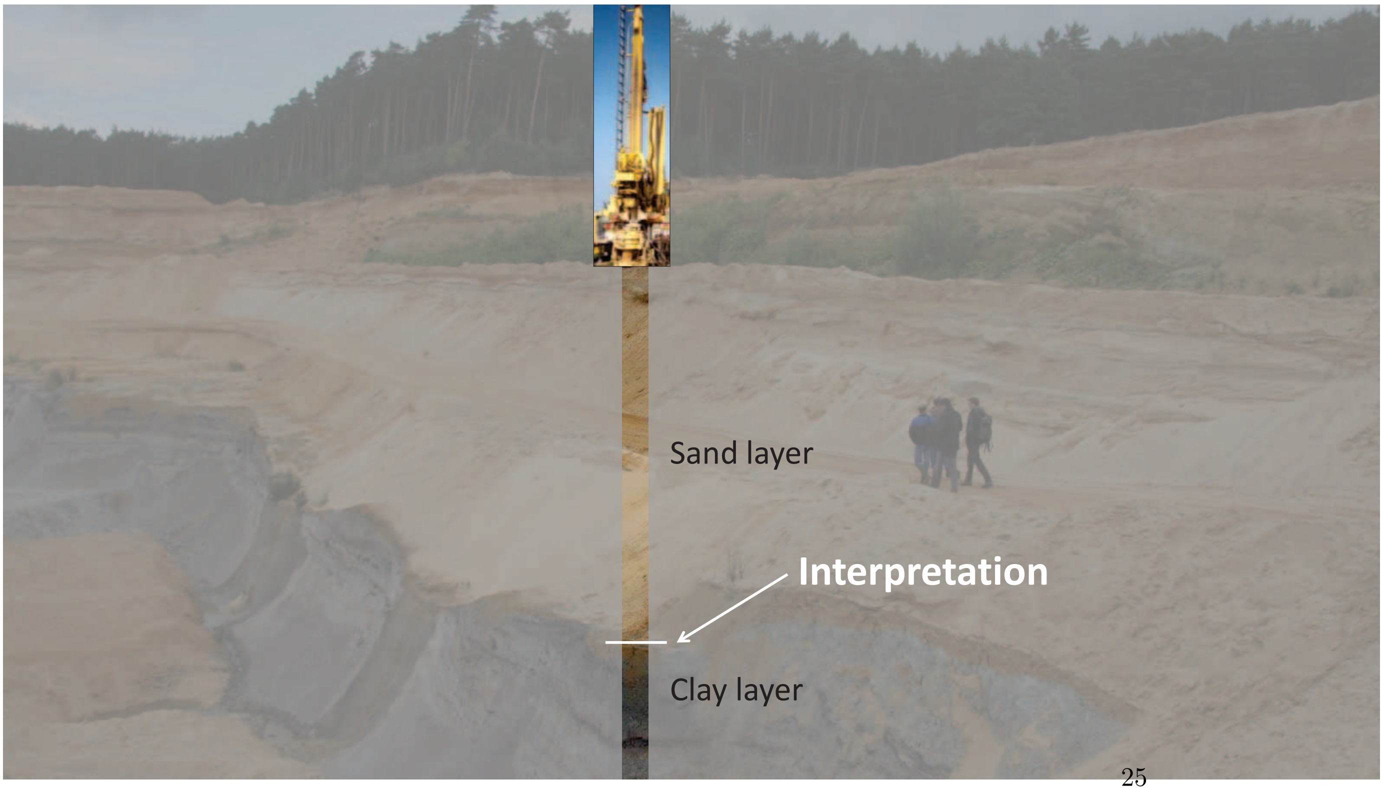
Sand-resource accounting is ideally done using 3D pixel models

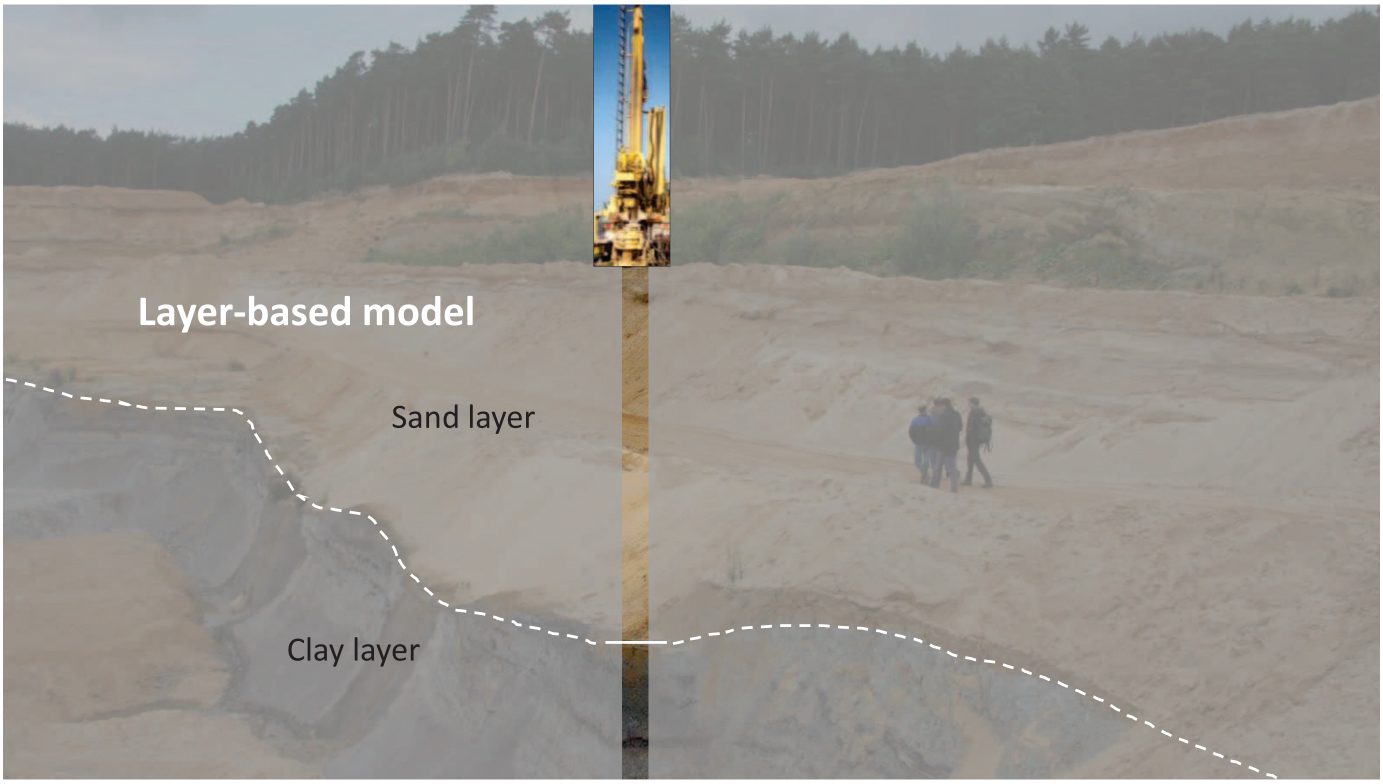
Sand-stock assessments should include the quality of the resource. 3D pixel (voxel) models incorporate multiple properties and allow in-depth analyses of their interrelationships. Because of the structured geometry, voxels capture the 3D-spatial heterogeneity within a resource layer better than maps.

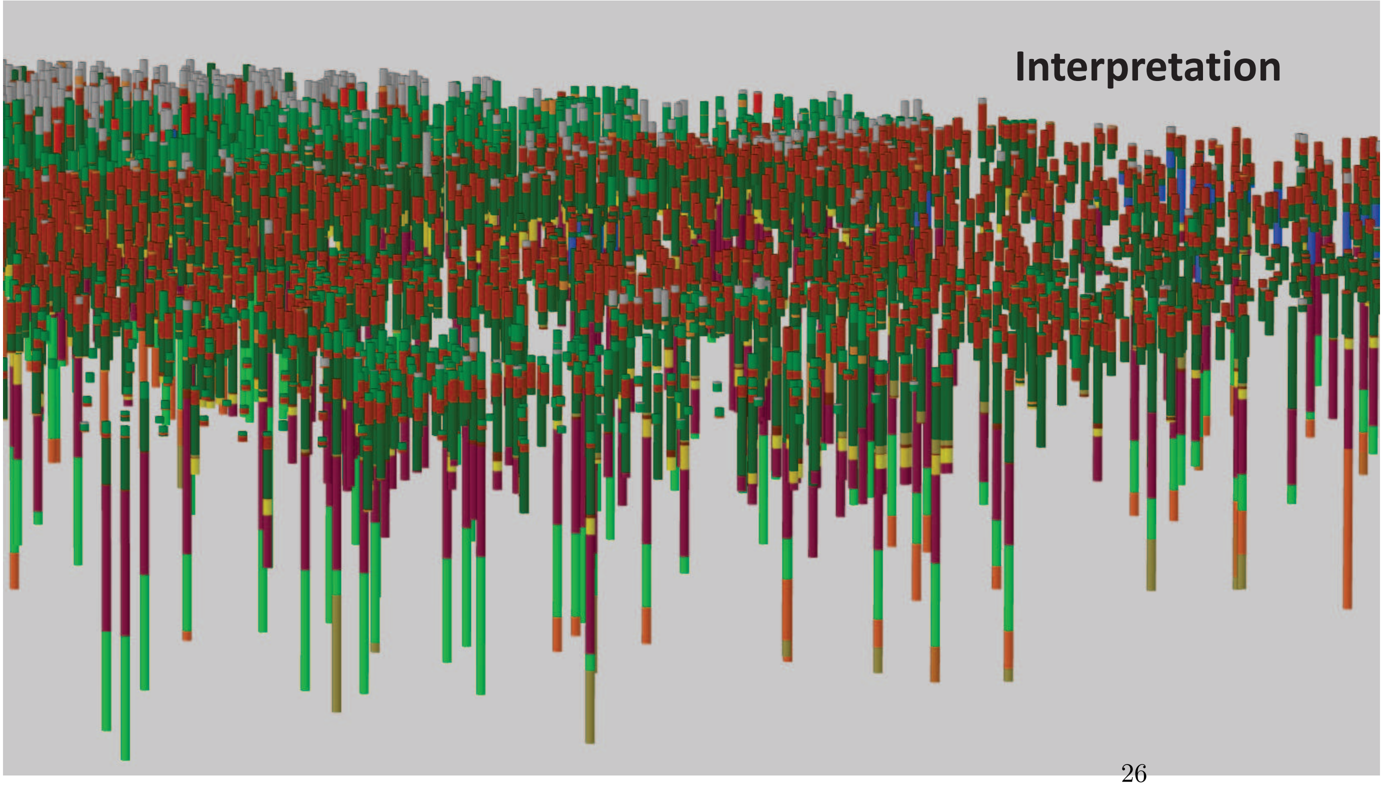
Jan Stafleu
TNO - Geological Survey of the Netherlands

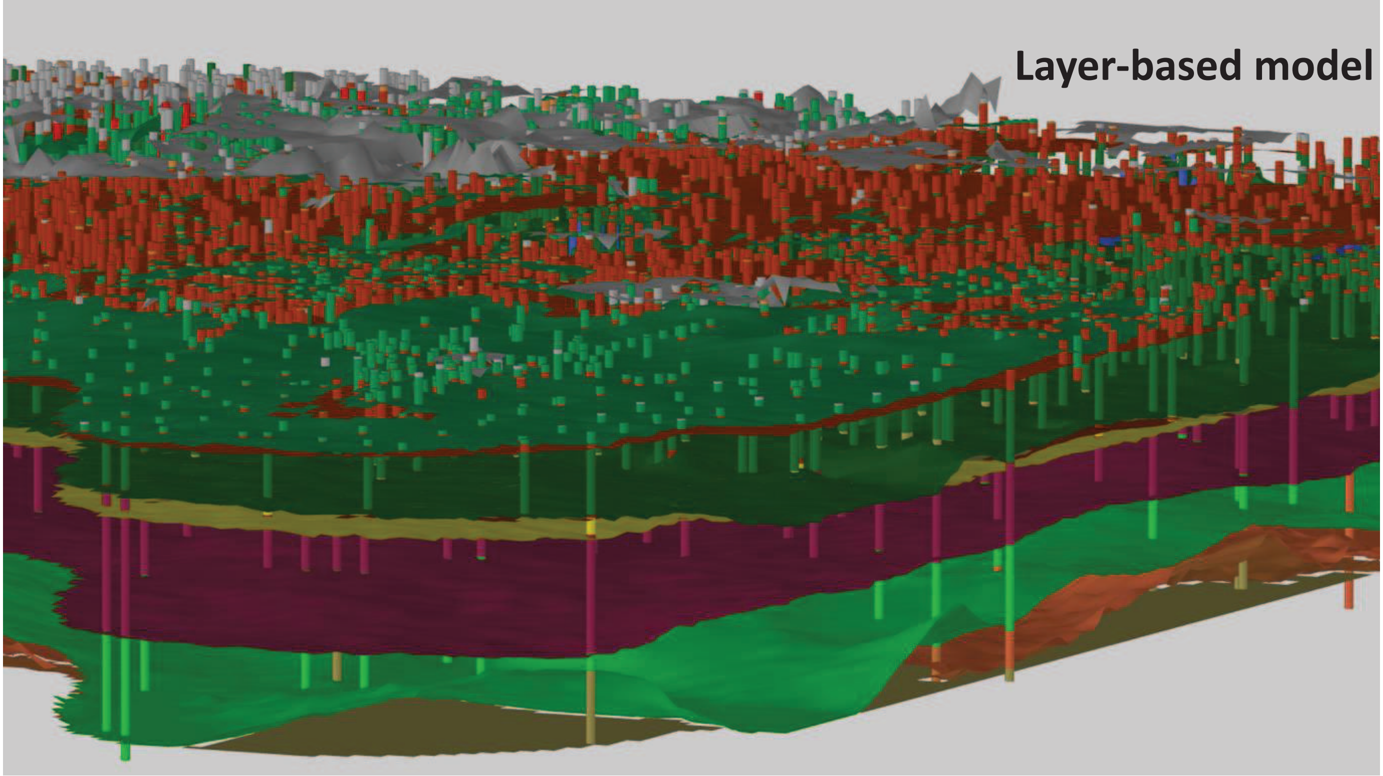
TNO innovation for life   100 JAAR GEOLOGIE IN KAART

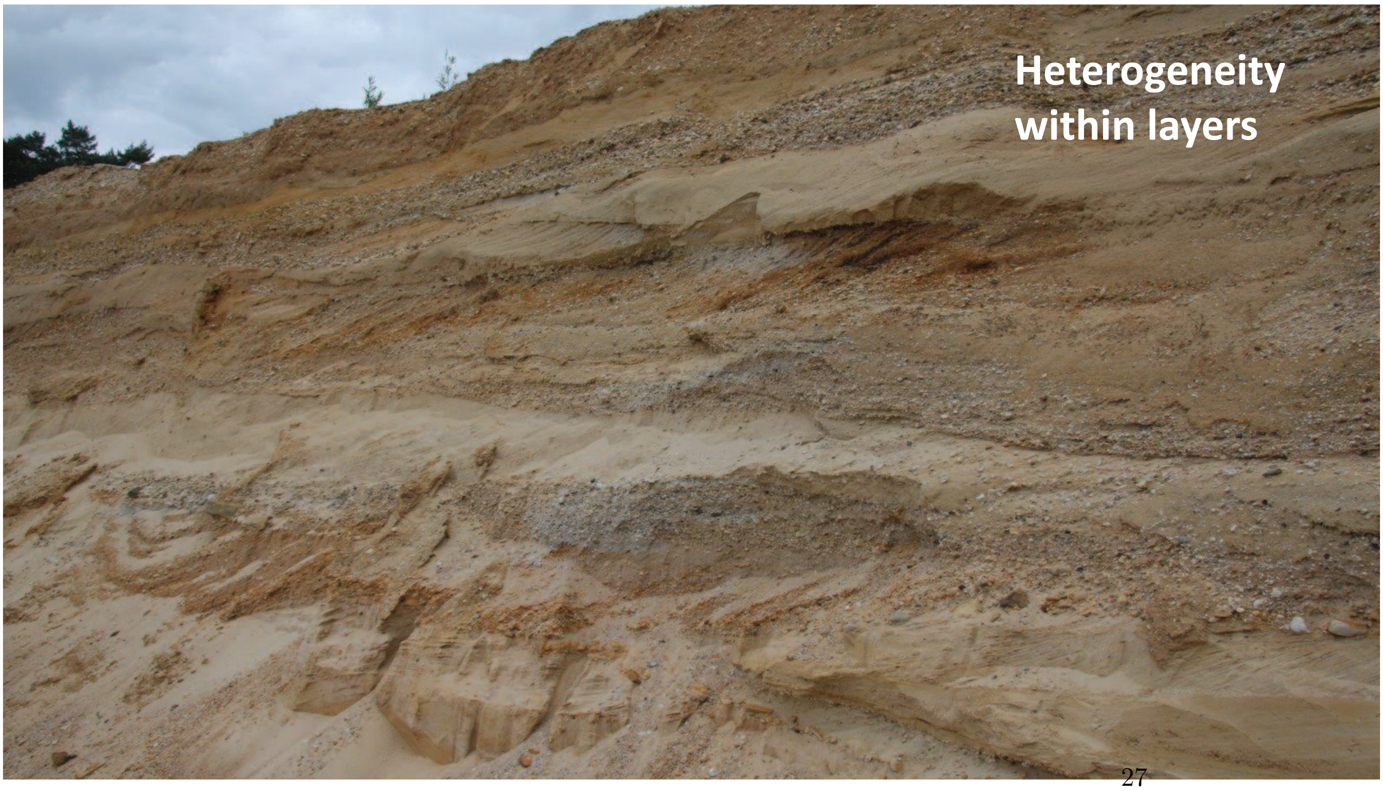

Sand
Data (borehole)
Clay

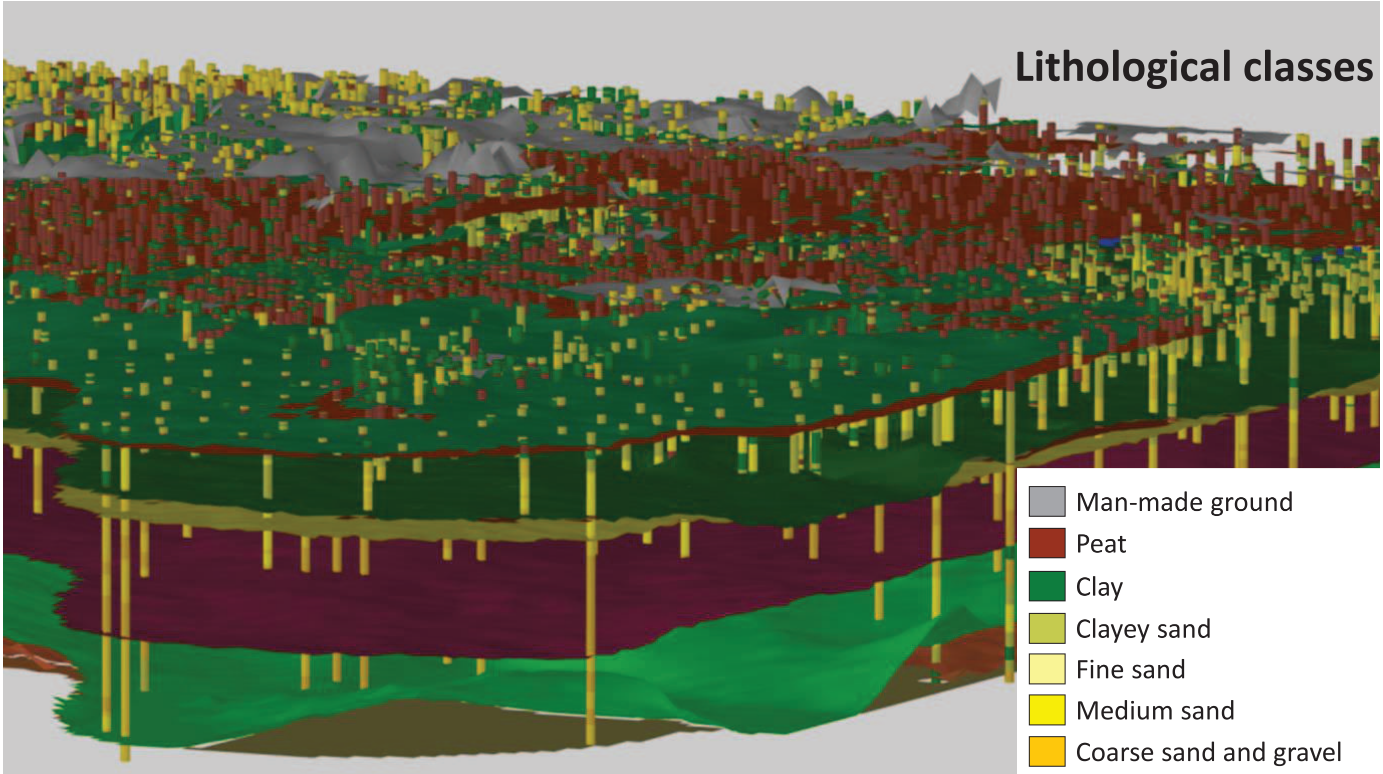

Sand layer
Interpretation
Clay layer

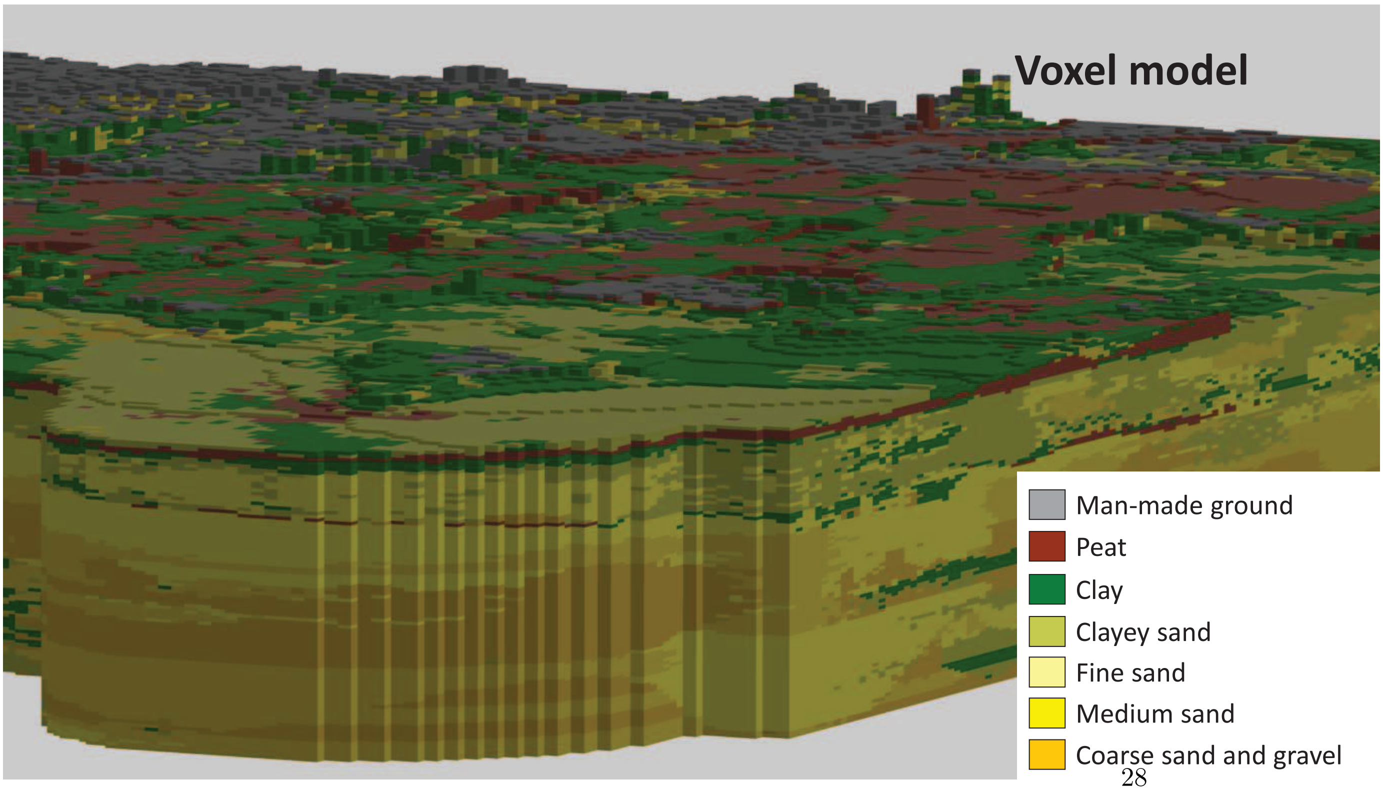

Layer-based model
Sand layer
Clay layer


Interpretation


Layer-based model

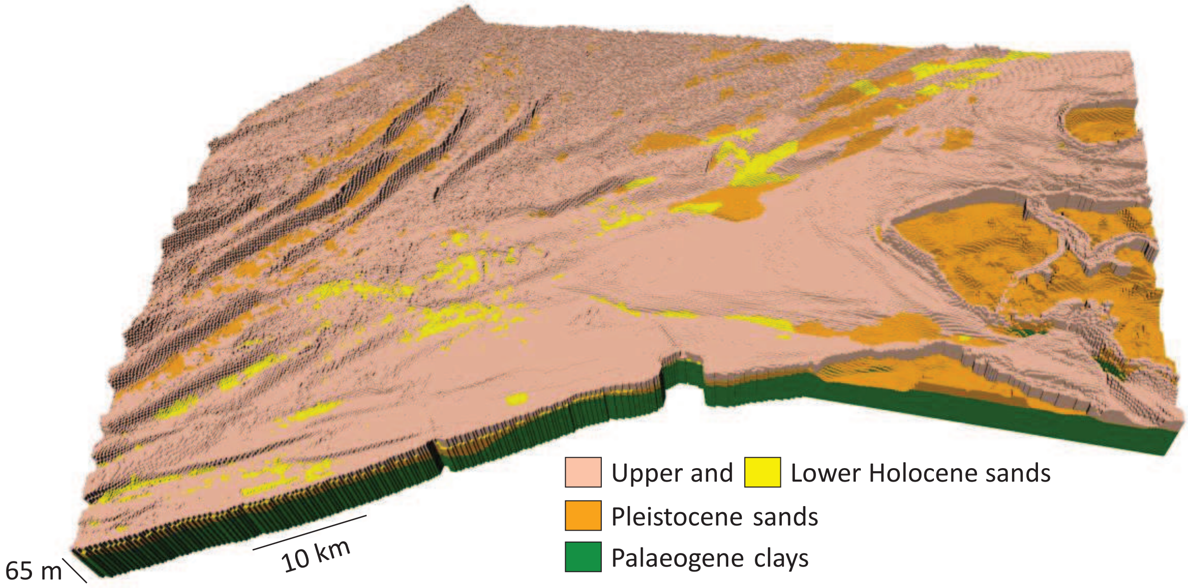

Heterogeneity
within layers


Lithological classes
Man-made ground
Peat
Clay
Clayey sand
Fine sand
Medium sand
Coarse sand and gravel


Voxel model
Man-made ground
Peat
Clay
Clayey sand
Fine sand
Medium sand
Coarse sand and gravel

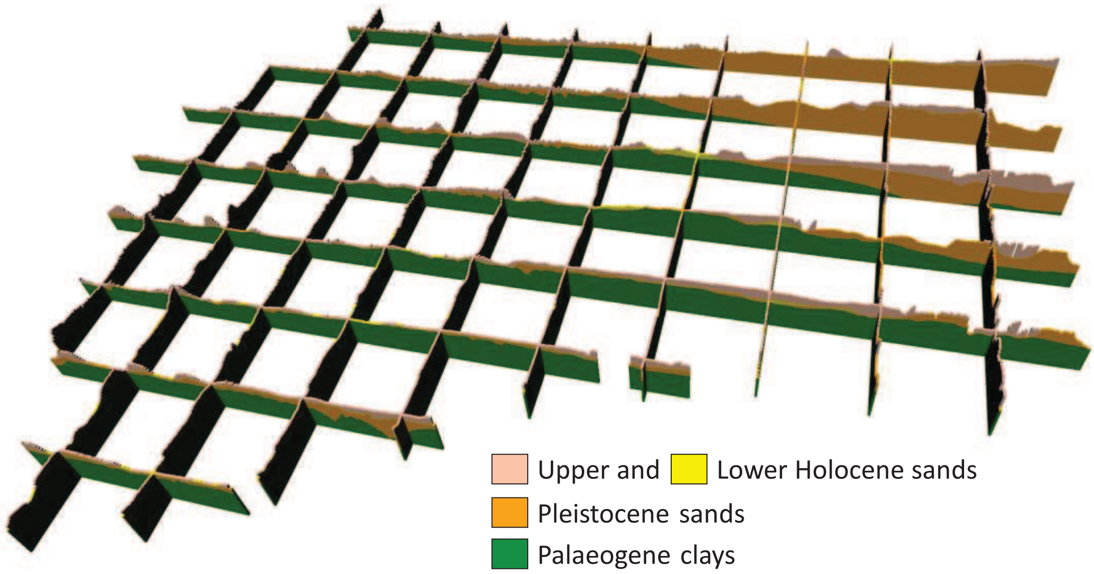
Tiles Transnational layer-based model

layers based on seismic interpretation



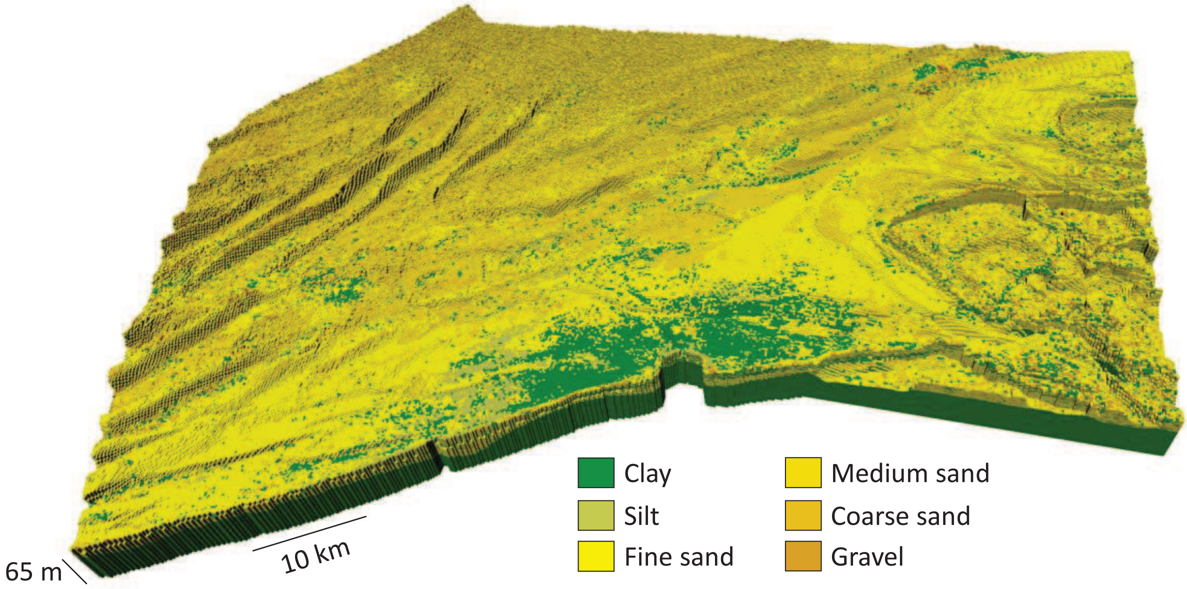
Tiles Transnational layer-based model

layers based on seismic interpretation



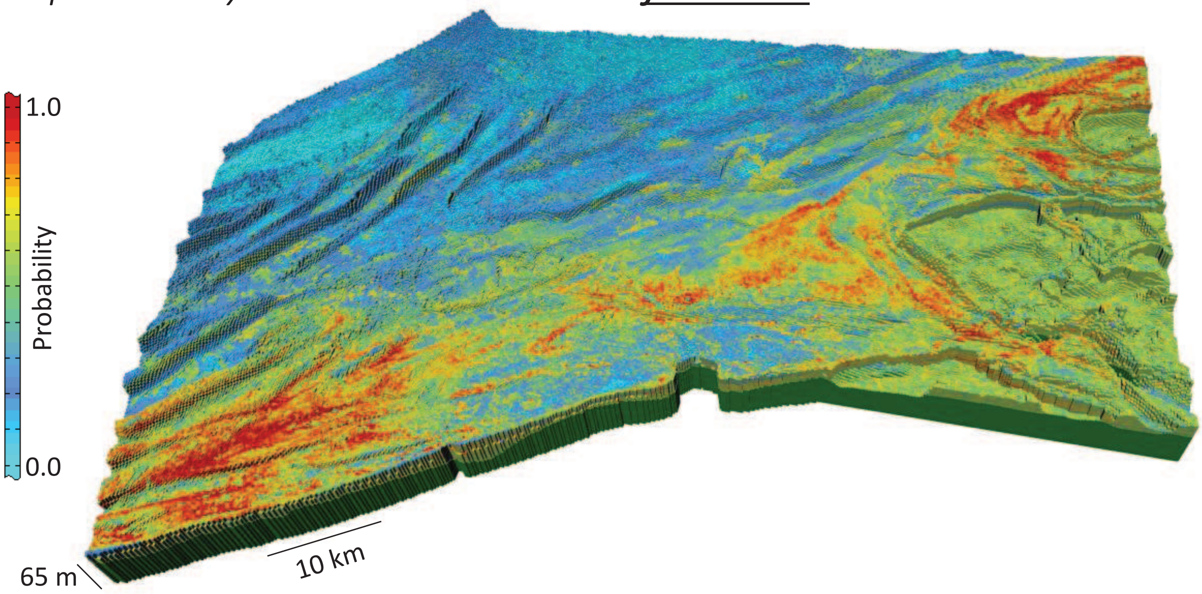
Tiles Transnational voxel model

most likely lithological class



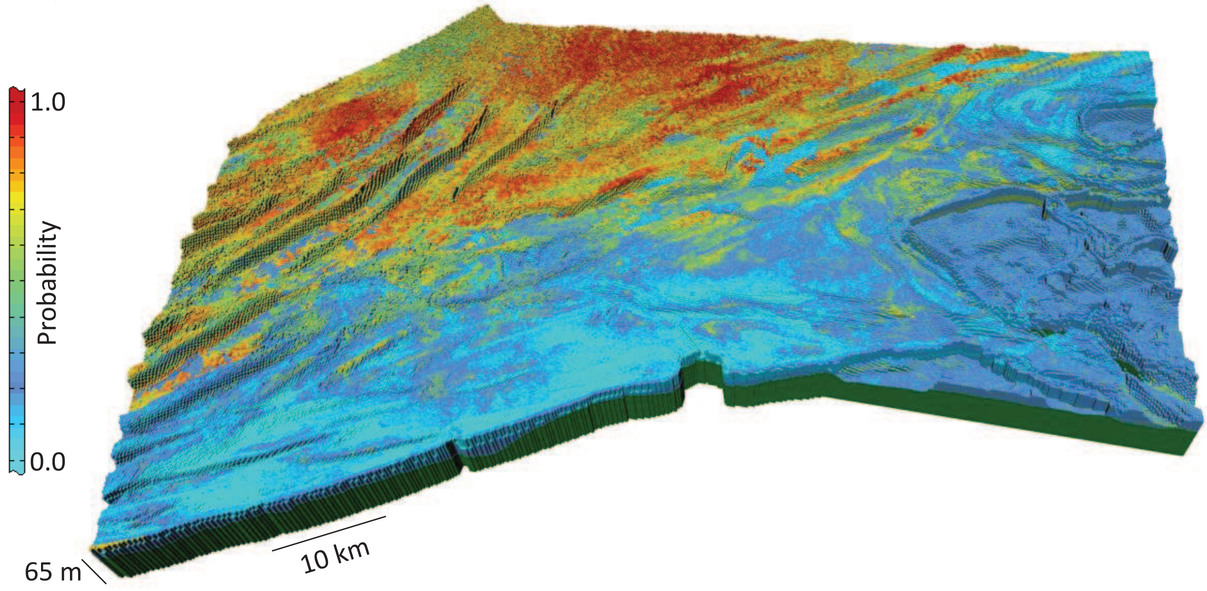
Tiles Transnational voxel model

*probability that a voxel contains **fine sand***



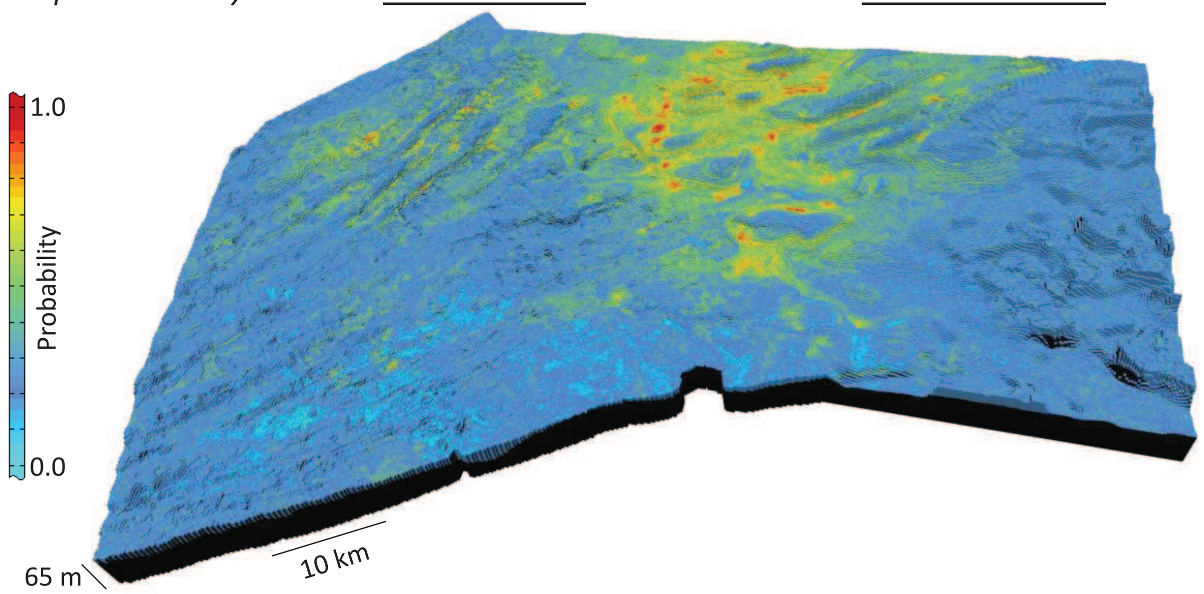
Tiles Transnational voxel model

*probability that a voxel contains **medium sand***

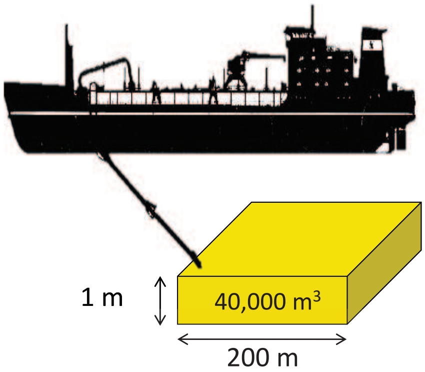


Tiles Transnational voxel model

*probability that a **Pleistocene** voxel contains **medium sand***

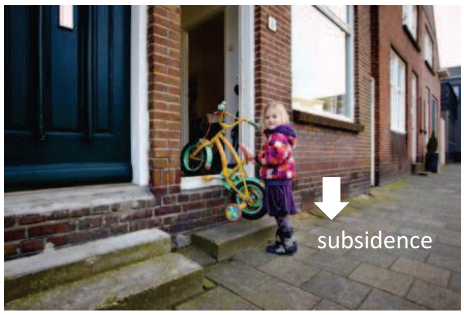


Voxel ‘standard’ attributes



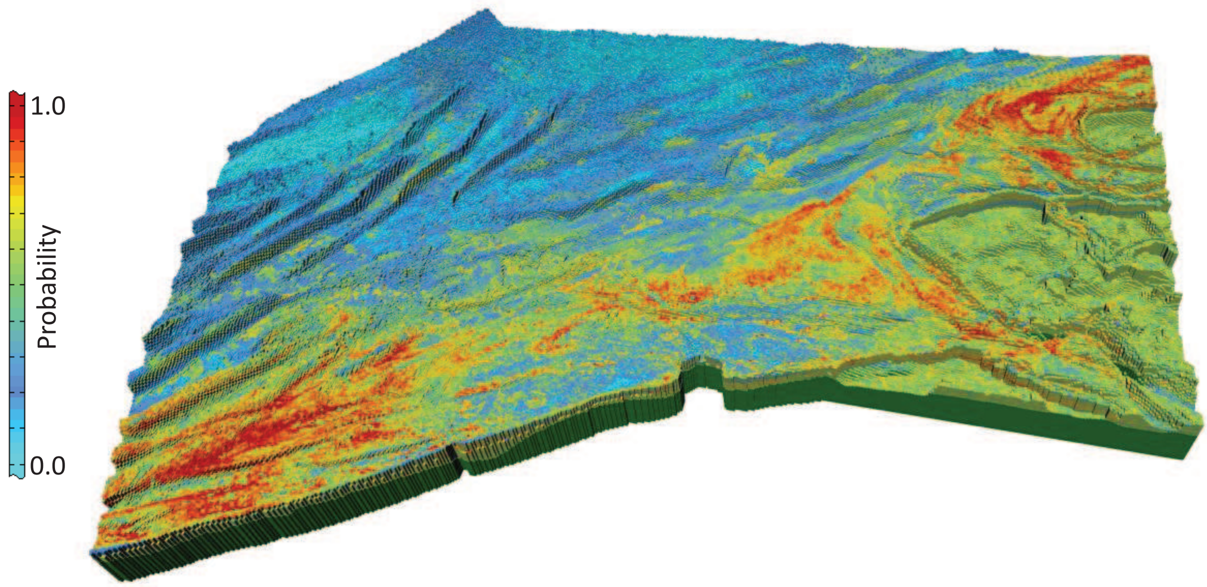
- Location (x, y, z)
- Geological unit (layer)
- Most likely lithological class
  - from 100 model runs
- Probabilities of occurrence:
  - Clay
  - Silt
  - Fine sand
  - Medium sand
  - Coarse sand
  - Gravel

Voxel additional attributes for applications



- Bearing capacity … construction works
- Hydraulic conductivity … groundwater flow
- Peat oxidation rate … land subsidence
- Seismic velocity … earthquake damage
- And many more …

Thank you for your attention



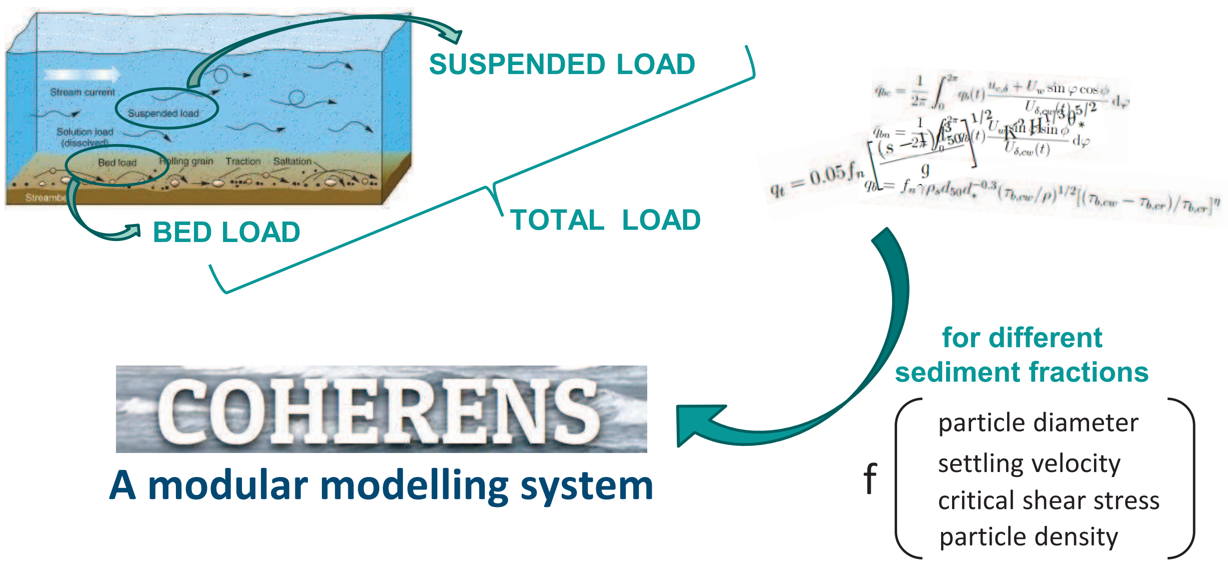
SAND TOOLS

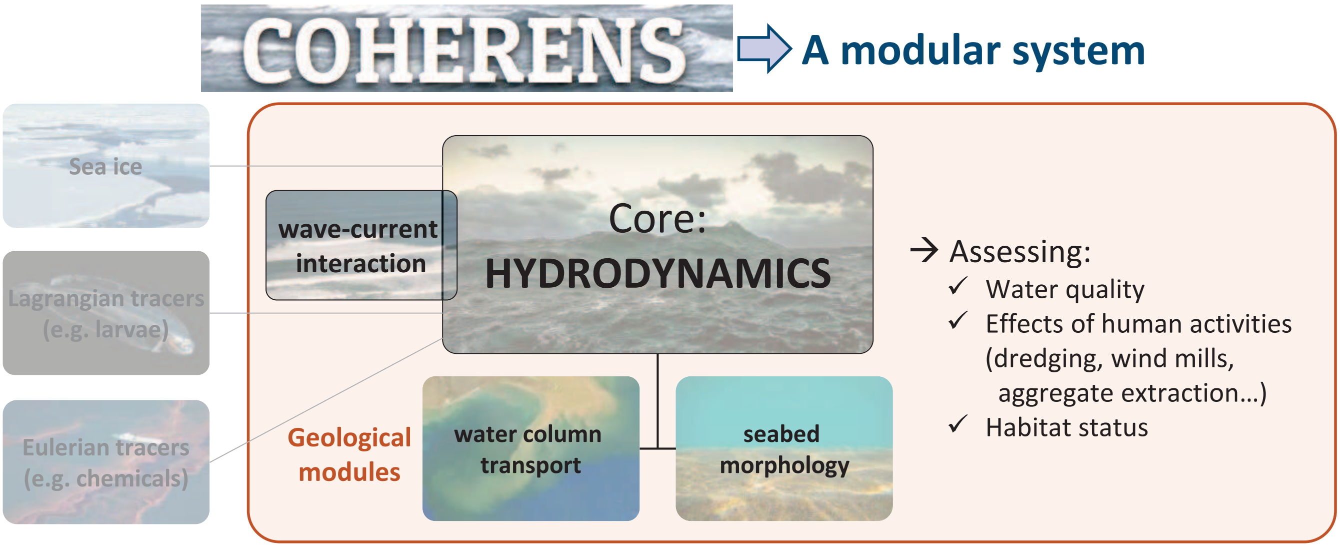
Sand-system models should guide long-term management

Sand management necessitates more than information on the material itself. The dynamic nature of marine resources and their human exploitation calls for numerical simulations of their evolution through time. Importantly, material flow between land and sea and across borders must be quantified. Goods and services brought by the material to the ecosystem need to be valued.

Dries Van den Eynde
Royal Belgian Institute of Natural Sciences

Modelling sand dynamics

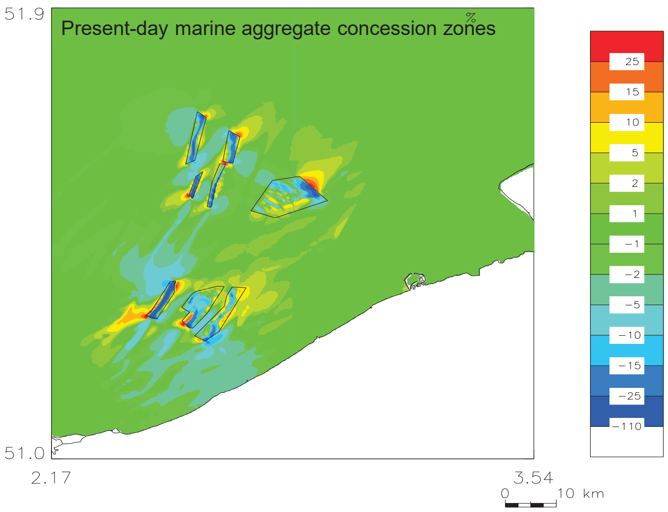




Applications *w.r.t.* compliancy with European Directives

e.g. ***Marine Strategy Framework Directive****, targeting*

Good Environmental Status of marine waters by 2020



Descriptor Hydrographic Conditions

Bottom shear stress is key indicator

Here: changes in bottom shear stress due to aggregate extraction

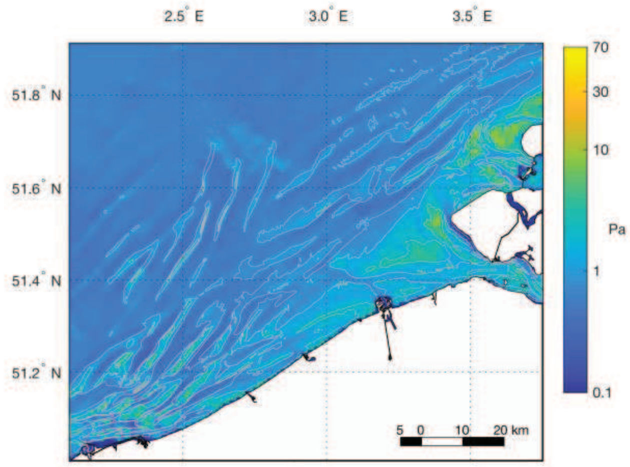
Quantifying Variability

Long-term dataset on sediment transport parameters

16-year long hindcast

1999 – 2014

- Quantification of spatial and temporal variability:
  - Year-to-year
  - Seasonal
  - Long term
- Areas preferentially erosional or depositional



Quantifying Variability

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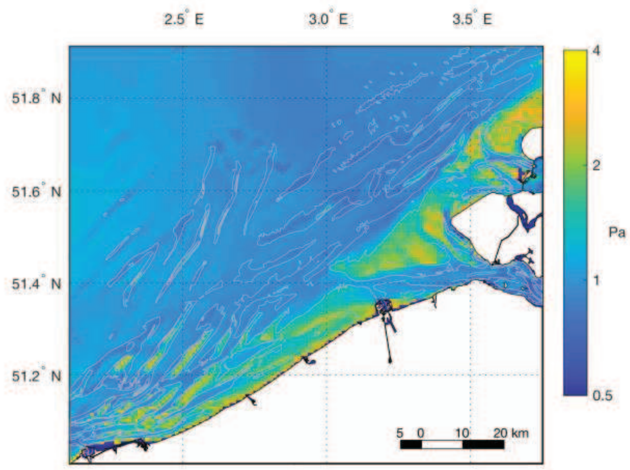

Quantifying Variability

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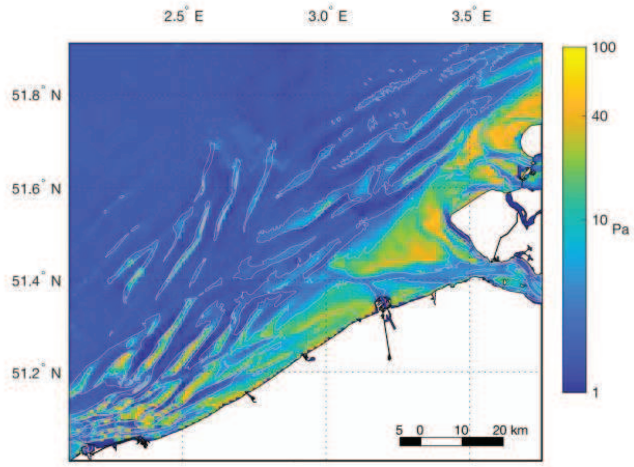
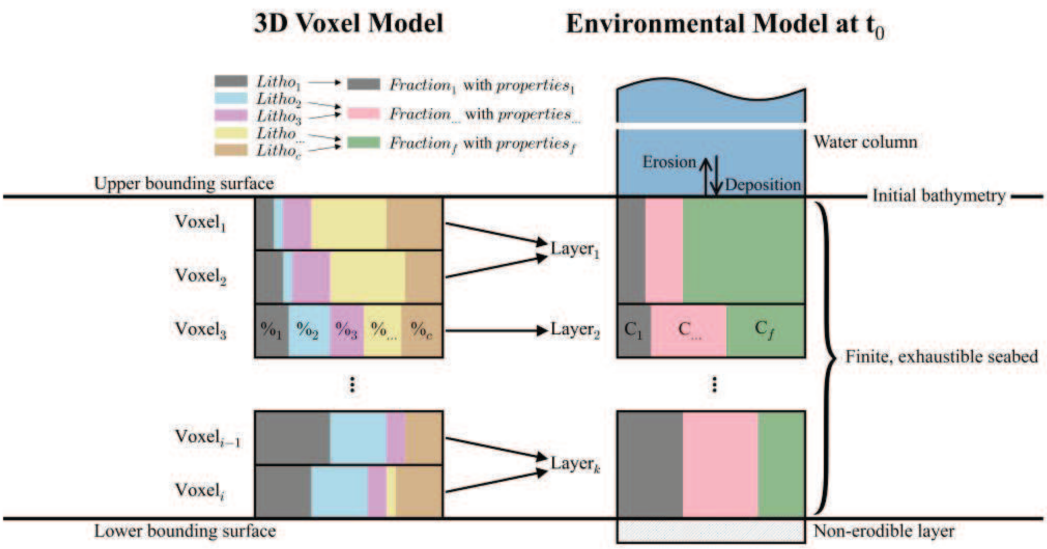
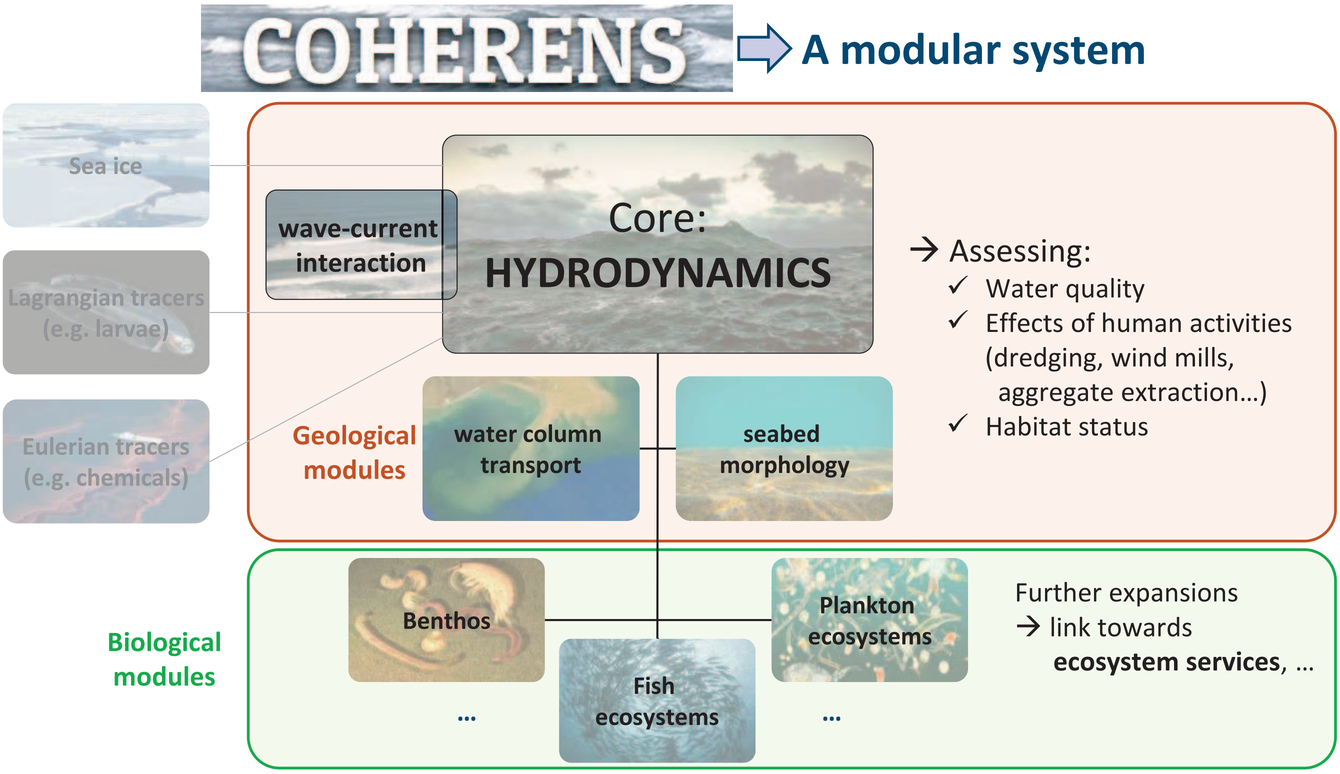


Accounting for geology in sediment transport

A new 3D-4D coupling procedure



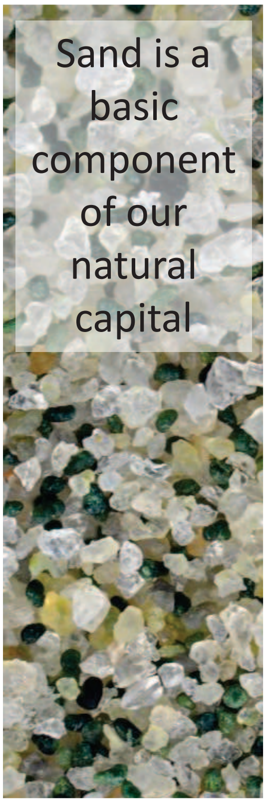
Van Lancker et al., 2017



Conclusions

- Numerical modelling is a crucial tool to assess the dynamic nature of sand resources
- Long-time series allow quantification of both naturally and man-made changes
  → *acceptable thresholds for alterations to the seabed*
  → *seabed recovery potential*
- Modular modelling systems allow further expansions with growing insights
  → *e.g., link towards ecosystem services and values*


Sand is a basic component
of our natural capital



SAND AS A RESOURCE

Sand is a finite, non-renewable resource

Sand grains are made on geological time scales. From a human perspective, they do not regenerate. Exploitation is followed by redistribution of sand as it seeks to find new equilibria. Impacted sandbanks, for example, recover by moving sand from trough to crest. In sediment-starved systems they cannibalize themselves, becoming thinner through time.

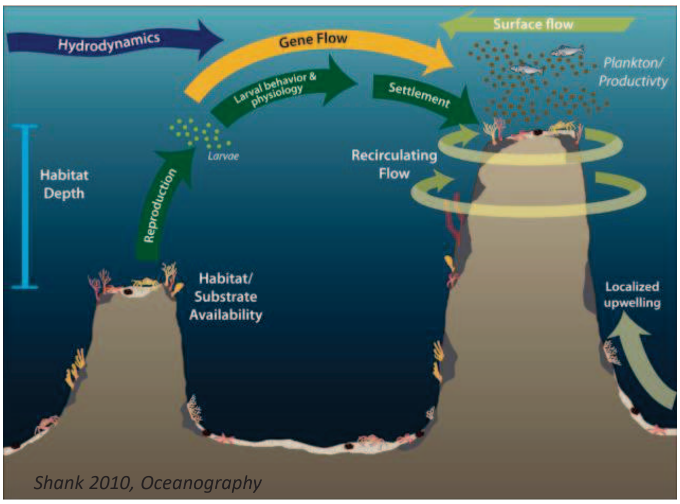
Vera Van Lancker
Royal Belgian Institute of Natural Sciences

museum

Sand as a geological resource

Steemkr.com

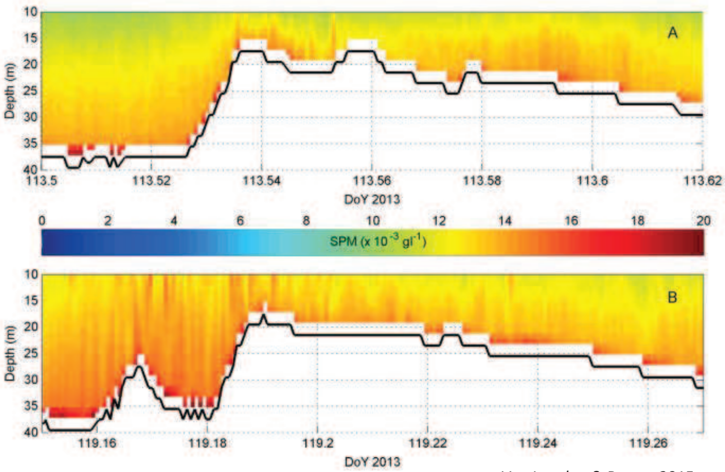
Sand as a biological resource



Shank 2010, Oceanography

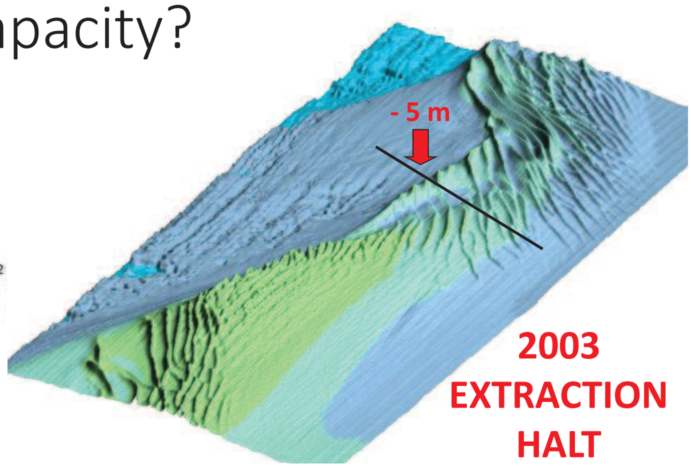
What if?
Large-scale habitat fragmentation
"Sand hunger"...

Sandbanks regenerative capacity?

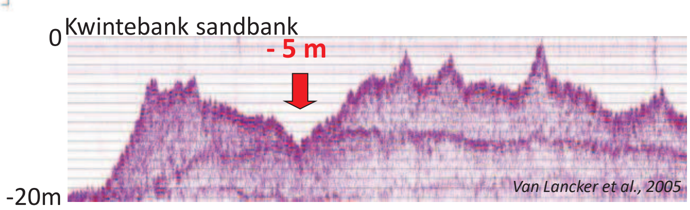


Van Lancker & Baeye, 2015

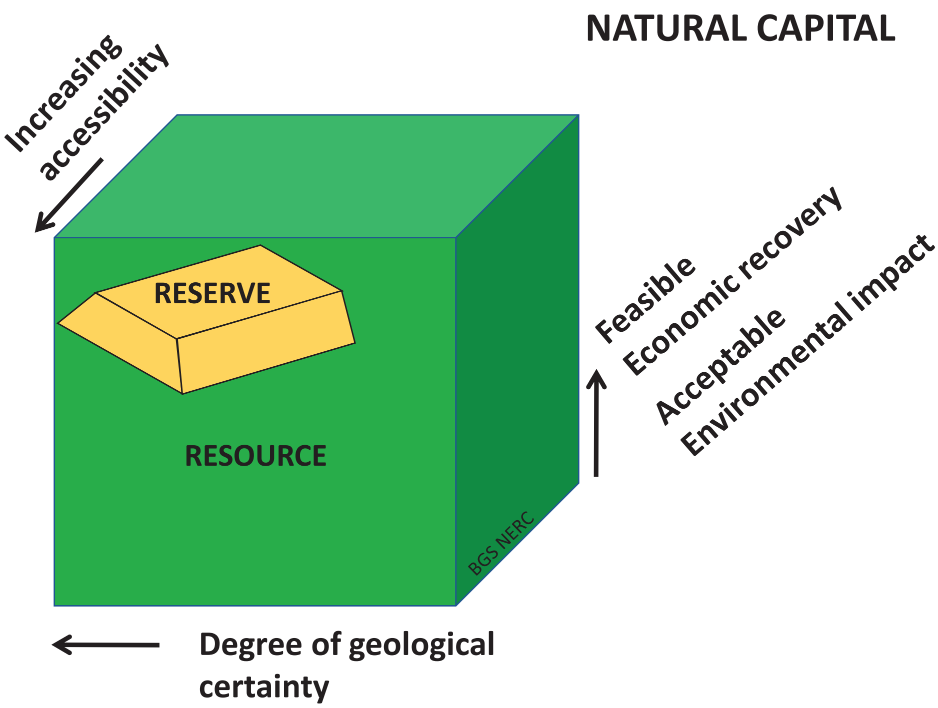
Sand fluxes: YES, but mostly fine sand



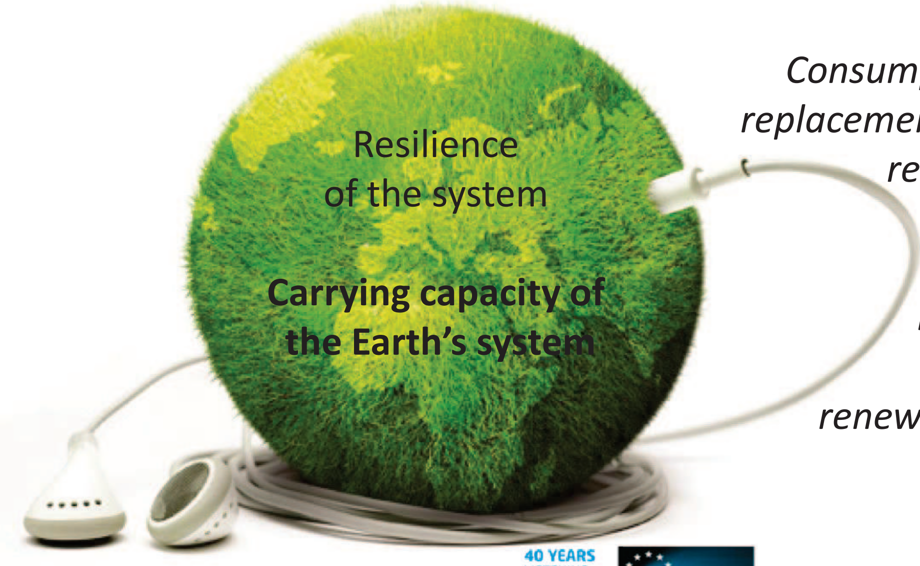
NO REGENERATION *Roche et al., 2017*



Depletion rate?



Use of non-renewable resources

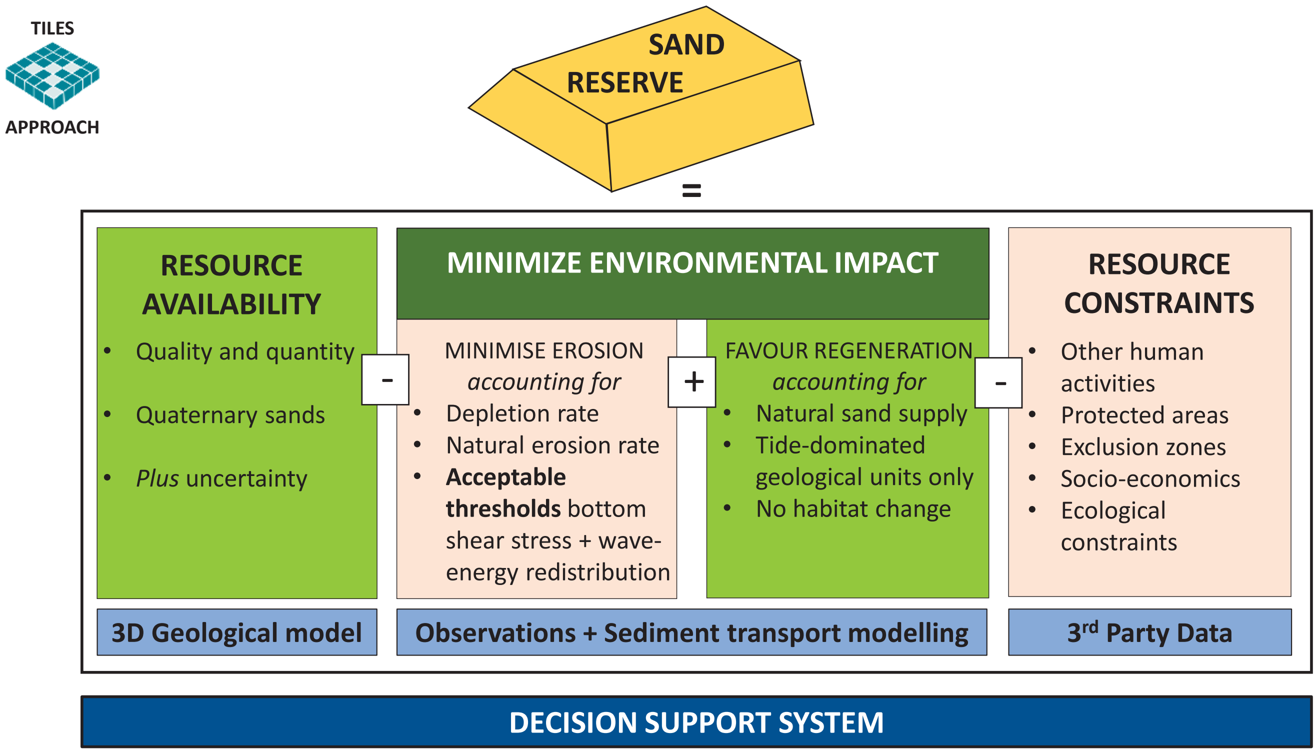


Consumption should be less than replacement by functionally equivalent renewable resources

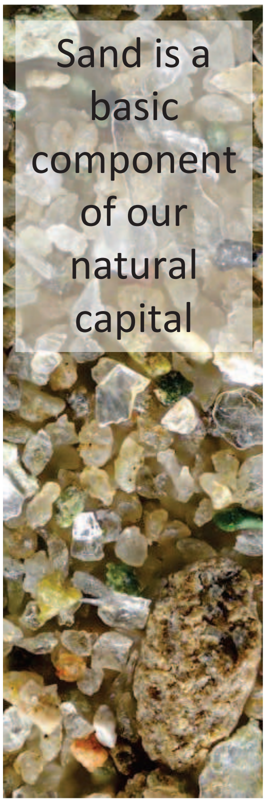
or

by attaining a ***higher efficiency*** *in the use of renewable or non-renewable resources*

40 YEARS LISTENING TO THE BEAT OF THE EARTH EuroGeoSurveys




Conclusions
• Relict sands do not regenerate
• Need for higher efficiency in resource use
• Need for better comprehension of interrelationships



SAND AS A RESOURCE

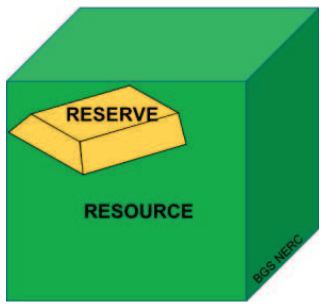
Sand quality and quantity are unequally distributed

Sand usage is function of abundance. If supplies are limited, long-term exploitation requires resource efficiency. The right quality of sand should be used for the right purpose: valuable coarse sands should not end up in low-end products. Shell and mud admixtures can be avoided.

Vasilis Hademenos
Ghent University – Renard Centre of Marine Geology

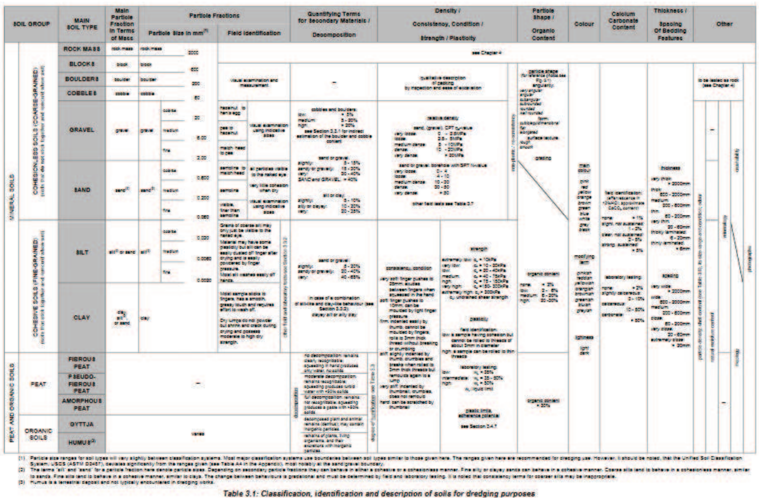
Resource > Reserve

- Sand type
    - Targeting the right quality
        - Suitable lithological class
    - Avoiding undesired admixtures
    - Favouring deposits with high degree of certainty
- Resource quantities
- Location



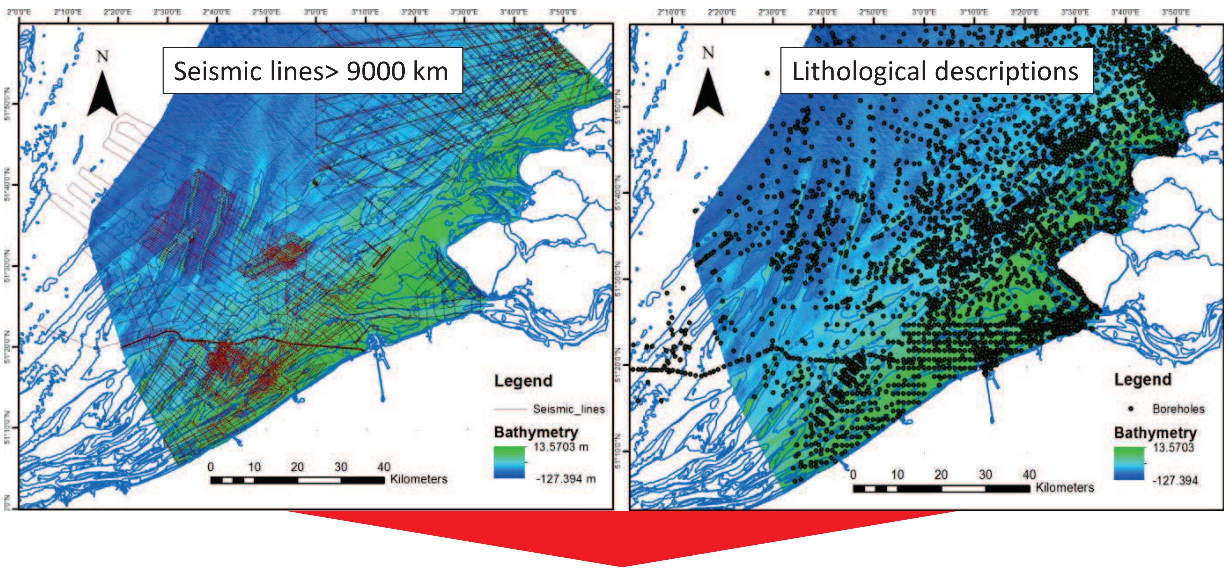
Different users – different requirements

Classification, identification and description of soils for dredging purposes (PIANC, 2014)



Right quality?

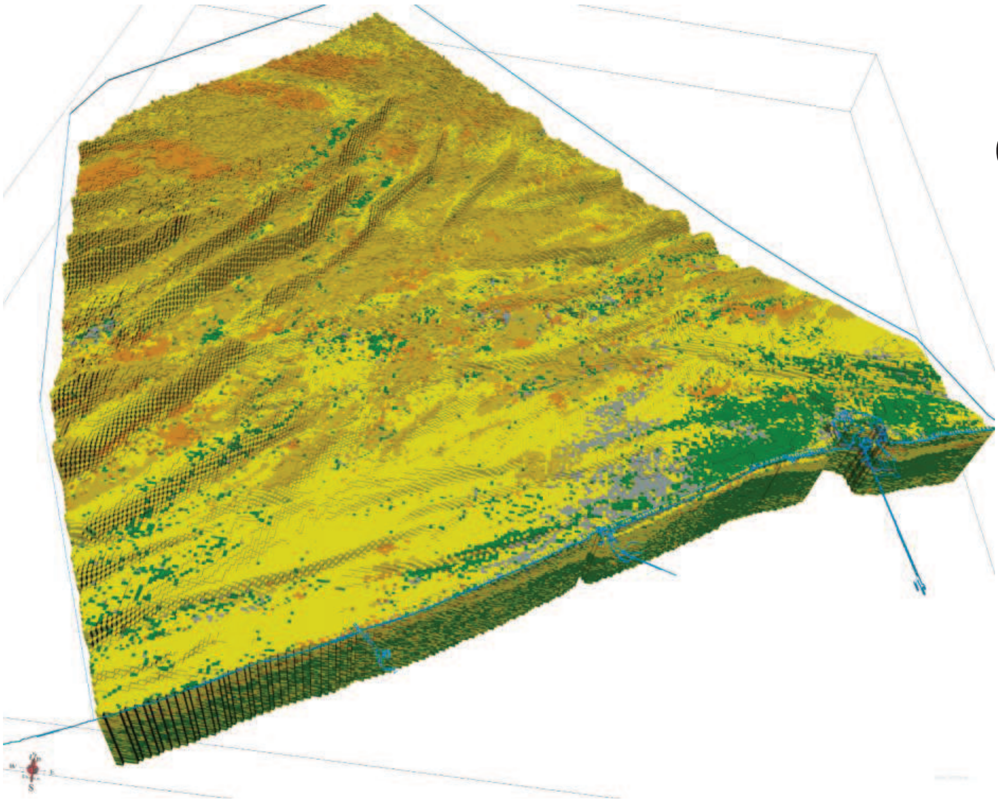
Resource database



Voxel modelling

Resource Categorization

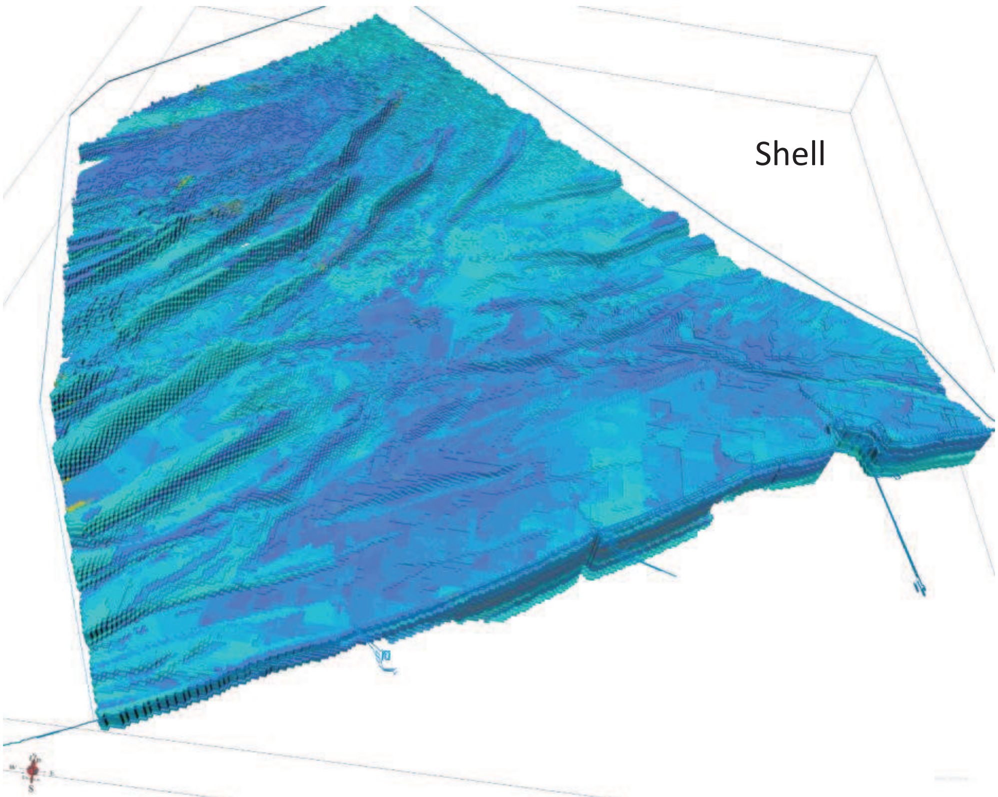
Lithological class



- Clay
- Silt
- Fine Sand
- Medium Sand
- Coarse Sand
- Gravel

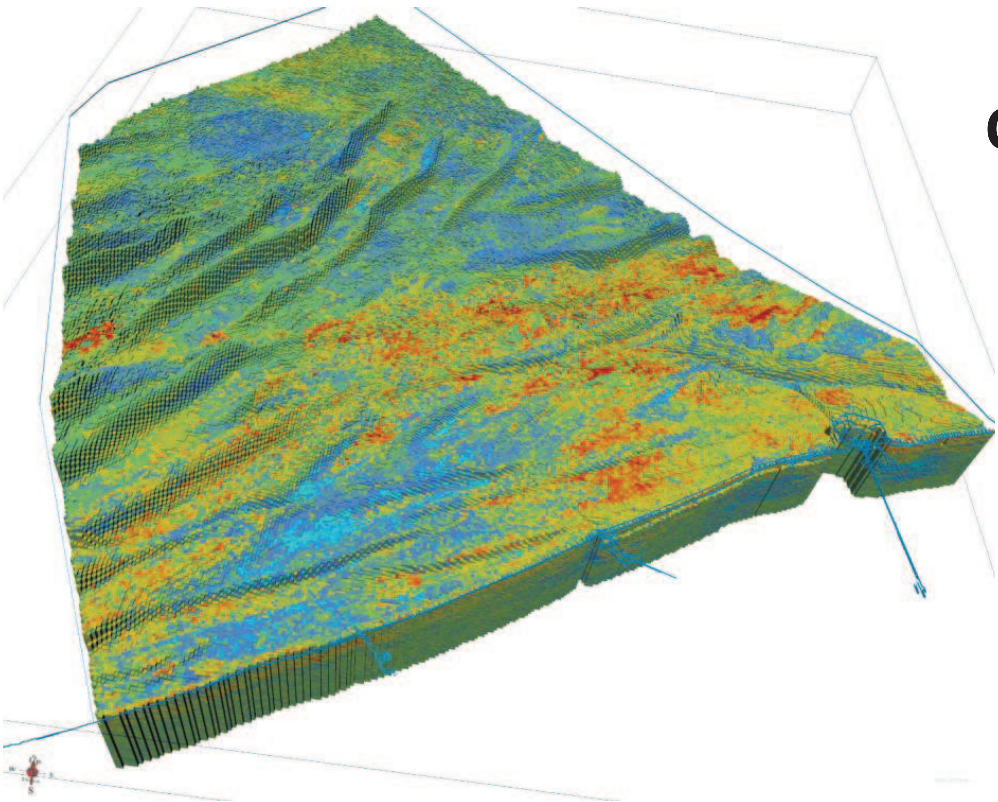
Resource Categorization

Admixture



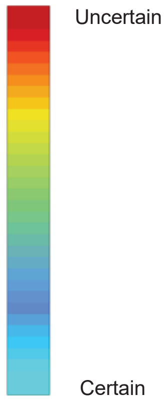
100%

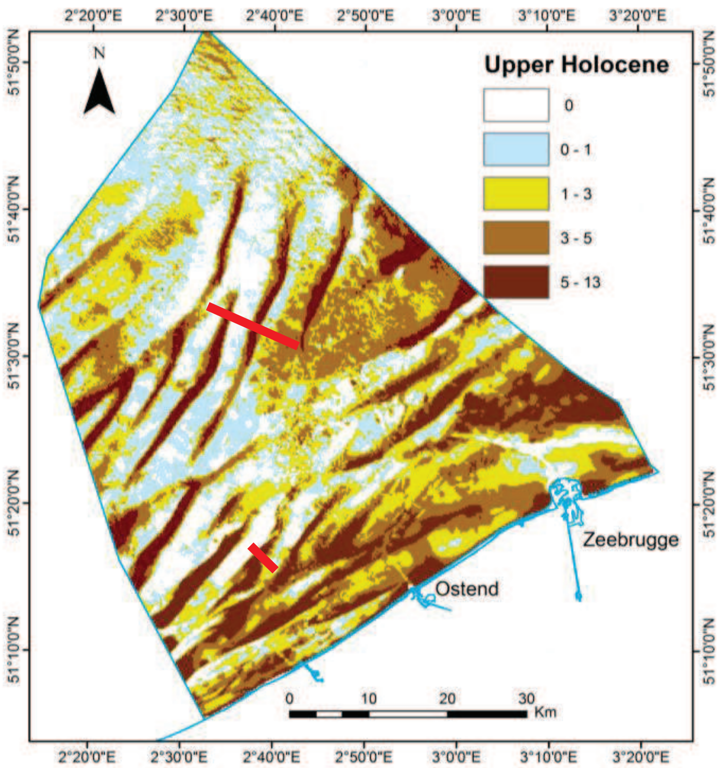
0



Resource Categorization

(UN)CERTAINTY

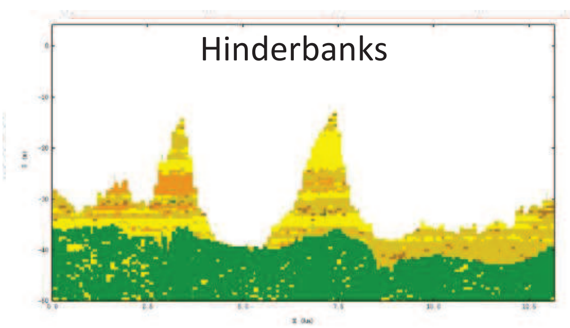




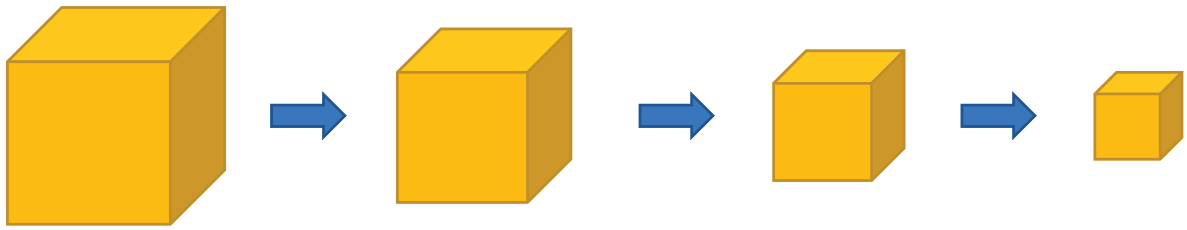
Upper Holocene Sediment availability

14 billion m^3

47.7 % of the Quaternary cover

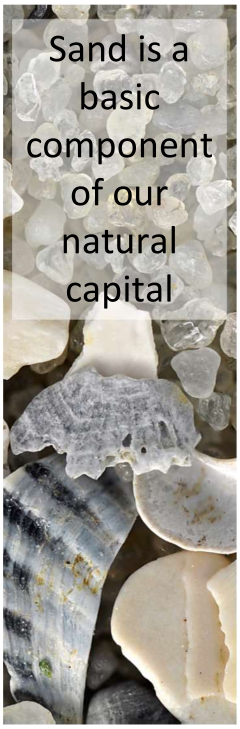


Conclusions



Quaternary	Upper Holocene	Right Quality	Guaranteed Quality
28 BILLION	14 BILLION	2.8 BILLION	2.5 BILLION

Available resource → **Geological reserve with the right and guaranteed quality**



SAND AS A RESOURCE

Sand-resource sustainability calls for an industrial ecology approach

Sand exploitation needs to be governed by long-term socio-economic considerations. Sufficient resource ought to be left for future generations and the integrity of the natural capital must be safeguarded. Industrial ecology adds a system approach and enlarges the view by including flows and stocks in society as well as nature. This enables to assess the potential effectiveness of options to address problematic issues. Resource efficiency and circular economy options could help reduce primary production.

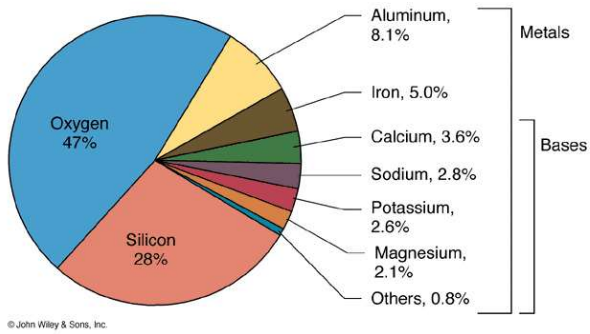
Prof. dr. Ester van der Voet
Leiden University

Sand as a Resource: an IE approach

- Sand as a Resource
- An Industrial Ecology approach to sand:
  - Flows and stocks in society
  - A life cycle approach
  - Issues of concern
  - Solutions
- Some Recommendations

Sand as a Resource

- Mass of Earths crust (continental): 1.4 * 10^{22} kg
- Composition of Earth's crust:



Sand as a Resource

- Sand is extracted and used for various purposes
- Traditionally a local resource
- Traditionally approached like other geological resources:
  - Much effort goes into locating, characterising and assessing sources in the environment
  - Data mainly on geological stocks and on extraction
  - Problem definition: Shortages? Look for new sources in the environment!

Sand as a Resource

- Is not the whole story:
  - Sand is used for certain purposes
  - Involves cradle-to-grave chains
  - Involves attention for main applications: consumption instead of (in addition to) production
  - Not just assessing flows, but also stocks in society: urban mines!
- Metals & mining sectors are slowly starting to acknowledge the relevance of urban mines
- Also potentially interesting for sand sector?

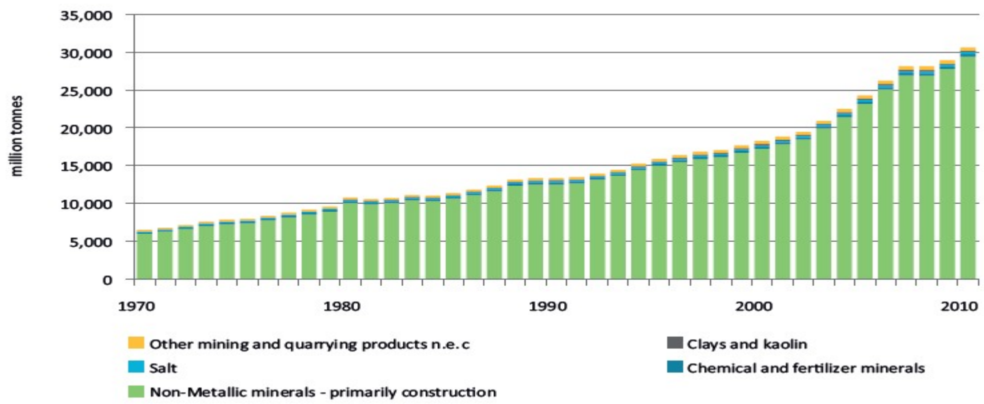
Industrial Ecology approach to Sand

IE assessment of sand is what we need

- How much is used
- What is it used for
- How is that changing over time
- What are losses, waste, emissions
- Issues for concern
- Potential solutions

Industrial Ecology approach to Sand: MFA

- MFA of sand (source: UNEP, 2016)



Industrial Ecology approach to Sand: MFA

Data from Material Flow Accounts

- quite uncertain, not standardly collected
- including also gravel
- (possibly?) only sand & gravel for construction

Such as it is:

- Sand extraction is very large
- Sand extraction is growing fast
- Main growth at the moment in Asia Pacific

Uses of sand 1. Construction (cement, concrete)

Uses of sand 2. Infrastructural works

Uses of sand 3. Coastal defense

Uses of sand 4. Glass and other industrial minerals

Uses of sand 5. Others

Industrial Ecology approach to Sand

- Huge amounts of sand are used
- But only a hazy picture of applications
  - Reasonably good data on cement / concrete
  - Hardly any data on infrastructure / coastal defense

- A sustainable sand use requires information on the complete life cycle
- .. and an analysis of what the issues are exactly

IE approach to Sand: Issues to resolve

Issues of concern related to resources:

- Scarcity / criticality / accessibility
- Waste generation
- Environmental impacts

To what extent are these issues relevant for sand?

IE approach to Sand: Issues to resolve

- Scarcity / Criticality / Accessibility: issues indeed!
  - One fourth of the earth's crust is sand
  - But apparently not all sand is equal

In the news:

https://www.smithsonianmag.com/science-nature/world-facing-global-sand-crisis-180964815/

https://scroll.in/article/836336/the-new-oil-the-global-battle-for-sand-is-getting-ugly

https://www.independent.co.uk/environment/sand-mining-construction-black-market-gangs-a7097911.html

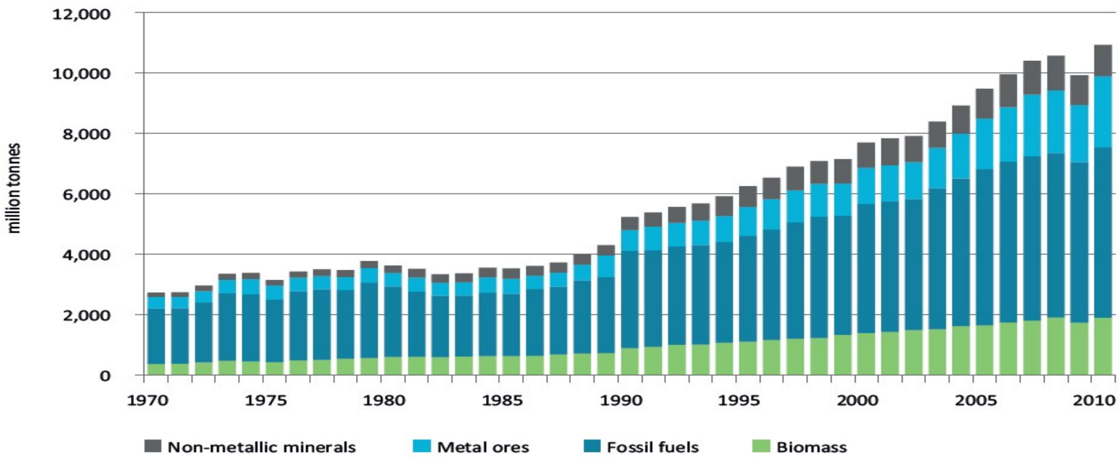
IE approach to Sand: Issues to resolve

- Seems to be linked to rapid urbanisation
- But probably more ongoing

- "Sand is moving from a local resource to an internationally traded commodity"
- Illegal extraction and trading in different parts of the world

IE approach to Sand: Issues to resolve

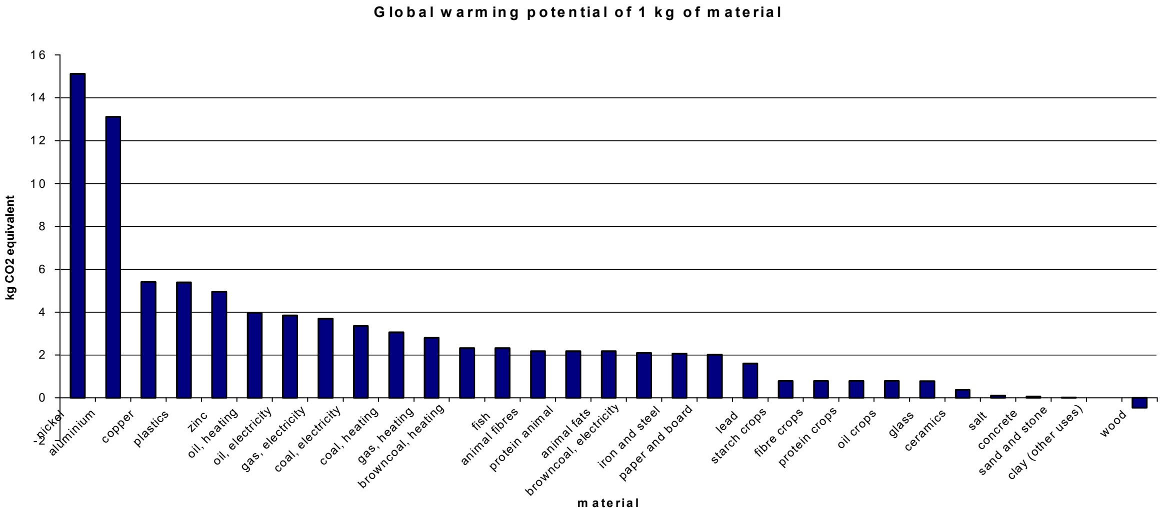
International trade in resources (UNEP, 2016)



IE approach to Sand: Issues to resolve

IE approach to Sand: Issues to resolve

- Environmental problems: emissions



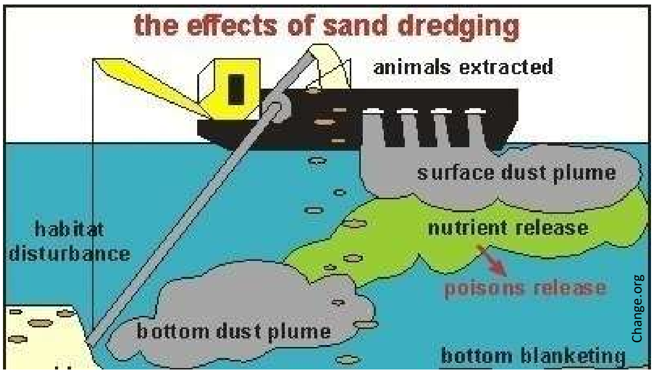
Landscape degradation

Ecosystem destruction

Restructuring the planet

Restructuring the planet

Marine habitat impacts



IE approach to Sand: Solutions

- How to resolve these issues? A few options, in general:

- Reduction of sand applications
  - Not so easy
  - Construction will increase in view of population increase and development
  - Maybe less resource intensive luxury projects?
- Efficiency of sand application
  - …?

IE approach to Sand: Solutions

- Substitution
  - Not so easy
  - Alternatives will pretty much have higher impacts
  - Maybe for industrial applications?
- Mining with less impacts
  - Probably possible to some extent
  - But large scale disturbances difficult to avoid
  - Especially in seas, knowledge gaps

IE approach to Sand: Solutions

- Circular Economy: Life span increase
  - Reuse, repair, remanufacturing, refurbishing
  - Longer life spans reduce demand
  - Here, probably a lot of possibilities
  - Already long life span applications in buildings and infrastructure, could be even longer
  - Refurbishment less resource intensive than new structures
- Circular Economy: Recycling / urban mining
  - Sand recycling ….? Creating new sands from old?
  - Concrete recycling is possible and already happens

Recommendations

Apply the Industrial Ecology Approach to sand!

- Life cycle thinking
- Supply chain cooperation
- Urban mining / circular economy

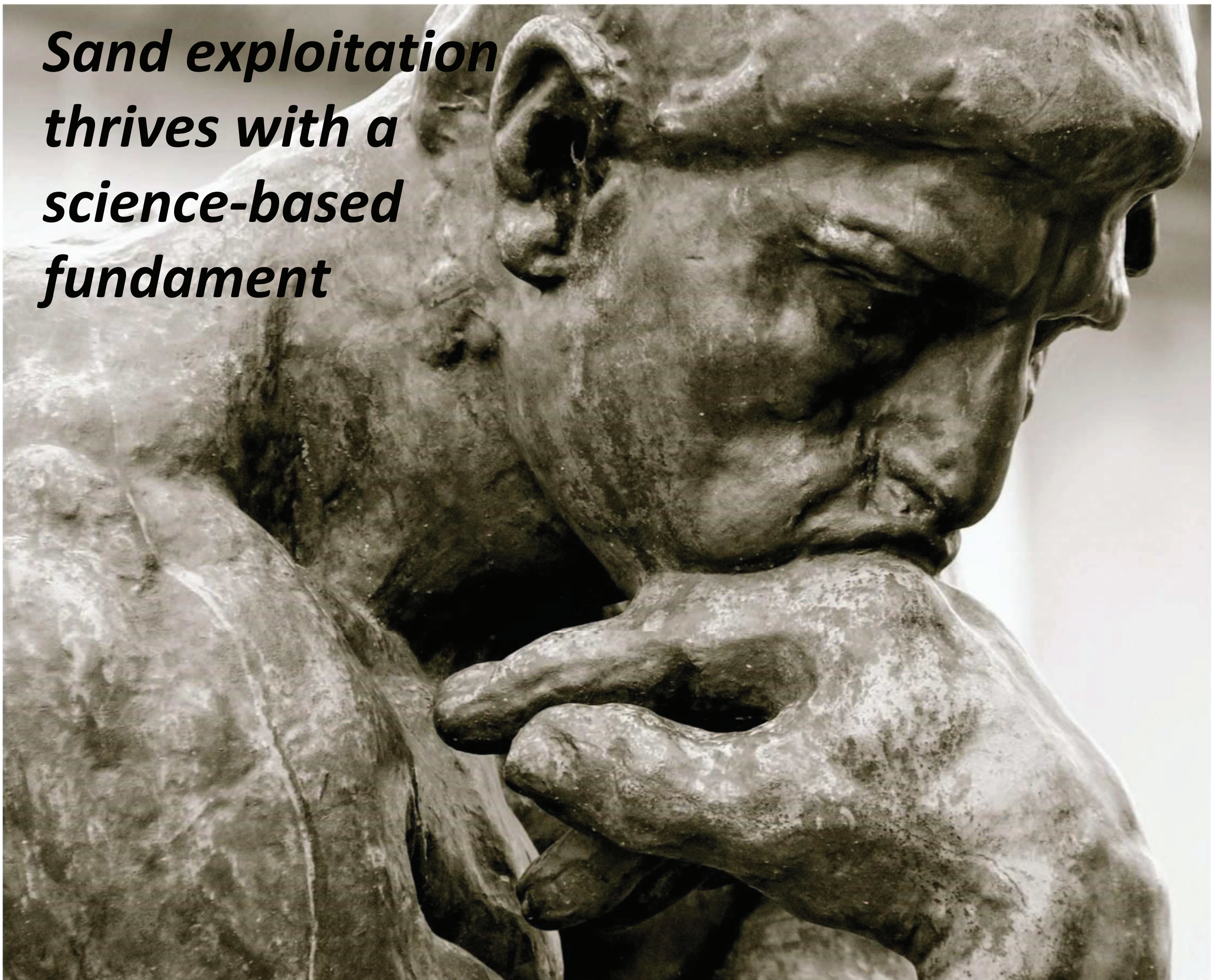
Analytical framework is available, data availability presently poor

So:

Start building up the database

Do the analysis

Take it from there!


Sand exploitation
thrives with a
science-based
fundament

SAND EXTRACTION

Sand-extraction monitoring and adaptive management go together

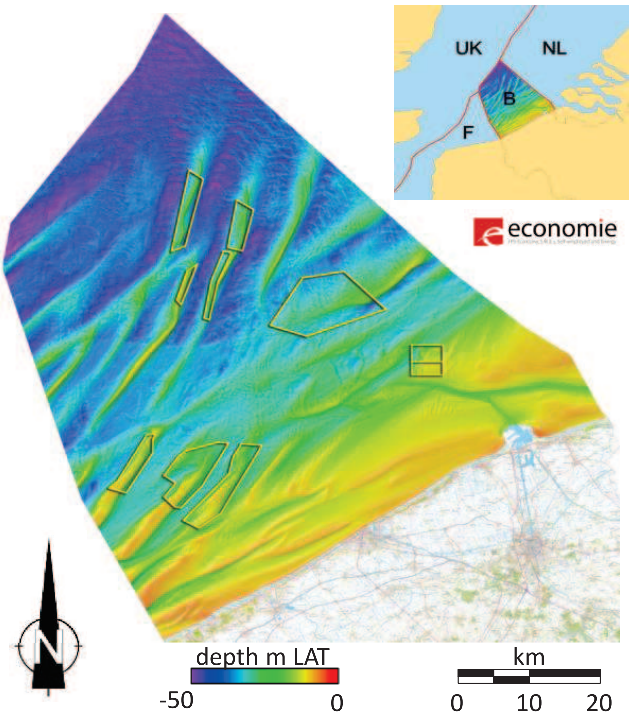
Sand extraction is constrained by resource availability, environmental impact, and competing user functions. Thorough and flexible monitoring is needed to adapt to changing circumstances and views, and to ensure long-term resource use. The precautionary principle is to be adopted if adequate information and knowledge are absent.

Marc Roche
FPS Economy, SMEs, Self-Employed and Energy. Continental Shelf Service

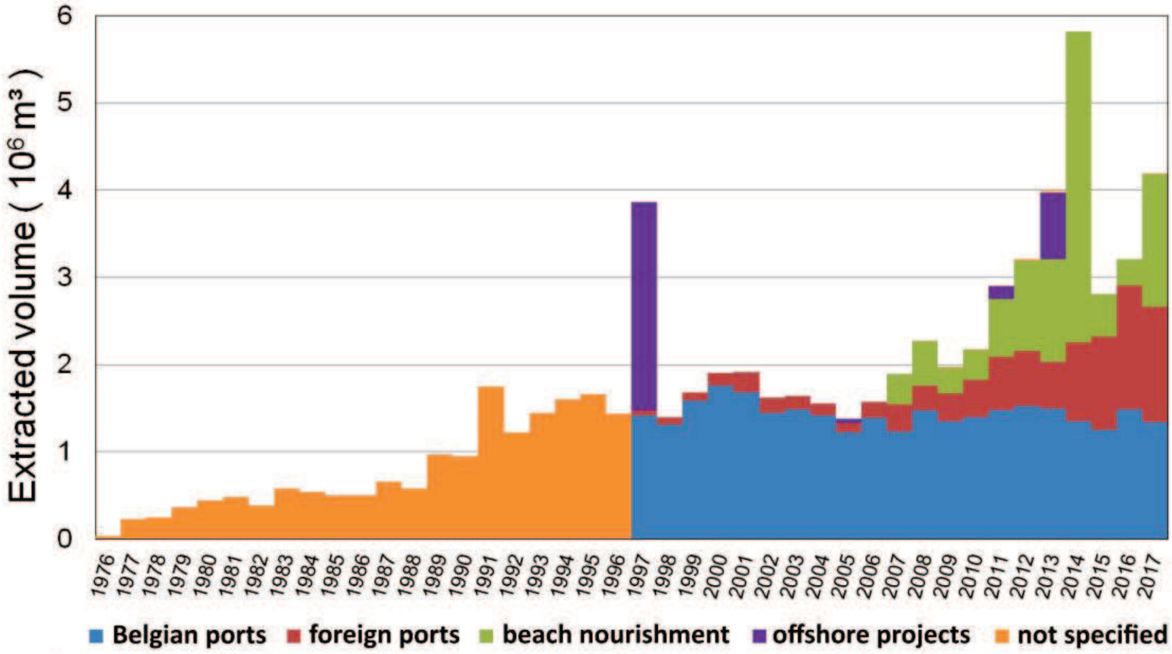
economie

Sand extraction in the Belgian part of the North Sea:

- **10 sectors on offshore sandbanks**
- **Production:**
  - **2.5 10^6 m³ / y for building industry**
  - **1.5 10^6 m³ / y for beach replenishment**
- **Current legislation:**
  - **By precautionary principle:**
    Bathymetric reference surface
    Maximum extraction allowed ↓ -5m
  - **Monitoring the sand extraction and its environmental impact = legal obligations**
- **Future legislation:**
  - **Marine Spatial Plan 2020**
  - **New reference surface**



Evolution of the sand extraction in the Belgian marine territories

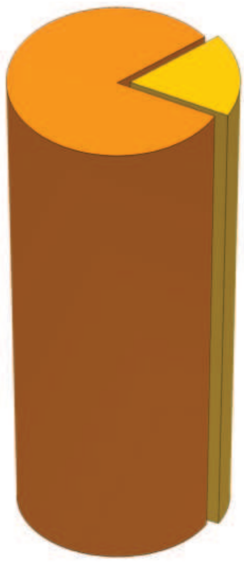


economie

Resource ≠ Reserve

Resource:

Volume of sand that nature has given us



Reserve: Evolution?

Part of the resource exploitable

- **Legal**

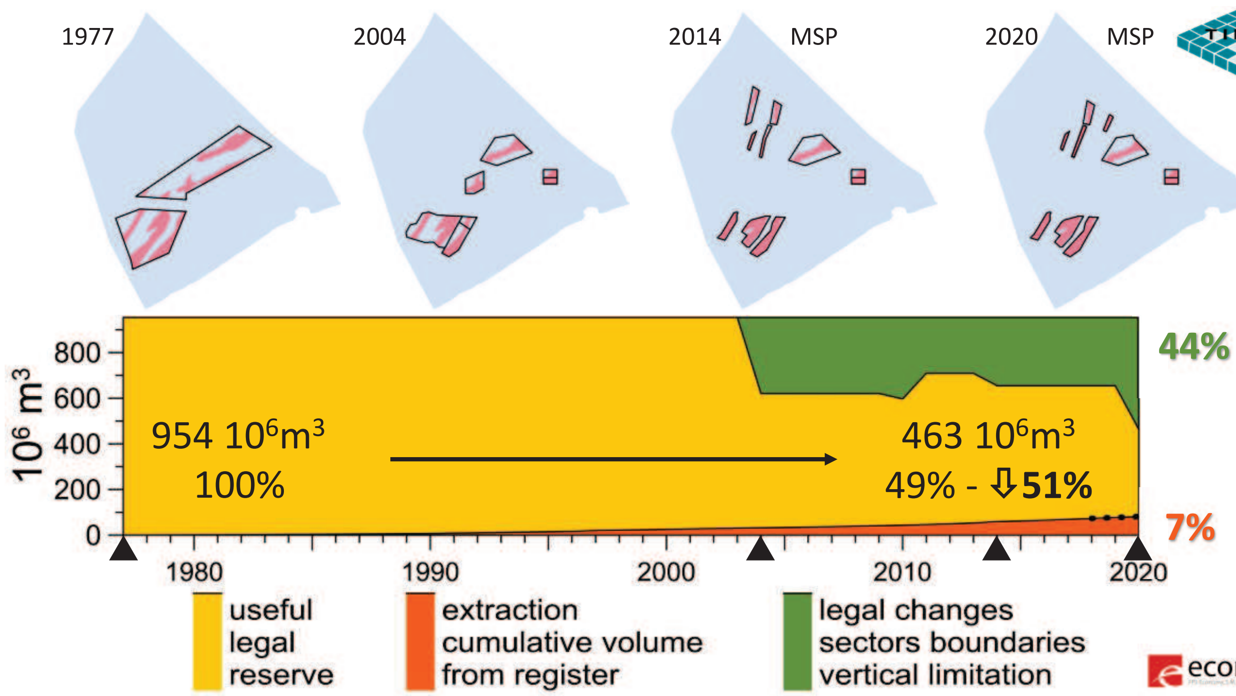
Inside sectors 1977 to 2014	Up to 5m below the seabed
Inside sectors MSP 2014	Up to 5m below the seabed
Inside sectors MSP 2020	Above new reference surface

- **Useful**

Sandbank = inside 20m isobath

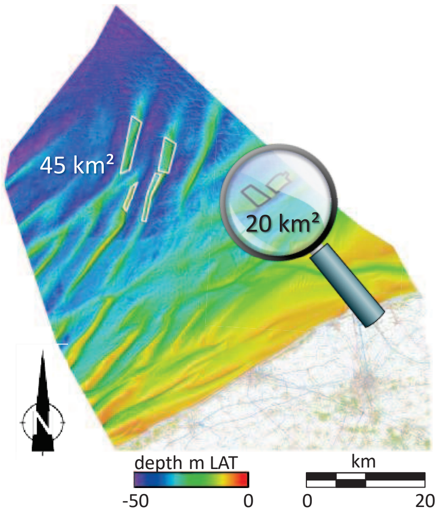
economie

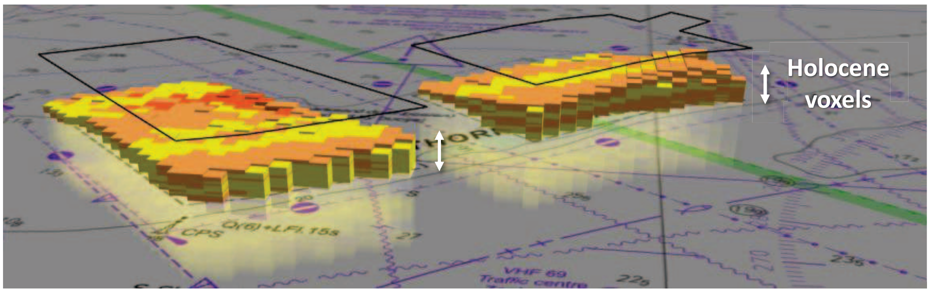
Evolution of the useful legal sand reserve



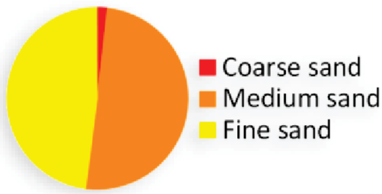
economie

TILES should help us to learn from history: C Power Park was installed on a huge medium sand reserve...



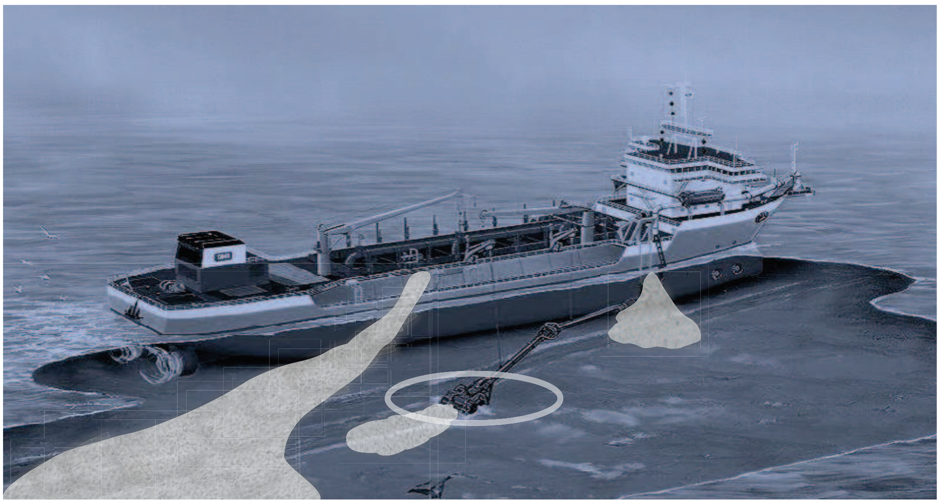


VOXEL VOLUME = 183 10^6 m^3
= 76 % of sectors 4 reserve
= 44 % of sectors 4 surface



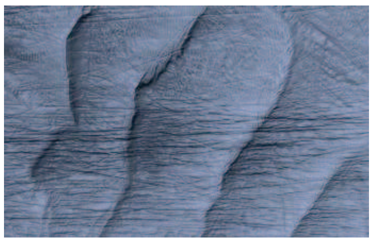
economie

Impacts of trailing suction hopper dredger :



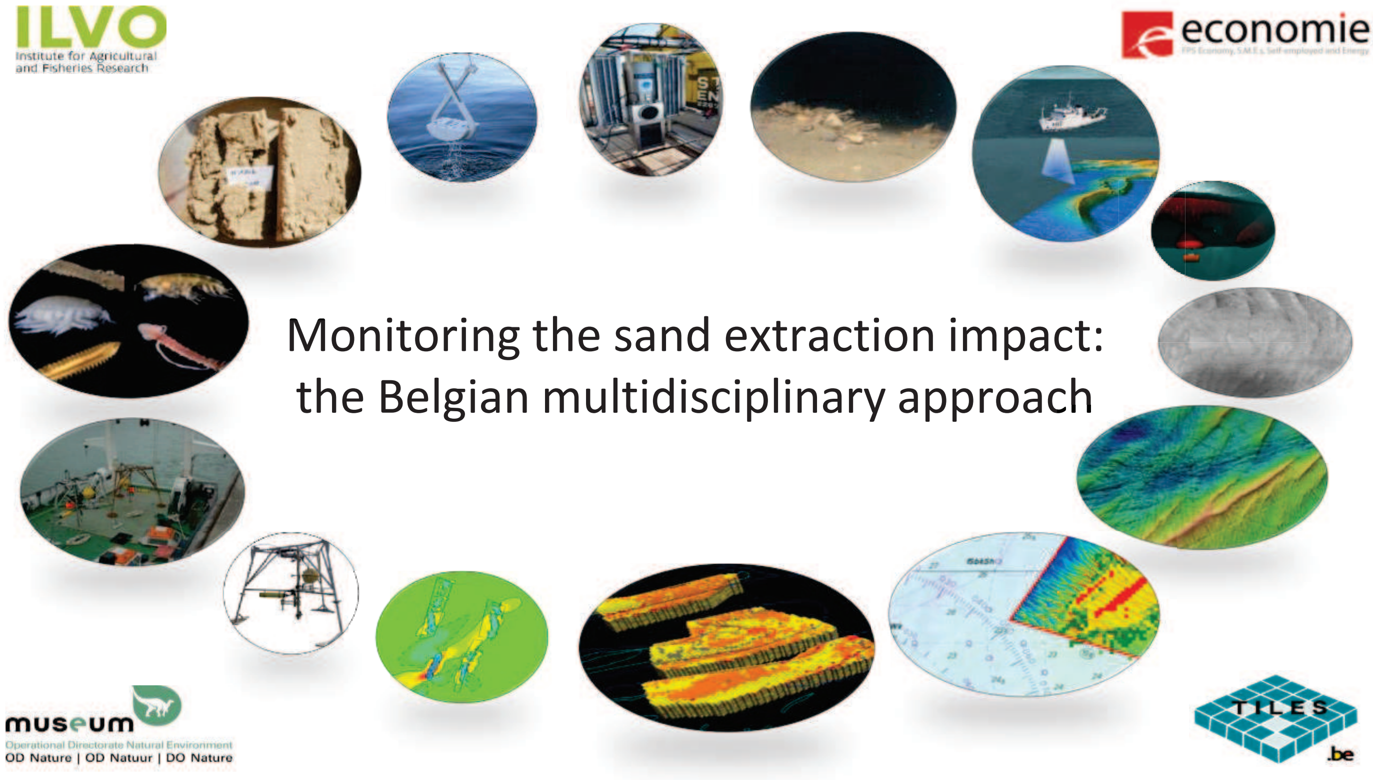
Seabed removal

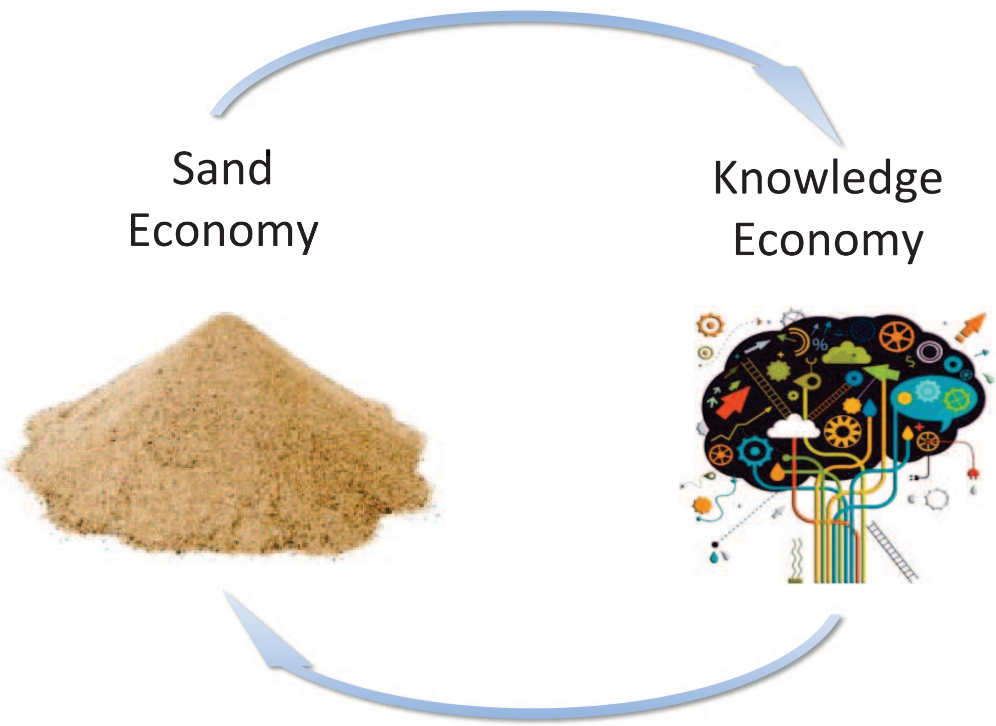
direct impact on
→ bathymetry morphology
→ sediment
→ benthic habitat



Sediment plumes
- **overflow**
- **screening**
- **draghead**

direct and indirect impact on
→ sediment
→ benthic habitat
→ turbidity


ILVO
Institute for Agricultural and Fisheries Research
economie
Monitoring the sand extraction impact:
the Belgian multidisciplinary approach
museum
Operational Directorate Natural Environment
OD Nature | OD Natuur | DO Nature
TILES
.be


Sand
Economy
Knowledge
Economy

Extraction and bathymetric monitoring main conclusions:

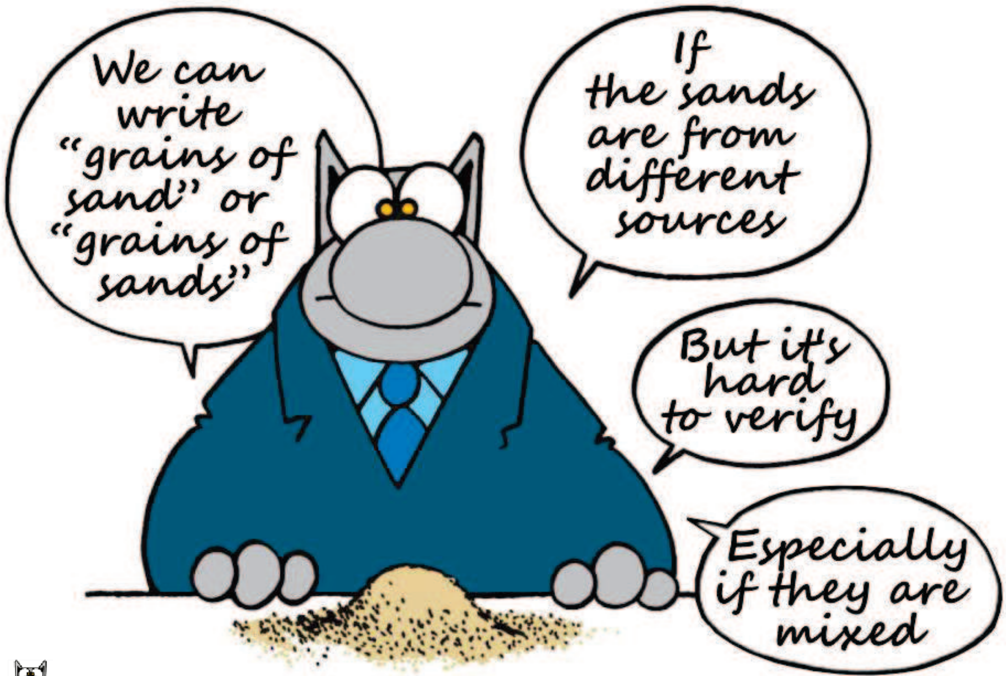
- straightforward relation

Volume Extraction ~ Bathymetric Variation

- Stability after extraction closure

At a decadal scale, sand is a non-renewable resource!

economie



From P. Geluck

SAND EXTRACTION

Sand-extraction depth should be guided by geology

Sand geology is the best predictor of resource quality and quantity, and a useful indicator of benthic habitat type. Preferably, extraction takes place where sand layers are homogeneous and thickest. It ensures constant quality and prevents habitat change. Given the ecological services that dynamic and patchy sandbanks provide, large-scale seabed flattening should be avoided.

Koen Degrendele
FPS Economy, SMEs, Self-Employed and Energy. Continental Shelf Service

economie

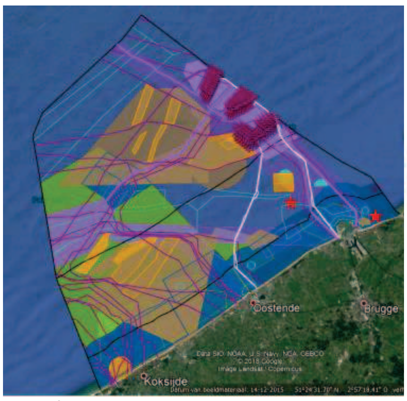
Sand-extraction depth should be guided by geology

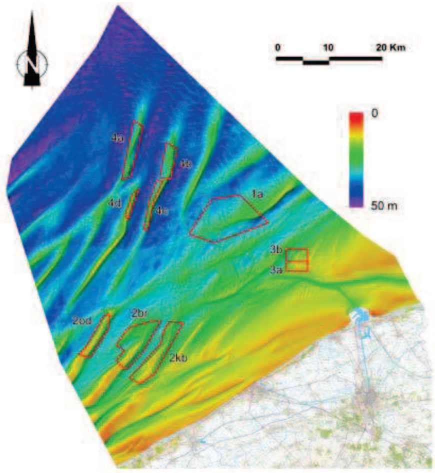
Sand = limited economic resource

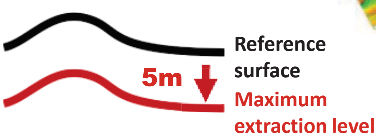
Sustainable management
↗ ↖
Availability   Quality

Legal and natural limitations:
XY: Sandbanks (offshore)
Other users (Marine Spatial Plan)
Z: precautionary principle 5m

legal volume: no indication of quality







Quality economie

Different types of sand for economic use.

Fine – medium – coarse

Requirements:

Homogenuous

$CaCO_3$ < 15%

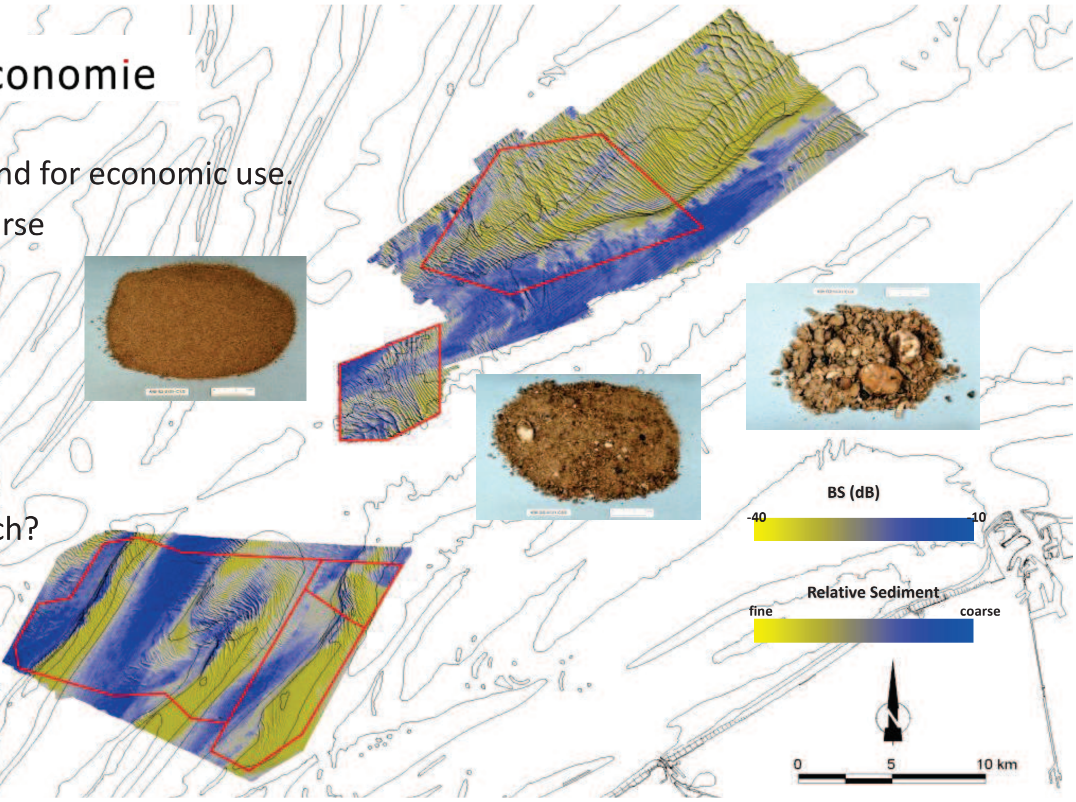
% Shells ?

Where and how much?

Goal:

Optimal exploitation

Limitation of impact

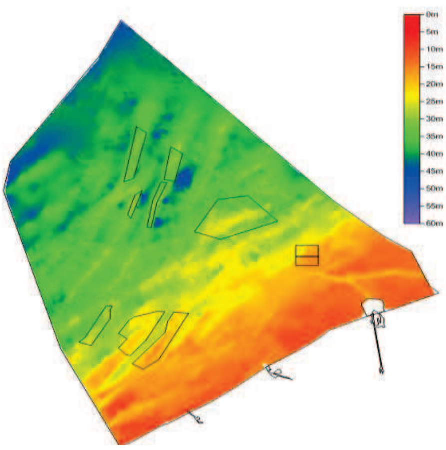


Geology -> quality and quantity

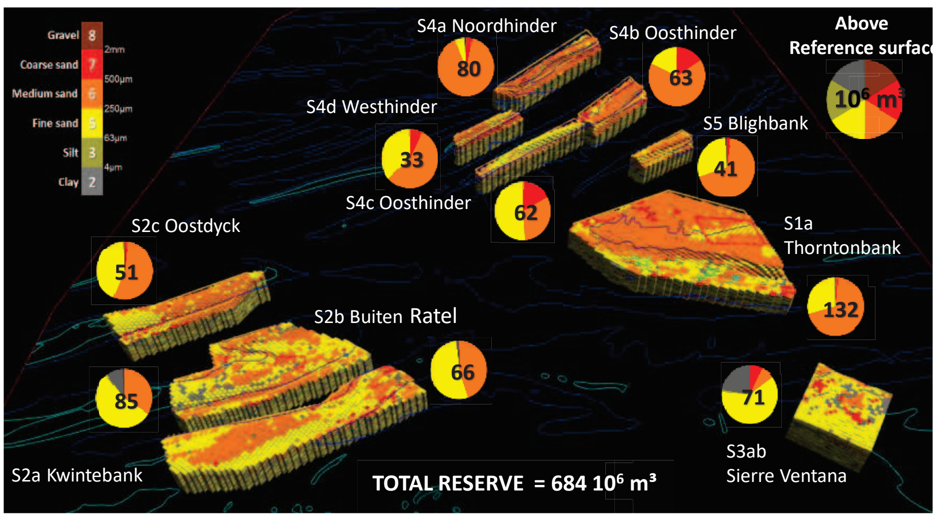
Tiles: Surfaces

Voxels

economie



Shallowest discordant surface



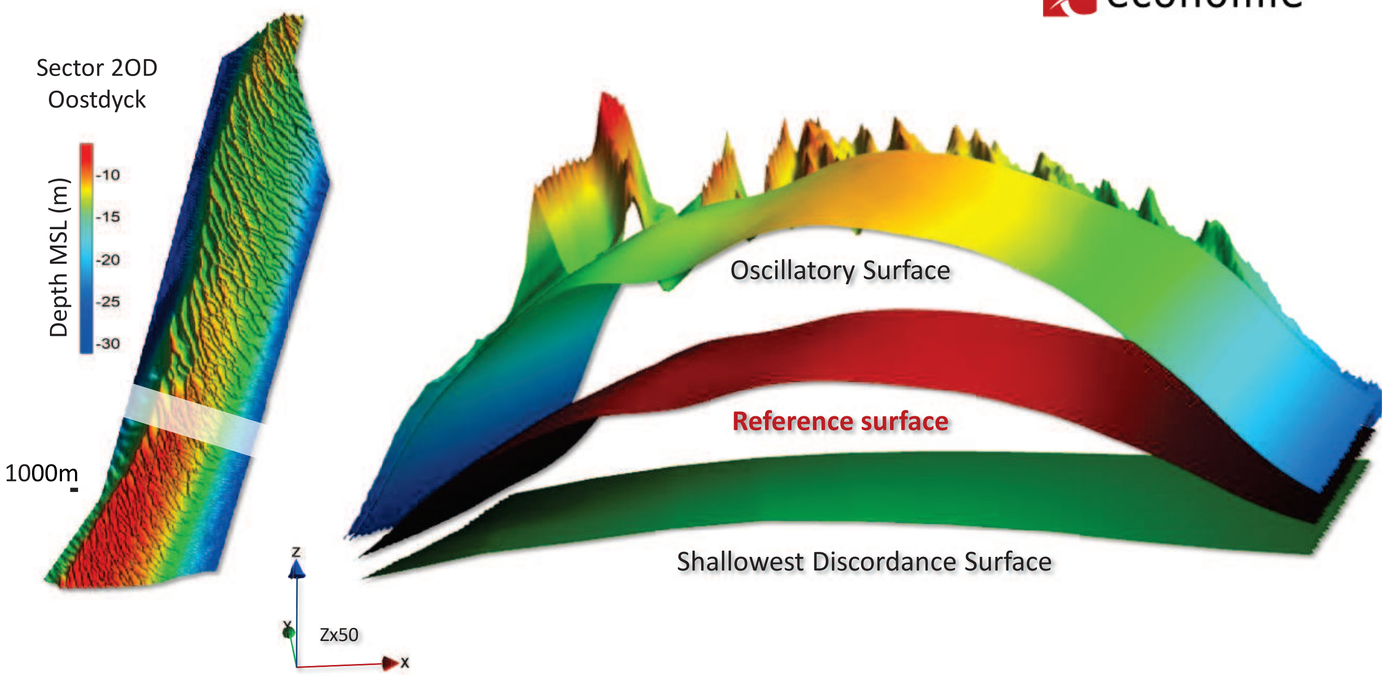
Geology -> redefine the limit for extraction

Reference surface defined on objective criteria

Criteria:

- upper homogeneous layer (ecological)
- preserve sand bank shape (safety)
- thickness (economic)

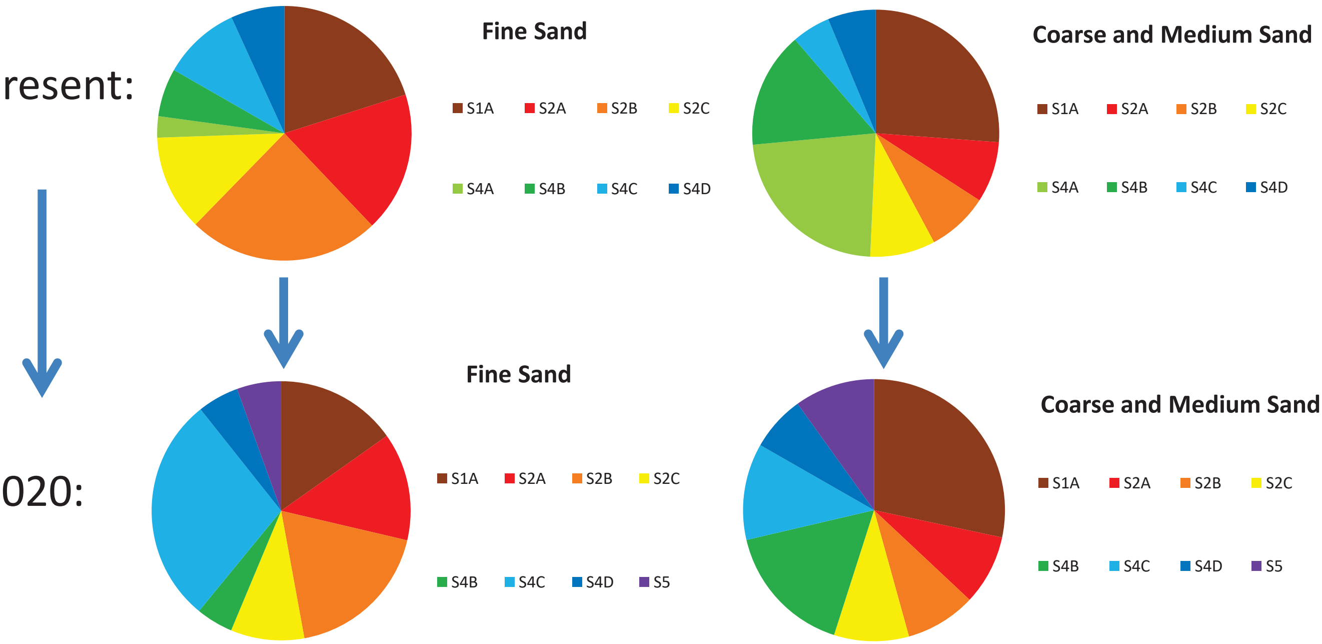
New reference surface project



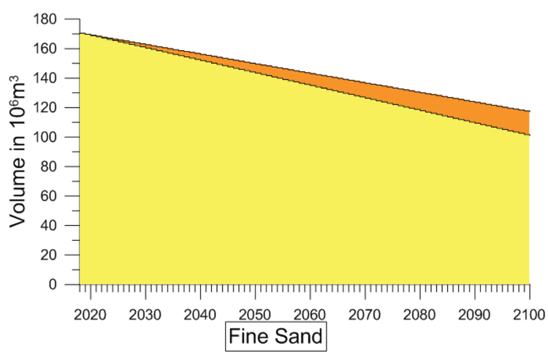
Availability

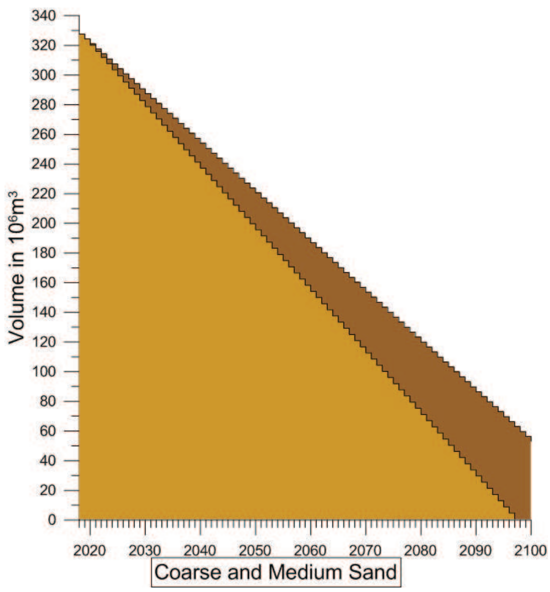
Present:

2020:



Geology -> Long term resource management





Steady decrease
but still dependent on policy…

Sand-extraction depth is guided by geology

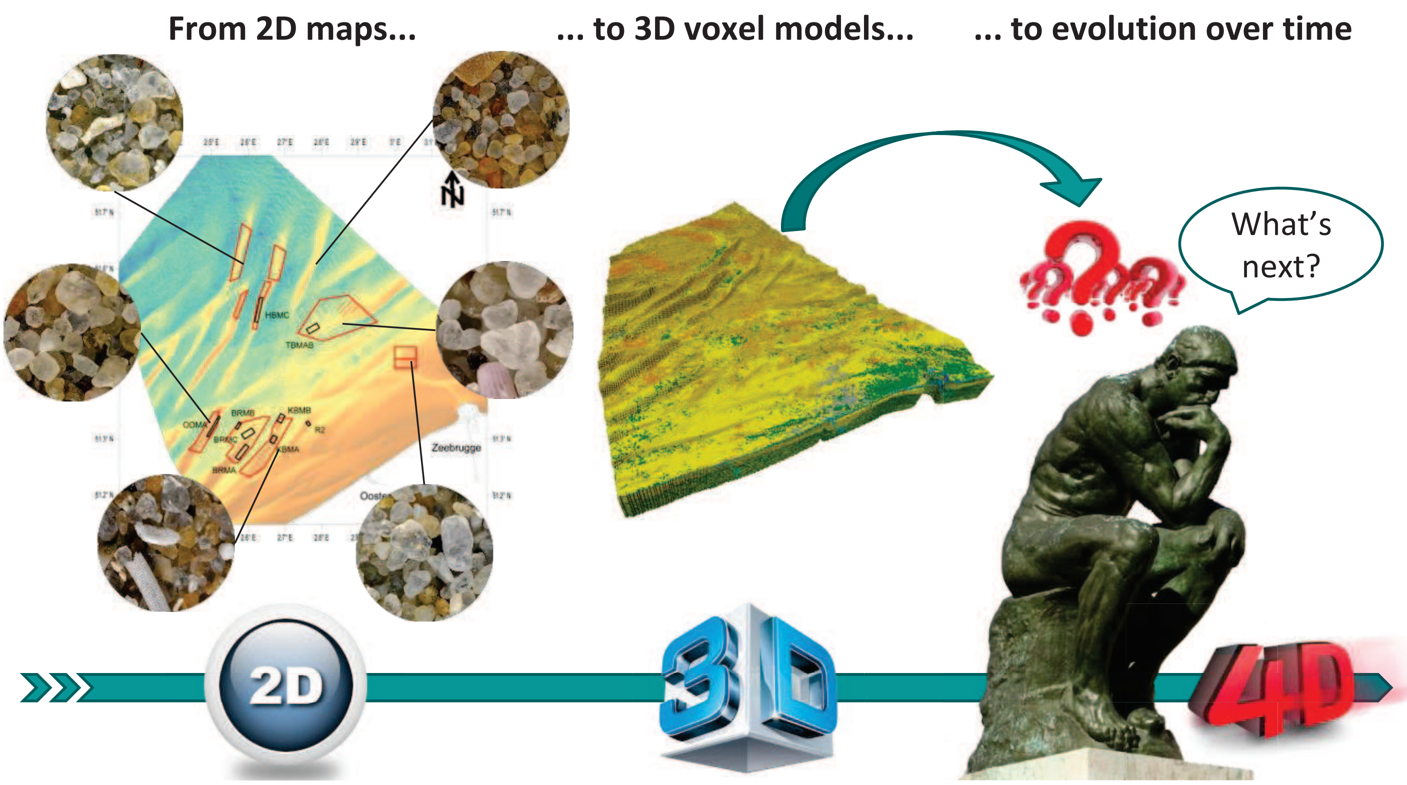
economie

SAND EXTRACTION

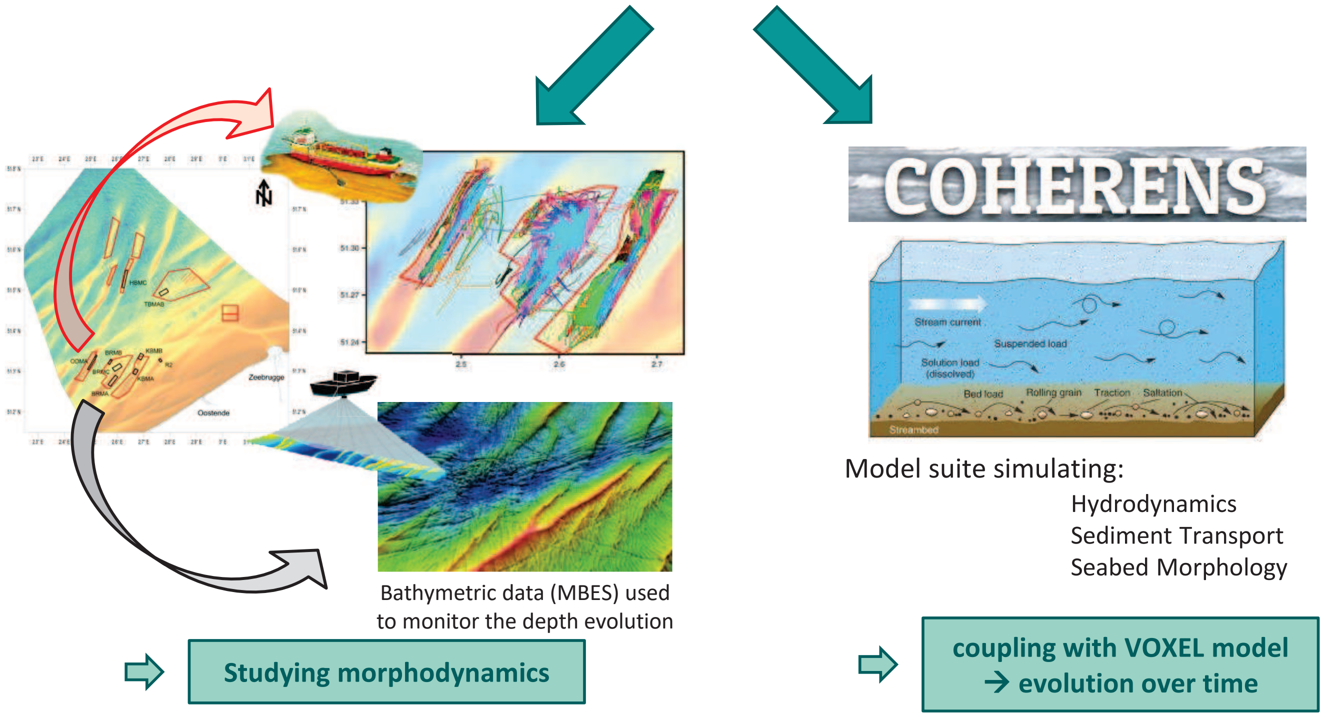
Sand-extraction impact can be minimized by marine system knowledge

Sand-system modelling at all spatial and temporal scales quantifies the natural envelope of seabed variability. To maximize the chance for rapid and lasting recovery after extraction, impacts should not supersede natural levels. Environmental impact analyses of extraction scenarios are crucial to plan long-term resource use and to safeguard the functional integrity of the system.

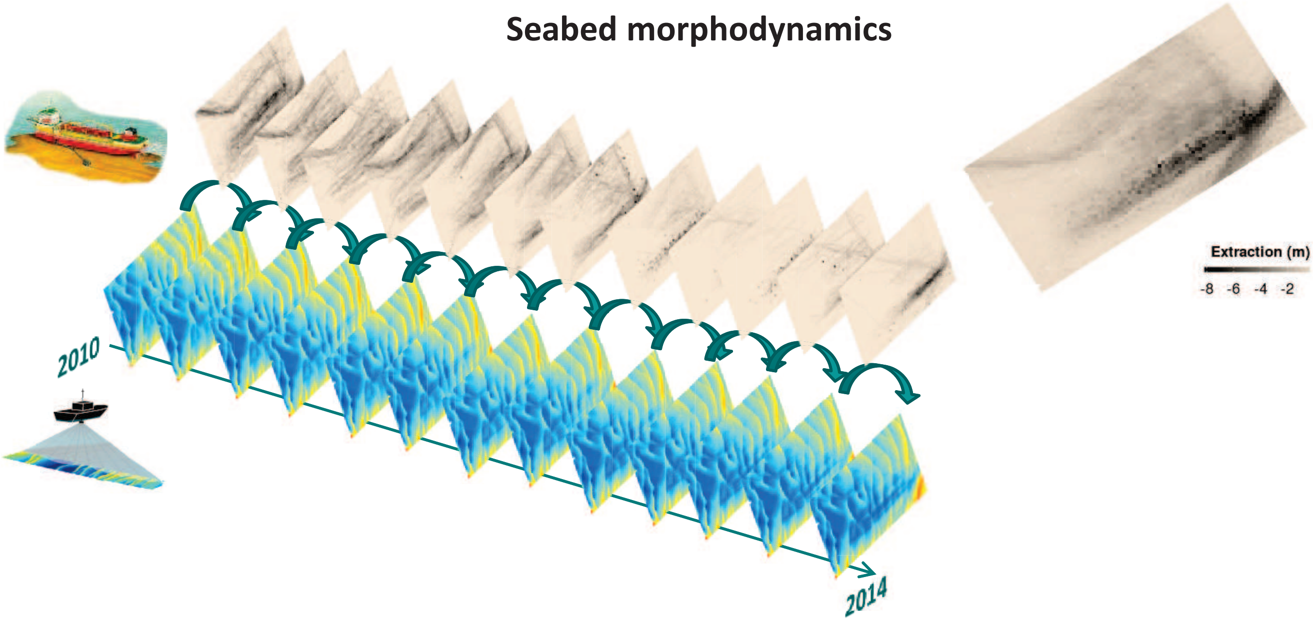
Nathan Terseleer
Royal Belgian Institute of Natural Sciences



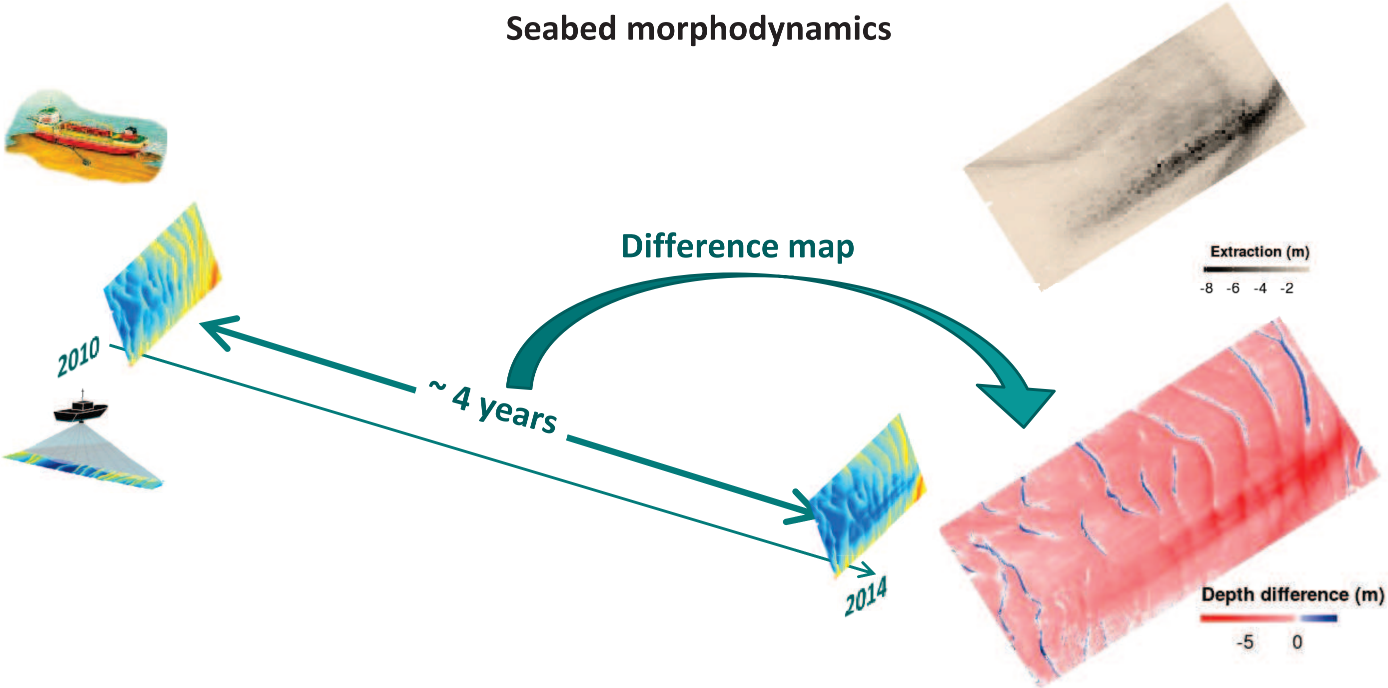
Geological resources over time



Seabed morphodynamics



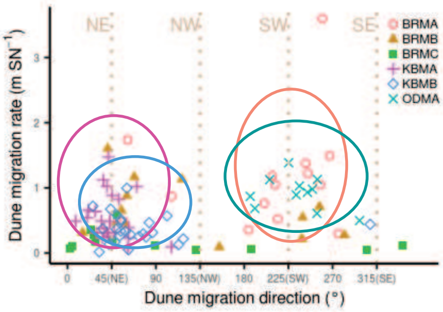
Seabed morphodynamics



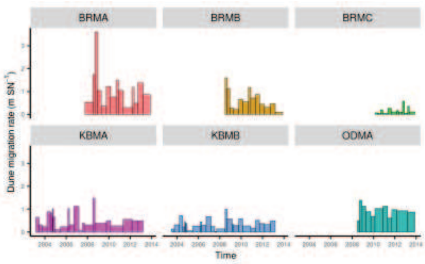
Analyse **dune migration** and assess the **remaining variability**

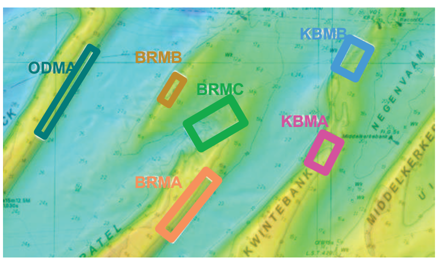
Dune migration: direction and magnitude

Magnitude *vs* Direction



Migration rate (per area)





S flank of the sandbank (**BRMA**, **ODMA**):

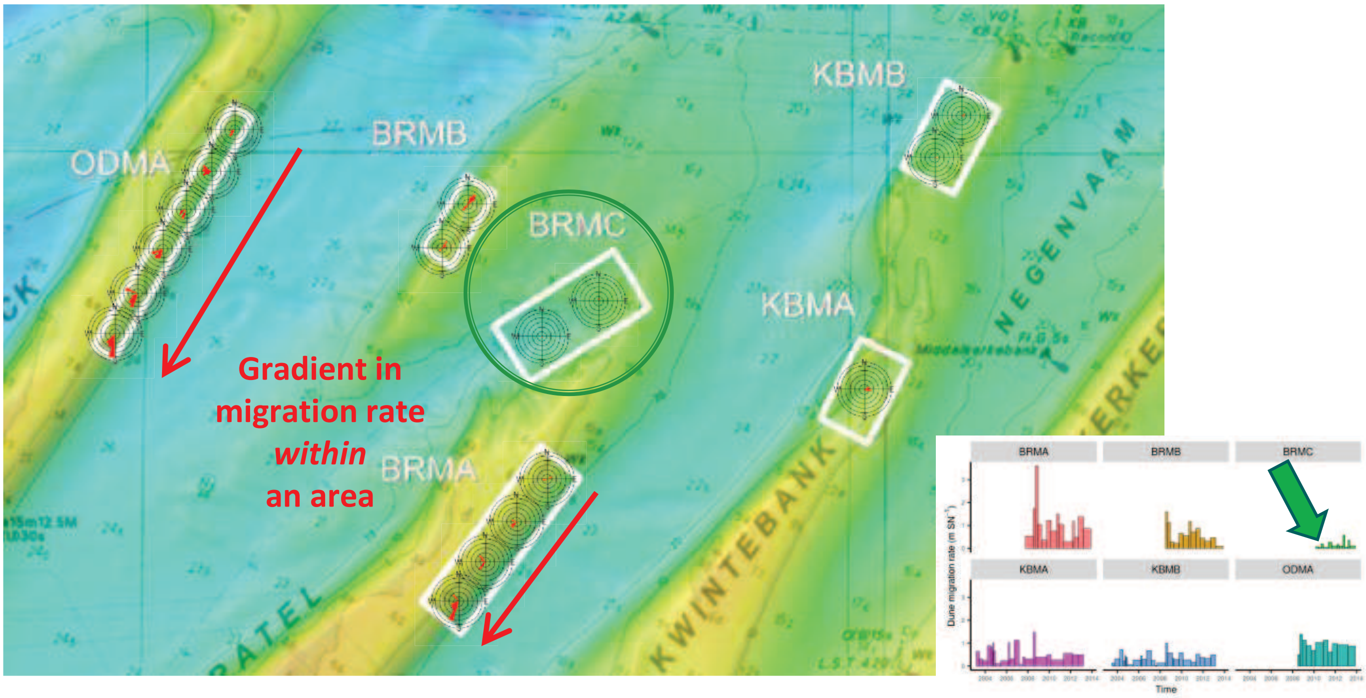
SW-dominated dune migration and currents (EBB)
Migration rates ↑

N flank of the sandbank (**KBMA**, **KBMB**):

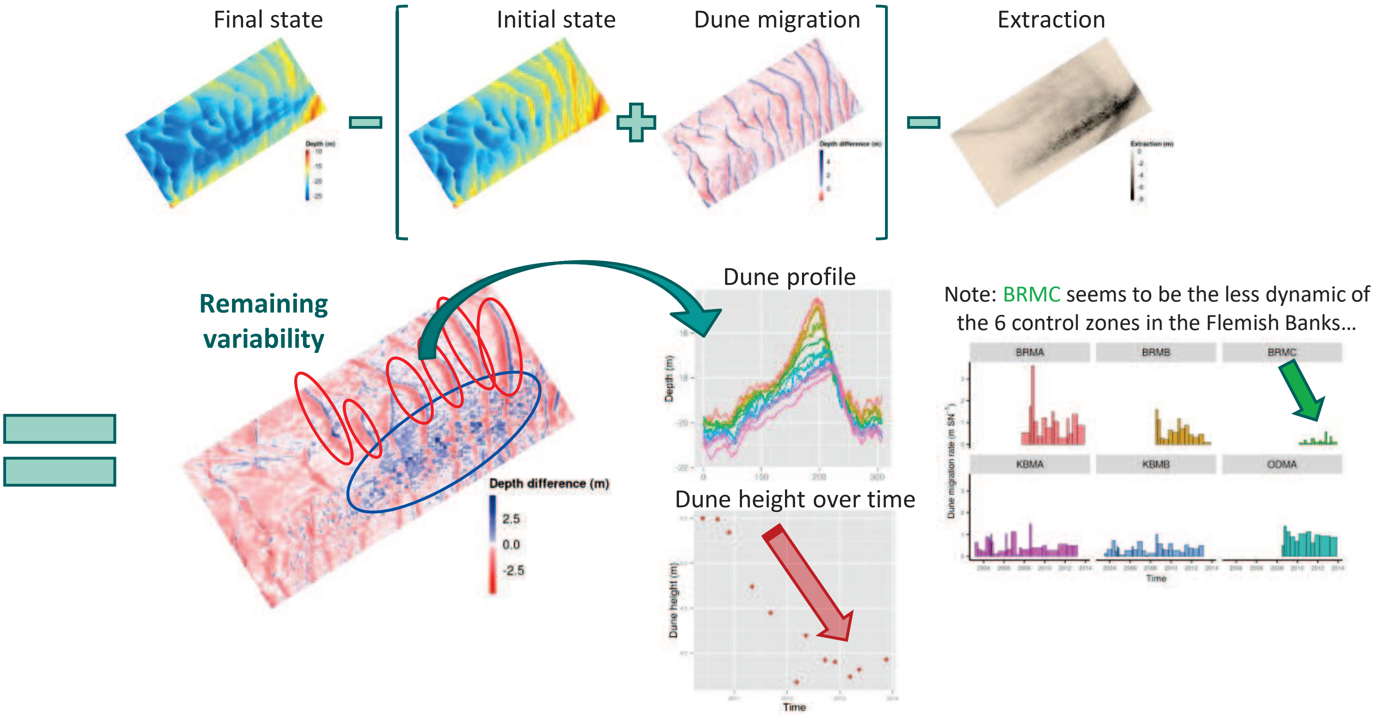
NE-dominated dune migration and currents (FLOOD)
Migration rates ~↑

More ambiguous: **BRMB**, **BRMC**

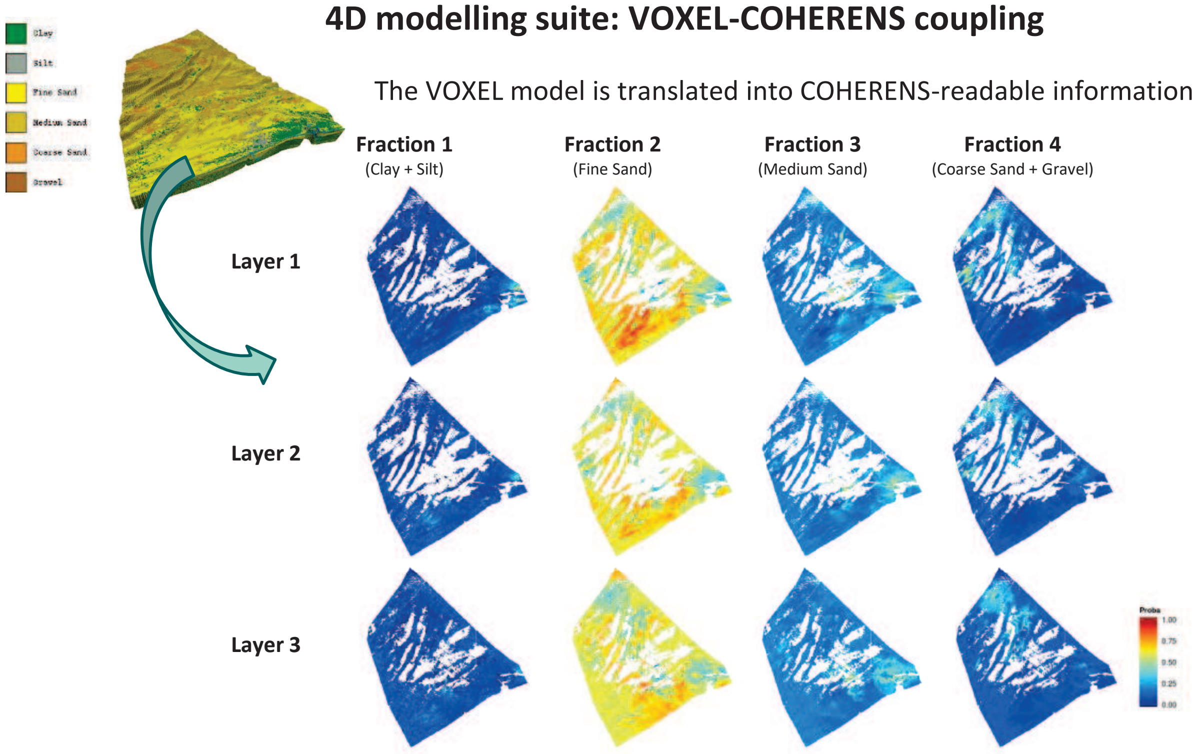
Dune migration: direction and magnitude



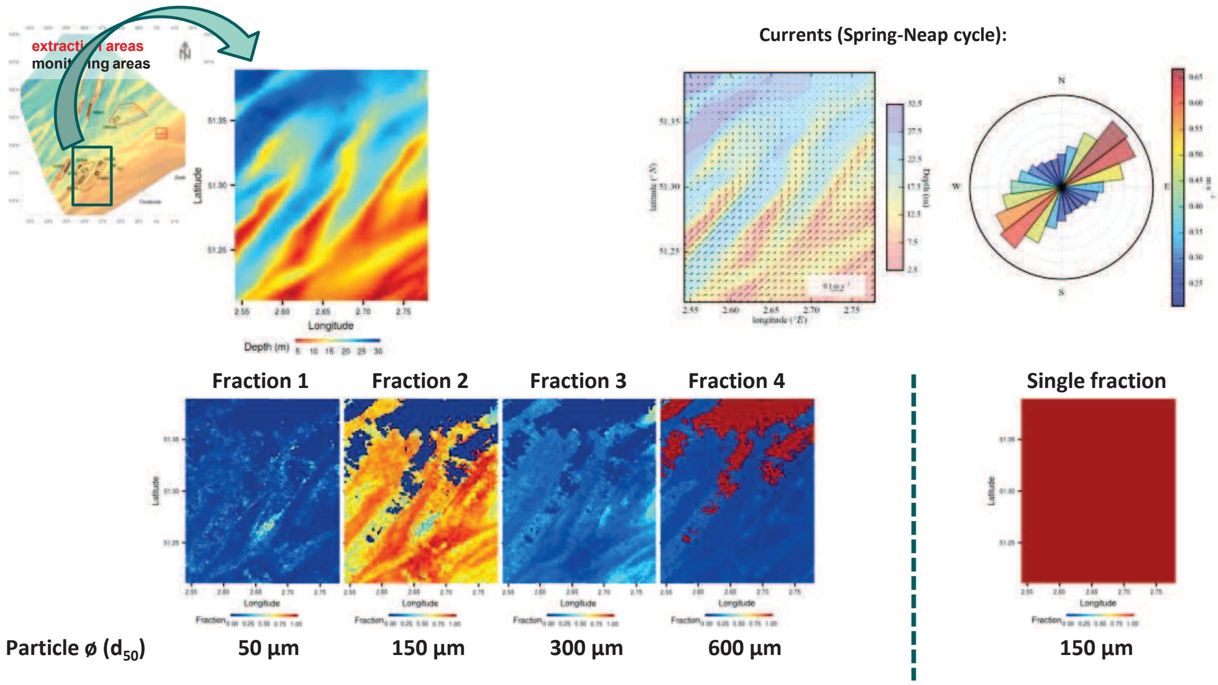
Seabed morphodynamics: variability beyond extraction and dune migration



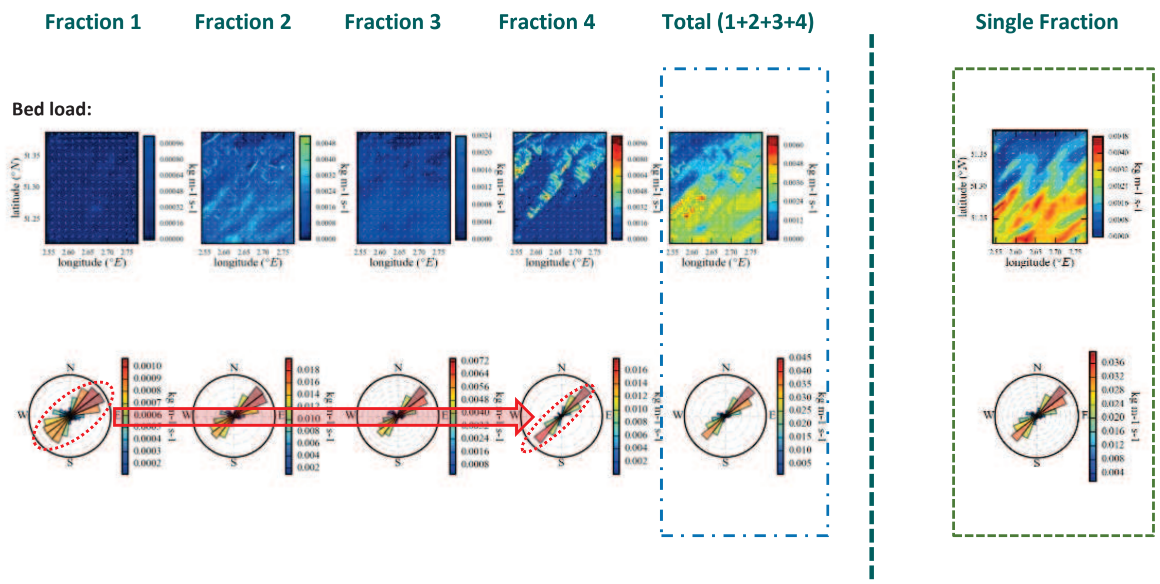
4D modelling suite: VOXEL-COHERENS coupling



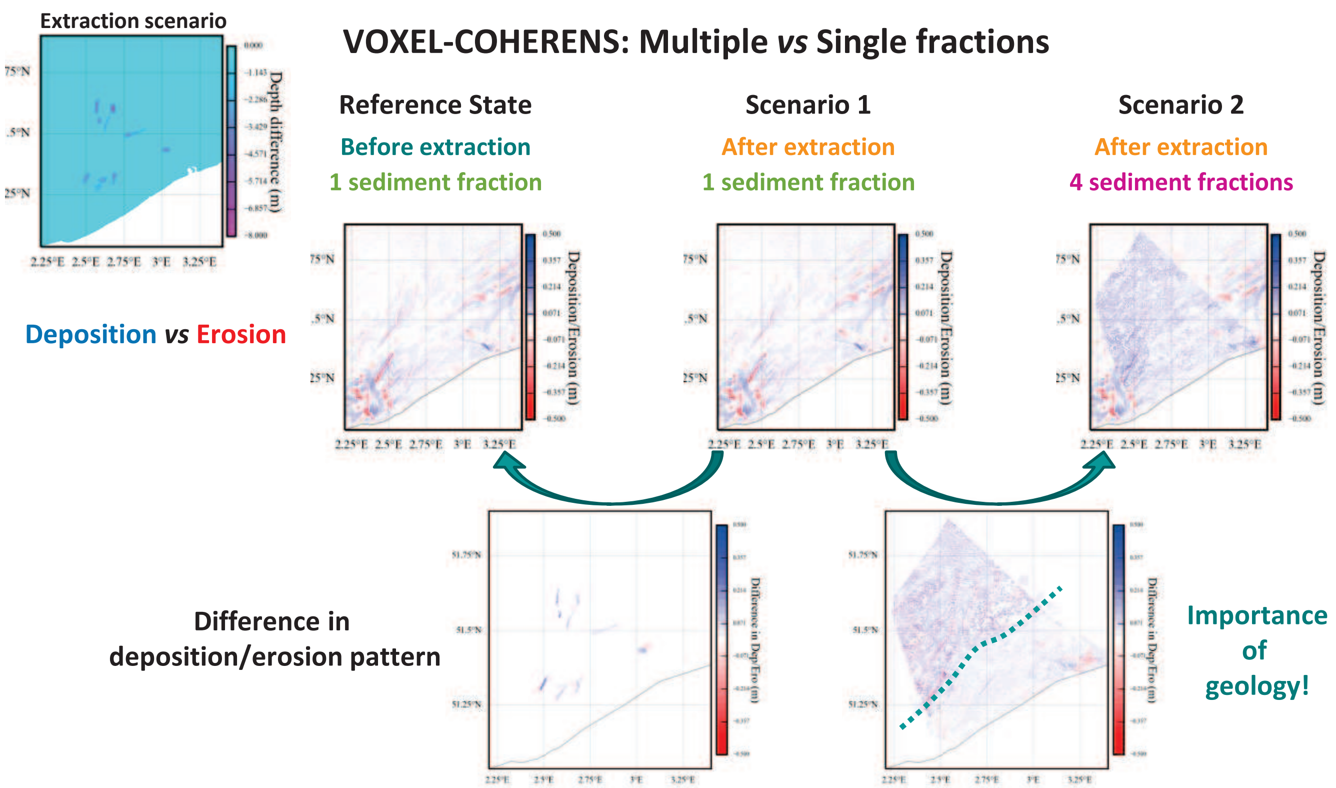
VOXEL-COHERENS: Application (Flemish banks)



VOXEL-COHERENS: Multiple *vs* Single fractions



VOXEL-COHERENS: Multiple *vs* Single fractions



Conclusions

Analysing seabed variability at ≠ temporal and spatial scales → marine system knowledge

- Envelope of natural variability
- Environmental impact analyses
- Suitability maps, additional layers of information to support decision

At the basis of knowledge:
observations & data!
(see next talks)

Sand decisions should be made together

SAND IN A DIGITAL ERA

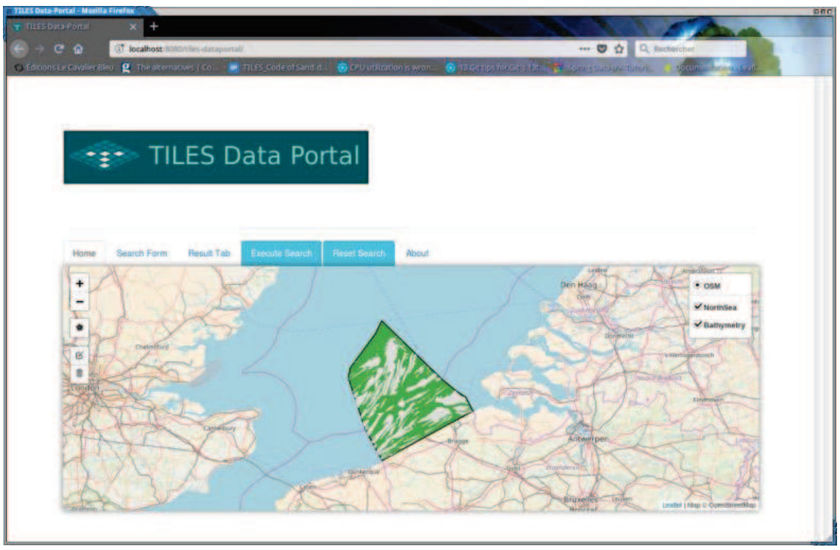
Sand data and information are best shared through open portals

Sand governance is best served by data portals that are easily accessible. Maintaining and updating data, information and products in national or regional portals is critical to ensure continued access. Networks of these portals in linked European or global data platforms are vital for common mapping initiatives and for analyses of sand flows on supra-regional scales.

Michel Kapel
Royal Belgian Institute of Natural Sciences

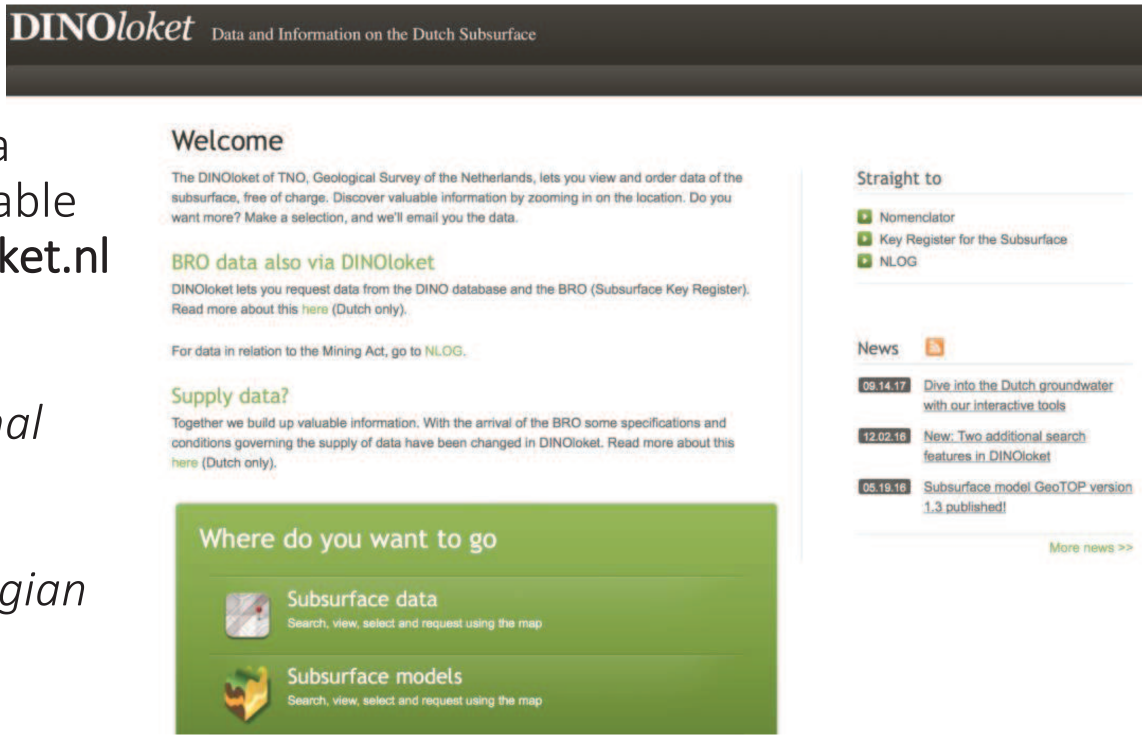
museum

A first portal for Belgian marine Geological Data!



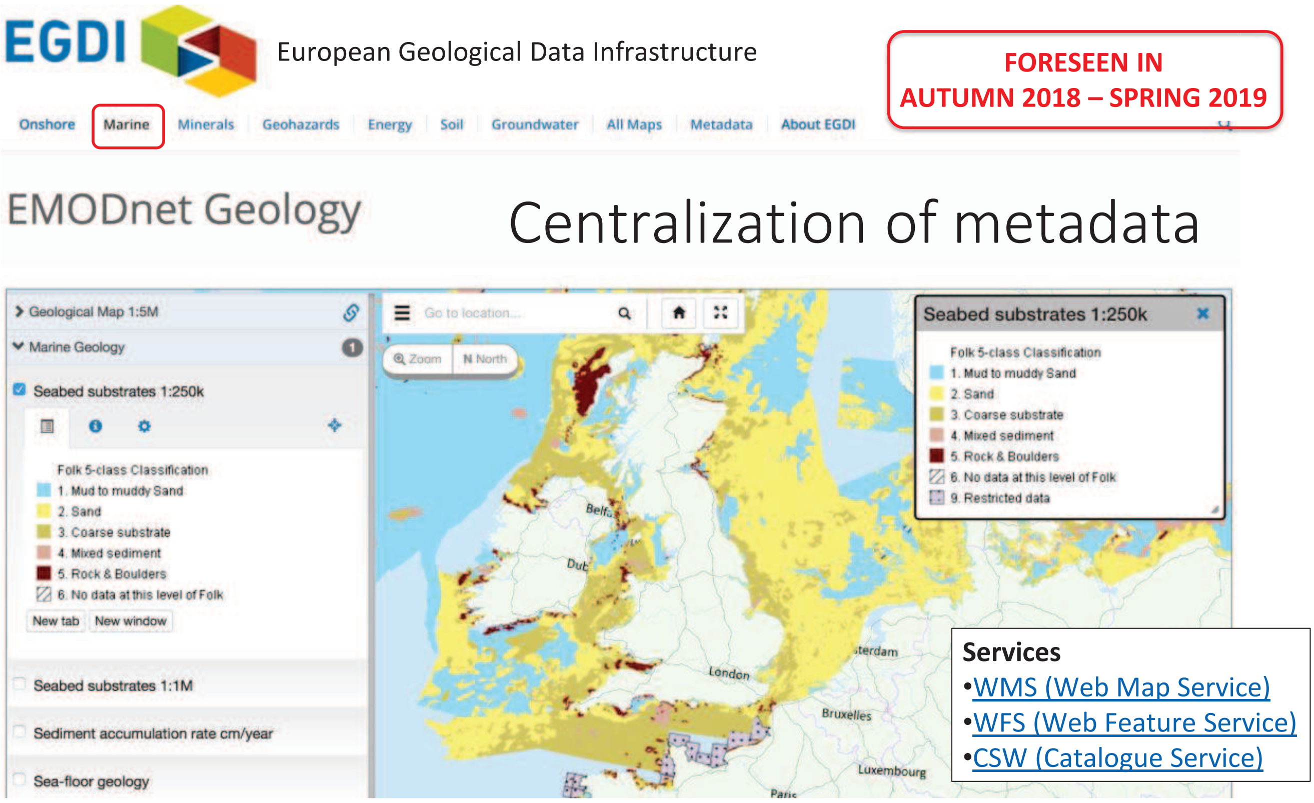
Dutch data downloadable via DinoLoket.nl

Transational model queryable via the Belgian portal

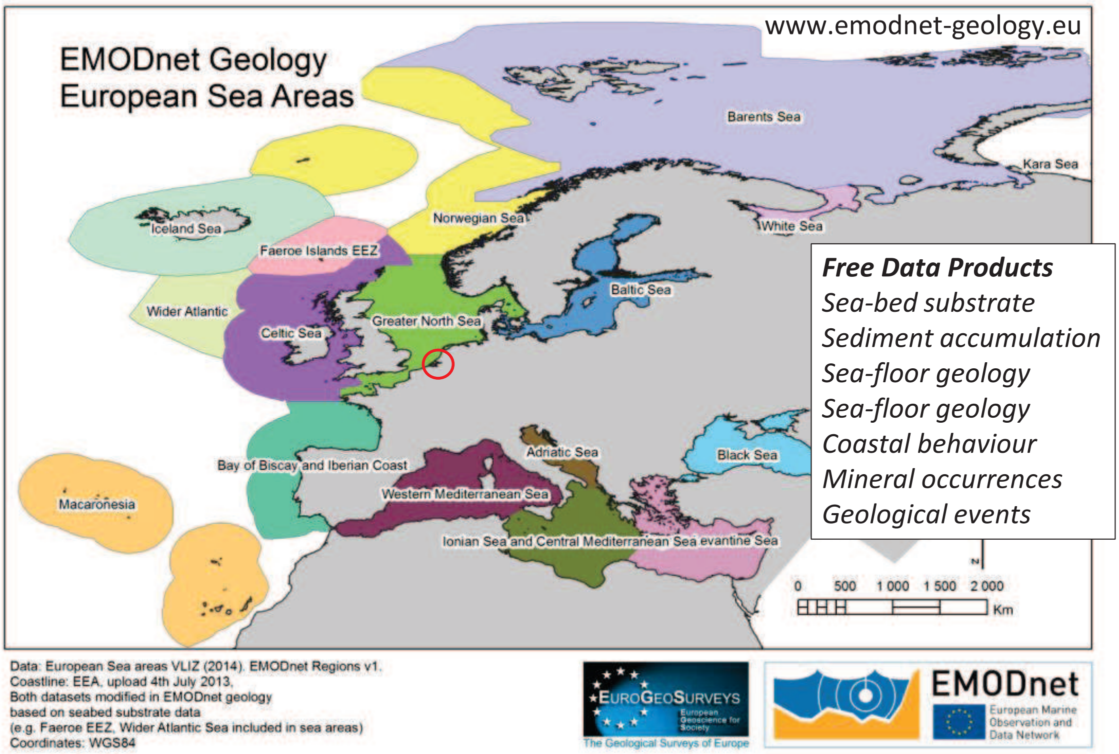


Data Portal Aims

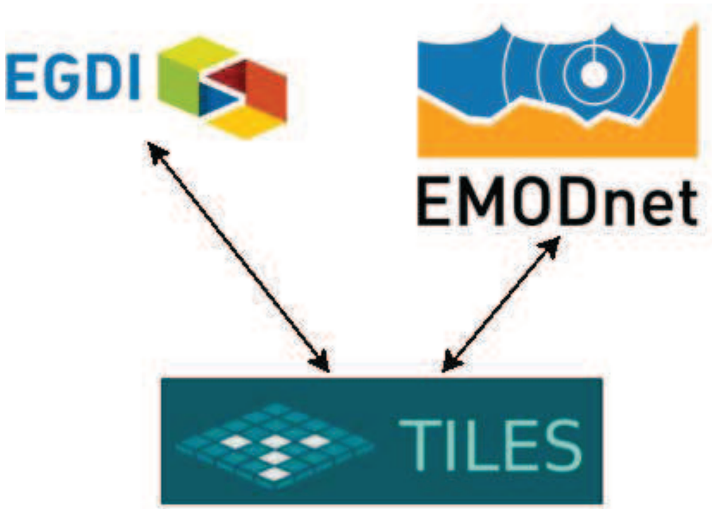
- Allow access to core-sediment data and metadata
- Centralization of sediment-related data products
- Ensure maintaining and updating data, information and products
- Allow cooperation with other Geological organizations like the European Geological Data Infrastructure (EGDI) and the geological part of the European Marine Data and Observation Network (EMODNet)



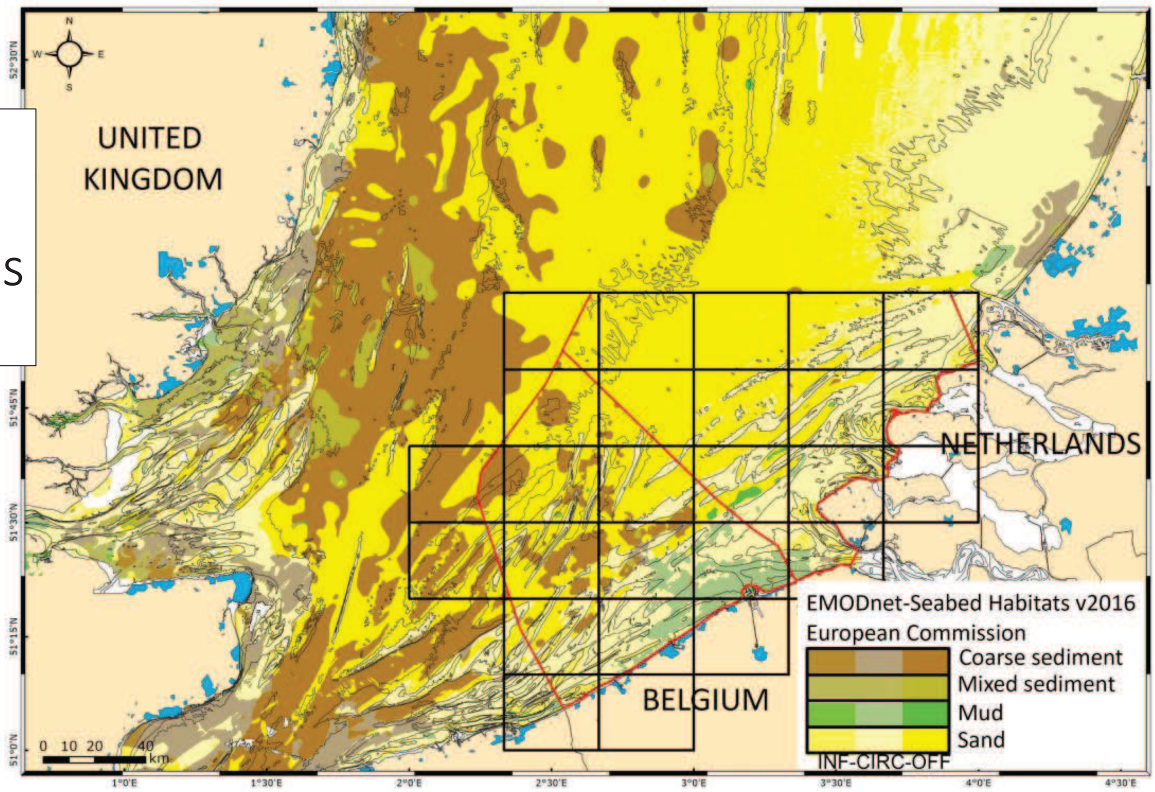
Link to European Initiatives



The point of data is to be shared



Common seabed sediments map



Future perspectives

- Centralizing relevant geological data and information
- Two-way link between data portal and decision support
- Integration into semantic search mechanisms

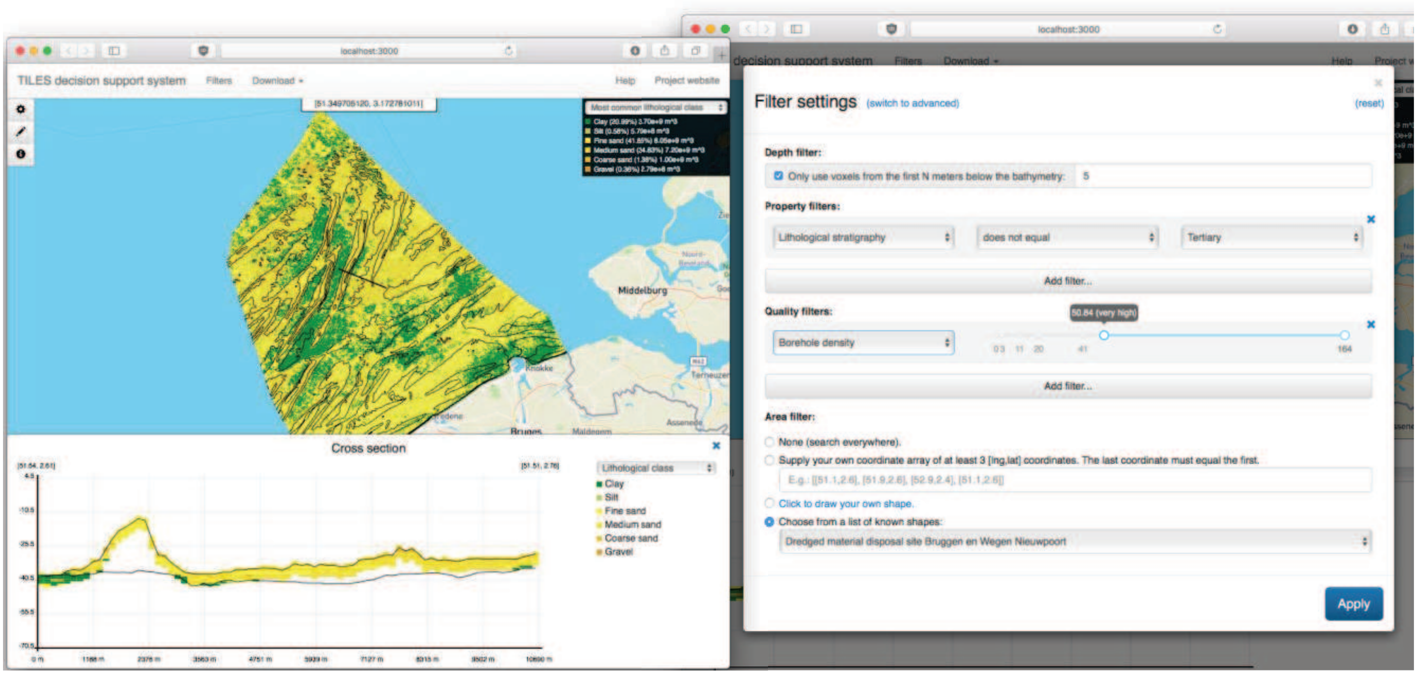
SAND IN A DIGITAL ERA

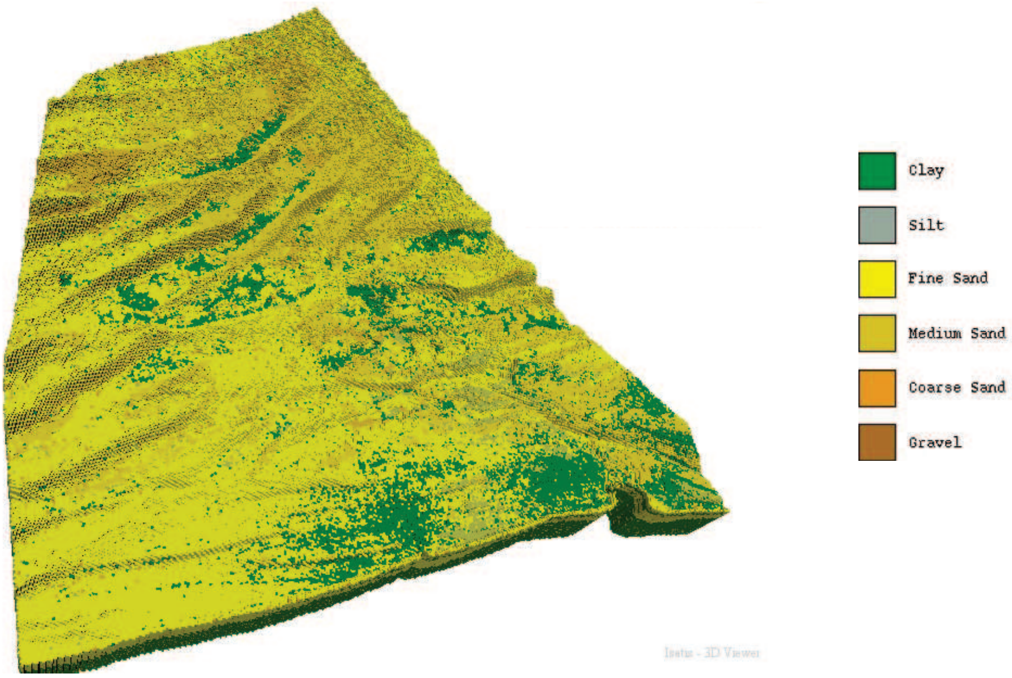
Sand decision support involves flexible visualization and querying tools

Sand evaluation is facilitated by web-based decision support tools with powerful querying and visualization properties. Flexibility, speed and accessibility are key to their use by stakeholders. Volume calculation and suitability-map generation are their main strengths. By encouraging the combination with third-party data, a modular instrument is created that meets tomorrow's needs.

Robin De Mol
Ghent University - Database, Document and Content Management

Decision support system





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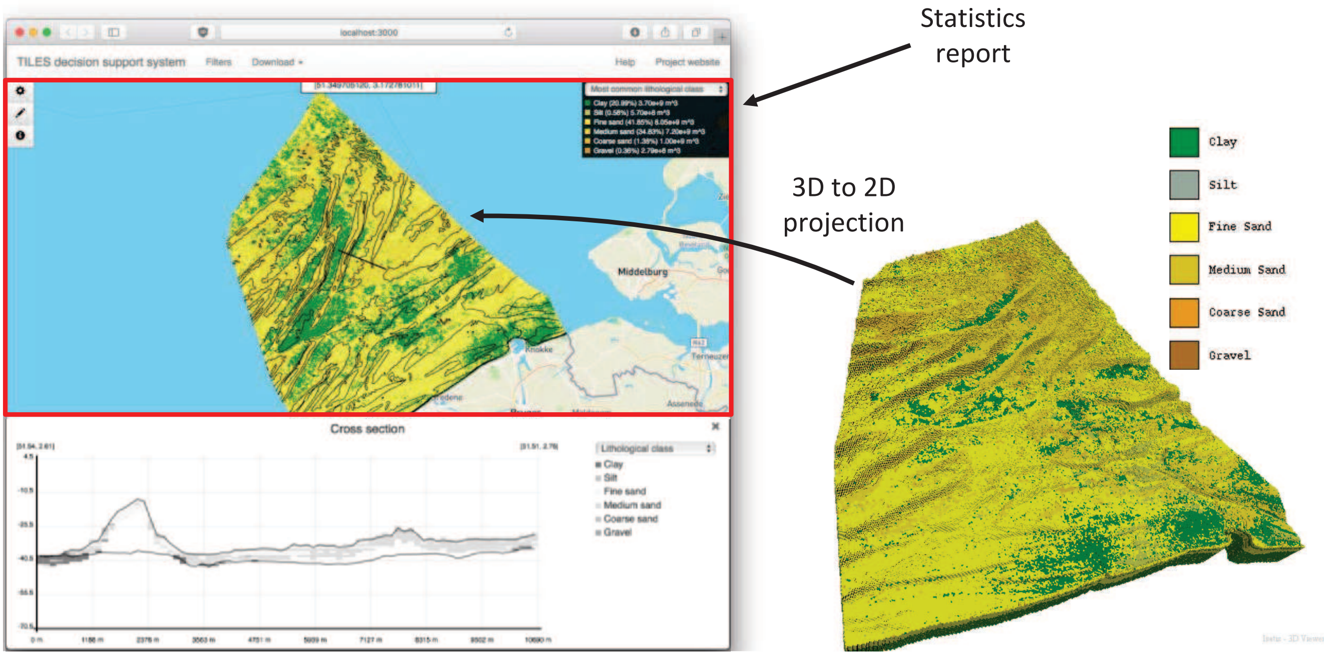
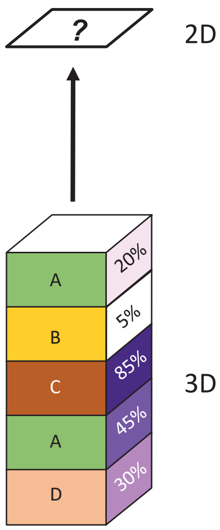
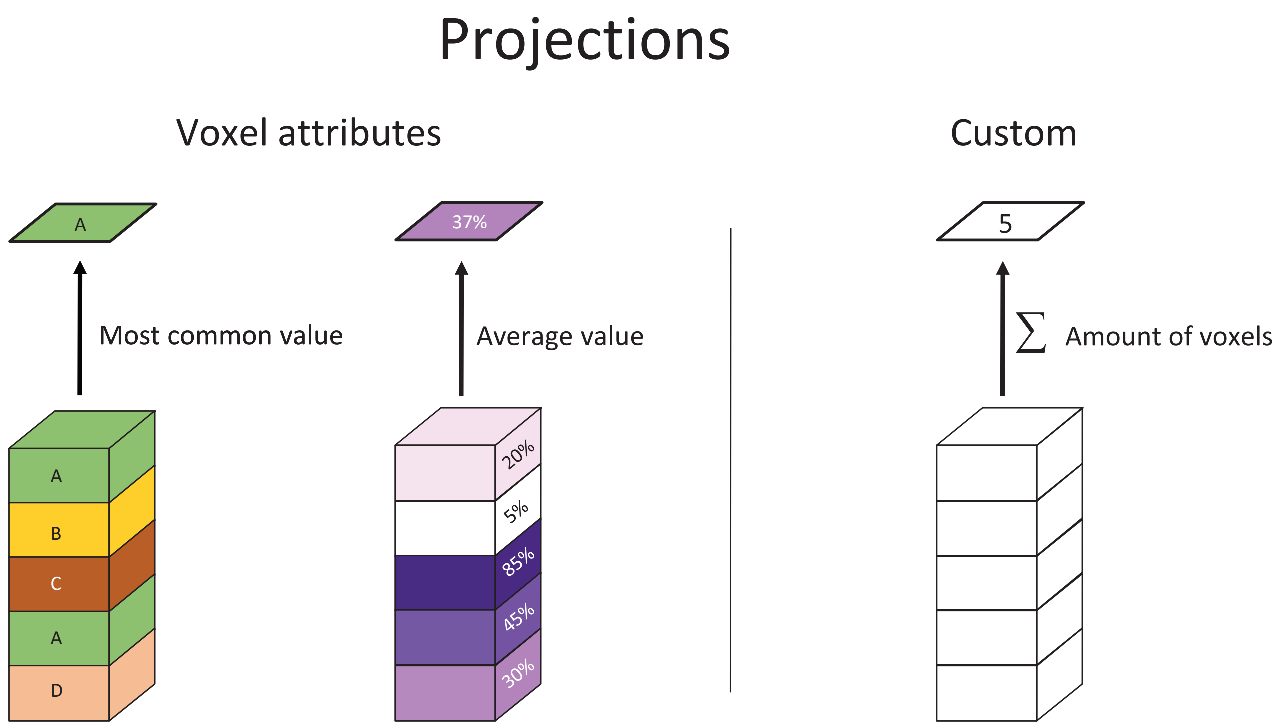
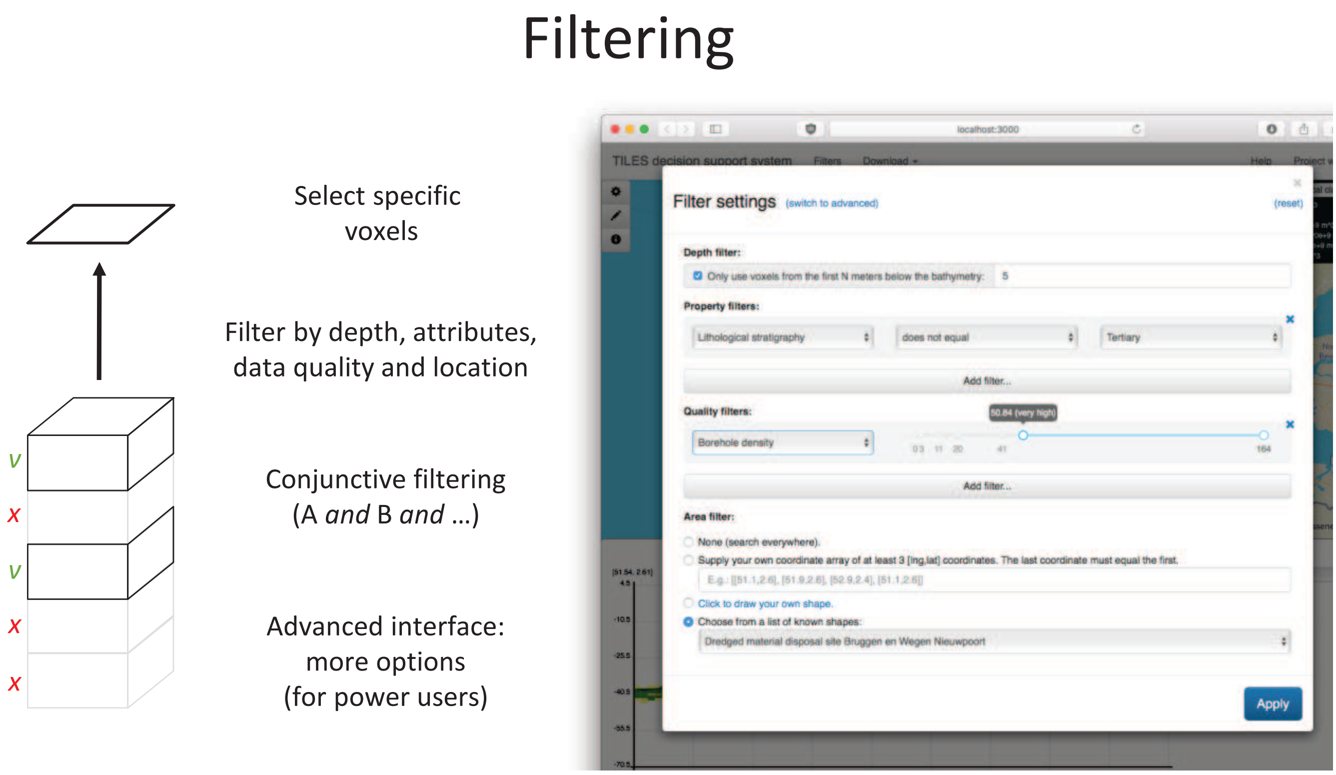
Top-down visualization



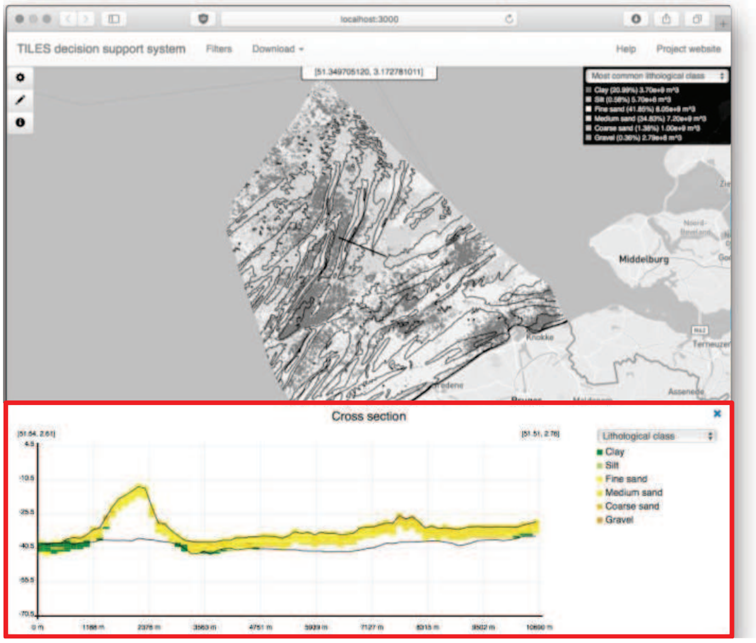
3D to 2D projection




Projections
Voxel attributes
Custom
A
Most common value
A
B
C
A
D
37%
Average value
20%
5%
85%
45%
30%
5
∑ Amount of voxels


Filtering
Select specific voxels
Filter by depth, attributes, data quality and location
Conjunctive filtering (A and B and ...)
Advanced interface: more options (for power users)
v
x
v
x
x
Filter settings
Depth filter:
Property filters:
Quality filters:
Area filter:
Apply

Cross section view



Profile view of the true data
(no aggregation!)

In straight line

Colorize different
voxel attributes,
independent from
top-down view

Active filters
taken into account

Summary

What it **can** do

visualize the voxel model
(top-down and cross section)

simple per-voxel filtering

rudimentary statistics like
volume calculations

What it **can not** do

advanced analytics
(but you can download the model)

make decisions for you

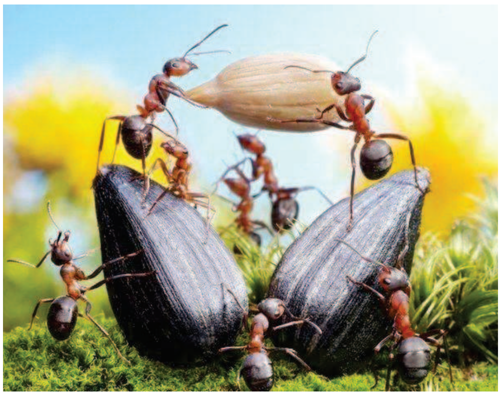
SAND IN A DIGITAL ERA

Sand knowledge bases require cooperative action

Sand knowledge is cross-disciplinary and cross-sectoral. Incorporating third-party data in community databases is important to obtain broad knowledge bases that serve all user applications. Common interest and finding solutions for confidentiality issues are the best incentives to make progress. Pan-European and global initiatives scale up both interoperability and use.

Serge Scory
Royal Belgian Institute of Natural Sciences

museum



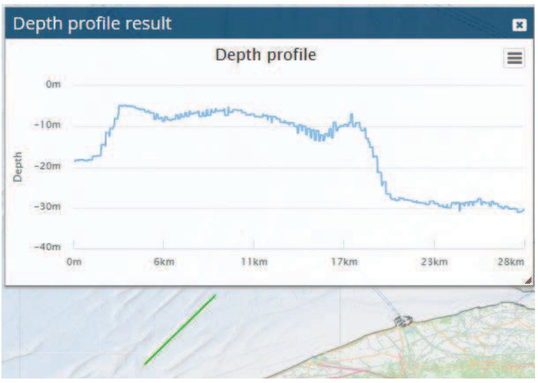
The two mottoes:

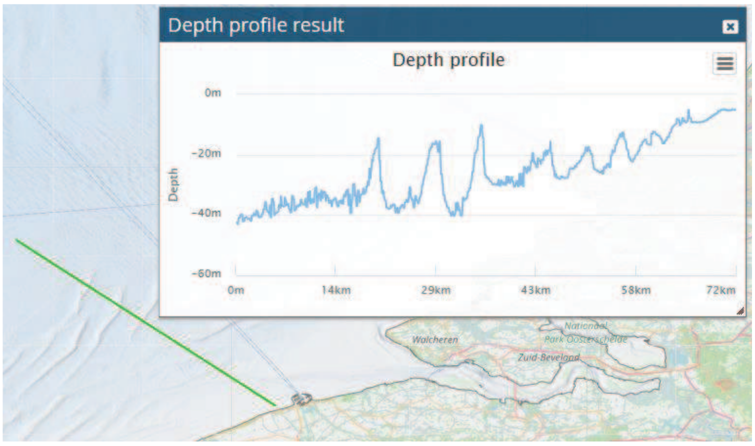
- ✓ **Together, we can do better!**
- ✓ **Collect once, use many times!**

Your local facilitator: the *Belgian Marine Data Centre*

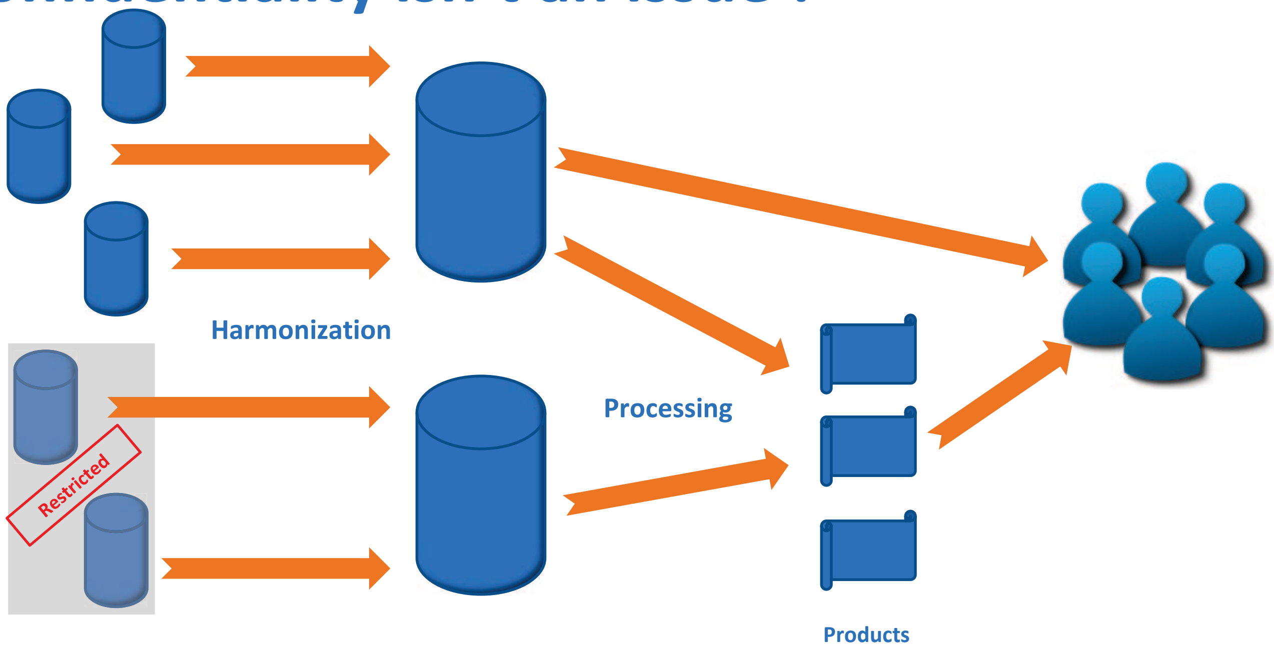
A close example: the success story of “EMODNET Bathymetry”:

- ✓ From a first “best effort” mapping,
- ✓ to a Digital Terrain Model with a resolution of a 1/8 minute (~230m x 145m),
- ✓ and now heading towards a resolution of 1/16 minute (~115m x 70m)



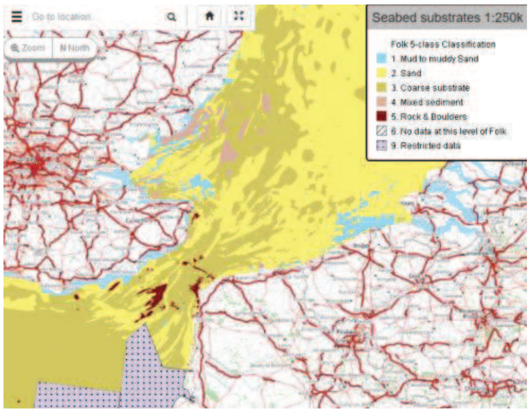


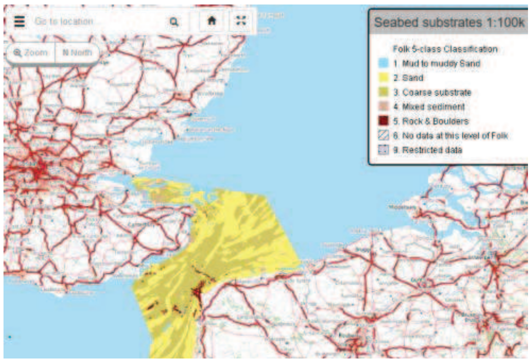
Confidentiality isn’t an issue !



Why should you contribute?

- ✓ ~~You are paid~~
- ✓ You are rewarded
- ✓ You are in line with your mission wrt societal involvement

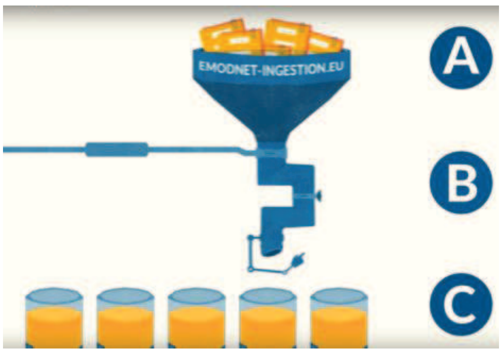




BMDC & SUMO as facilitators:

The EMODnet "Data Ingestion portal"

A semi-automated workflow that helps you publishing harmonized data.



SAND IN A DIGITAL ERA

Sand-resource comprehension is investing in our future

Sand availability is critical to realize grand initiatives envisioned by public-private partnerships. **Jointly** weighing geological, environmental and socio-economic parameters leads to a **collective understanding** of what is at stake. More **systematical comprehension** is needed of connections and feedbacks within a coupled human-natural system to achieve sustainability in an **interconnected world**.

Vera Van Lancker
Royal Belgian Institute of Natural Sciences
museum

TILES project

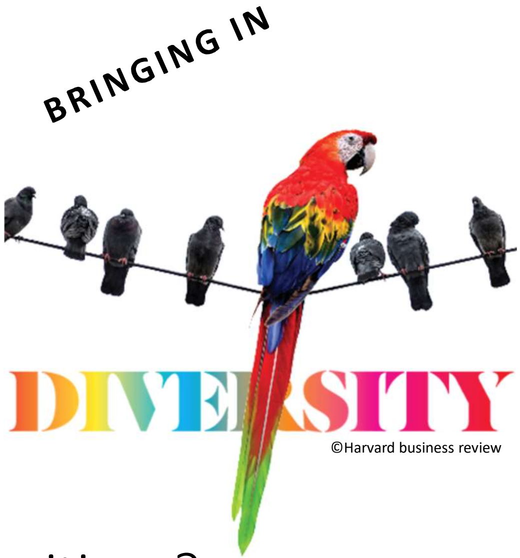
- Many challenges faced, often pioneering
- Range of *<data to product>* covered
- Products resulted from a true team effort

©Harvard business review

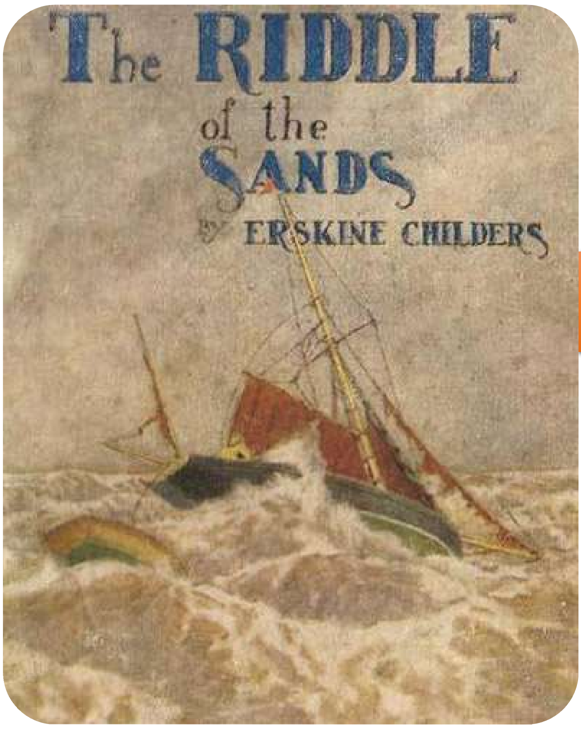
- Databases are ready for further exploration: valorisation into derivative, applied products **+ eager now for research spin-off**
- DSS tool awaits further modular expansion and 4D dynamic functionalities

NEXT?

- Coupling other environmental parameters, as well as socio-economics
- Making it more applied to other end users
- Embedding TILES output in ecosystem models
- Investigating new research avenues



or NEXT…NExus of Transitions?



Long-term resource use

^

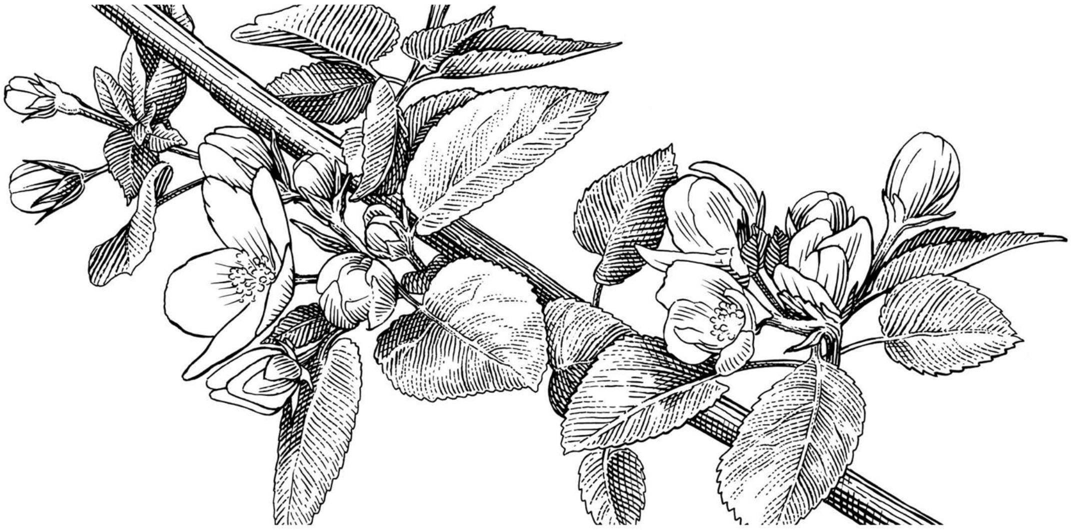
v

Understanding the stakes

A Cascade of Sand:
Complex Systems in a Complex Time

The newly developed scientific tools can now be the basis of

Jointly weighing geological, environmental and socio-economic parameters



Environmental Technology for Sustainable Development

https://lnu.se

Promising innovation trajectories

Biodegradable materials in the construction industry

©Finite is a new composite material made from desert sand!


in an Interconnected world of Sand…
• Material flow is quantified over distances:
• Source to sink
• Source to consumption
• Linking regions of scarcity to abundance
Science of Telecoupling
• Feedbacks are known within a coupled human-natural system
Sustainability is a learning process: continuous improvement and behavioural transitions
©Benjamin Grant

Experts contributing to the Code of Sand

Vera Van Lancker (PhD Ghent University, coordinator of TILES) is a marine geologist at the Royal Belgian Institute of Natural Sciences (Operational Directorate Natural Environment) and Professor at Ghent University. She focusses on sustainable exploitation of marine geological resources, studying interrelationships between human activities, spatiotemporal change in seabed habitats, and sediment dynamics.

Sytze van Heteren (PhD Boston University) is a coastal and marine geologist at the Geological Survey of the Netherlands and Vice Chair of the EuroGeoSurveys Marine Geology Expert Group. Key areas of expertise include coastal and marine sedimentology, coastal morphodynamics, and applied Quaternary geology. He has coordinated the Survey's coastal-zone and shallow-marine mapping program.

Tine Missiaen (PhD Ghent University) is a marine geophysicist at the Flanders Marine institute and Visiting Scholar at Ghent University's Renard Centre of Marine Geology. She has extensive experience in marine seismics, specializing in ultra-high-resolution 2D and 3D seismic data acquisition and processing, acoustic techniques for land-sea boundary studies, and submerged prehistoric landscapes.

Maikel De Clercq (PhD Ghent University – June 2018) just completed his dissertation on 'Drowned landscapes of the Belgian Continental Shelf: Implications for northwest European landscape evolution and preservation potential for submerged heritage'. He uses seismic and borehole data as well as sediment-sample analyses to reconstruct subsurface geological architecture and understand the preservation potential of the embedded archaeological and paleontological material. ***Invited***

Ad Stolk (MSc Utrecht University) worked for years as a marine and coastal researcher at Utrecht University before joining Rijkswaterstaat in the 1990s. His main responsibility concerns the science-based management of the Dutch seabed, primarily from a geological and archaeological perspective. He is Chair of the ICES Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem. ***Invited***

Katrijn Baetens (PhD KU Leuven) is a marine modeler at the Royal Belgian Institute of Natural Sciences (Operational Directorate Natural Environment), with a demonstrated history of working in the research industry and in capacity building. Skilled in mathematical modelling and sustainable development, she has contributed to the 'Capacities for Biodiversity and Sustainable Development' initiative. She runs the helpdesk for COHERENS, an in-house marine modelling software tool. ***Invited***

Lars Kint (MSc Ghent University) is a scientific collaborator at the Royal Belgian Institute of Natural Sciences (Operational Directorate Natural Environment), where he manages and processes geological data within international projects such as TILES and EMODnet, the European Marine Observation and Data network. He focusses on data and metadata harmonization, and specializes in confidence assessments.

Jan Stafleu (PhD VU Amsterdam) is a geomodeler and project manager at the Geological Survey of the Netherlands. Using his experience in programming, technical and functional software design, information analysis and project management, he has had a coordinating role in the development and optimization of GeoTOP, a detailed 3D voxel model of the shallow subsurface of the Netherlands. It provides a sound basis for applied subsurface-related questions from society.

Jelte Stam (MSc Utrecht University) is a broadly trained geologist with international experience in commercial exploration and mining of aggregates, minerals and metals. Based at the Geological Survey of the Netherlands, he has a strong focus on geological and resource modelling. He is project leader of the renewed mapping and modelling initiative on the shallow geology of the Dutch part of the North Sea.

Dries Van den Eynde (Ir KU Leuven) is a physical oceanographer at the Royal Belgian Institute for Natural Sciences (Operational Directorate Natural Environment). Team leader of a research group on Suspended Matter and Seabed Monitoring and Modelling. Extensive experience in the development and application of numerical models on hydrodynamics and waves, turbulence, cohesive and non-cohesive sediment transport, and morphodynamics.

Frederic Francken (Ir VU Brussel) researches sediment transport in the Belgian part of the North Sea in the framework of optimizing human activities, reducing their environmental impact. He also studies the effects of the dispersion of toxic compounds potentially leaking from dumped ammunition from World War I.

Vasileios Hademenos (MSc National and Kapodistrian University of Athens) is a PhD student at the Renard Centre of Marine Geology, Ghent University. He is a geologist with an MSc in geophysics. Currently, as part of the TILES project, his research focus is on the development of a 3D voxel model of the subsurface of the southern part of the North Sea. He uses this model for resource-volume calculations.

Ester van der Voet (PhD Leiden University) is an Associate Professor within the Department Industrial Ecology of the Institute of Environmental Sciences at Leiden University, and a member of UNEP's International Resource Panel. Within the field of Industrial Ecology, she specializes in methodology development as applied to the circular economy: life-cycle assessment, material flow analysis, substance flow analysis, natural resource accounting, and indicator development. ***Invited keynote***

Marc Roche (PhD University of Liège) is a Scientific Advisor in the Federal Public Service Economy. As Head of the Continental Shelf Service, he is in charge of the sand-extraction management for the Belgian part of the North Sea, promoting sustainability by combining strict control of the extraction itself (from the Electronic Monitoring System) with regular field monitoring of the extraction impact. This monitoring is based mainly on extensive multibeam bathymetric and backscatter data.

Koen Degrendele (MSc Ghent University) has been working for the FPS Economy since 1998. His main focus as a geographer in the team of the Continental Shelf Service is the organization and implementation of the monitoring of the impact of sand extraction on the Belgian part of the North Sea. He is responsible for the acquisition, processing and cartography of bathymetric data.

Nathan Terseleer Lillo (PhD Université libre de Bruxelles) is a marine modeler at the Royal Belgian Institute of Natural Sciences (Operational Directorate Natural Environment). Trained in marine ecosystem modelling, his research now focuses on seabed dynamics in aggregate-extraction areas. By including this 4D component in numerical models, and through validation and interpretation of model results, he contributes to a well-informed decision process aimed at sustainability.

Michel Kapel (BSc University of Namur) is an IT specialist at the Royal Belgian Institute of Natural Sciences (Operational Directorate Natural Environment), where he takes part in designing tools to display, manage, and process data within international projects such as TILES and EMODnet, the European Marine Observation and Data Network. He has also worked on freshwater-related projects for the Freshwater Information Platform.

Robin De Mol (MSc Ghent University) is a computer science engineer at Ghent University working on PhD research addressing information mining and data formatting. He developed the online decision support tool for querying and visualizing TILES sand-resource data, including the quantification of data quality and confidence assessments.

Guy De Tré (PhD Ghent University) is Head of the Database, Document and Content Management research group, part of the Department of Telecommunications and Information Processing at Ghent University. He is an expert in soft computing techniques for information management systems. He does fundamental and applied research focusing on handling imperfect information, data-quality issues, big unstructured data, spatiotemporal modelling, fuzzy querying, and decision support.

Serge Scory (MSc University of Liège) is Head of the Belgian Marine Data Centre at the Royal Belgian Institute of Natural Sciences. He is the Belgian delegate to the International Oceanographic Data and Information Exchange program of UNESCO's Intergovernmental Oceanographic Commission, the International Council for the Exploration of the Sea, and the Working Group on Data, Information and Knowledge Exchange for the implementation of the Marine Strategy Framework Directive. ***Invited***

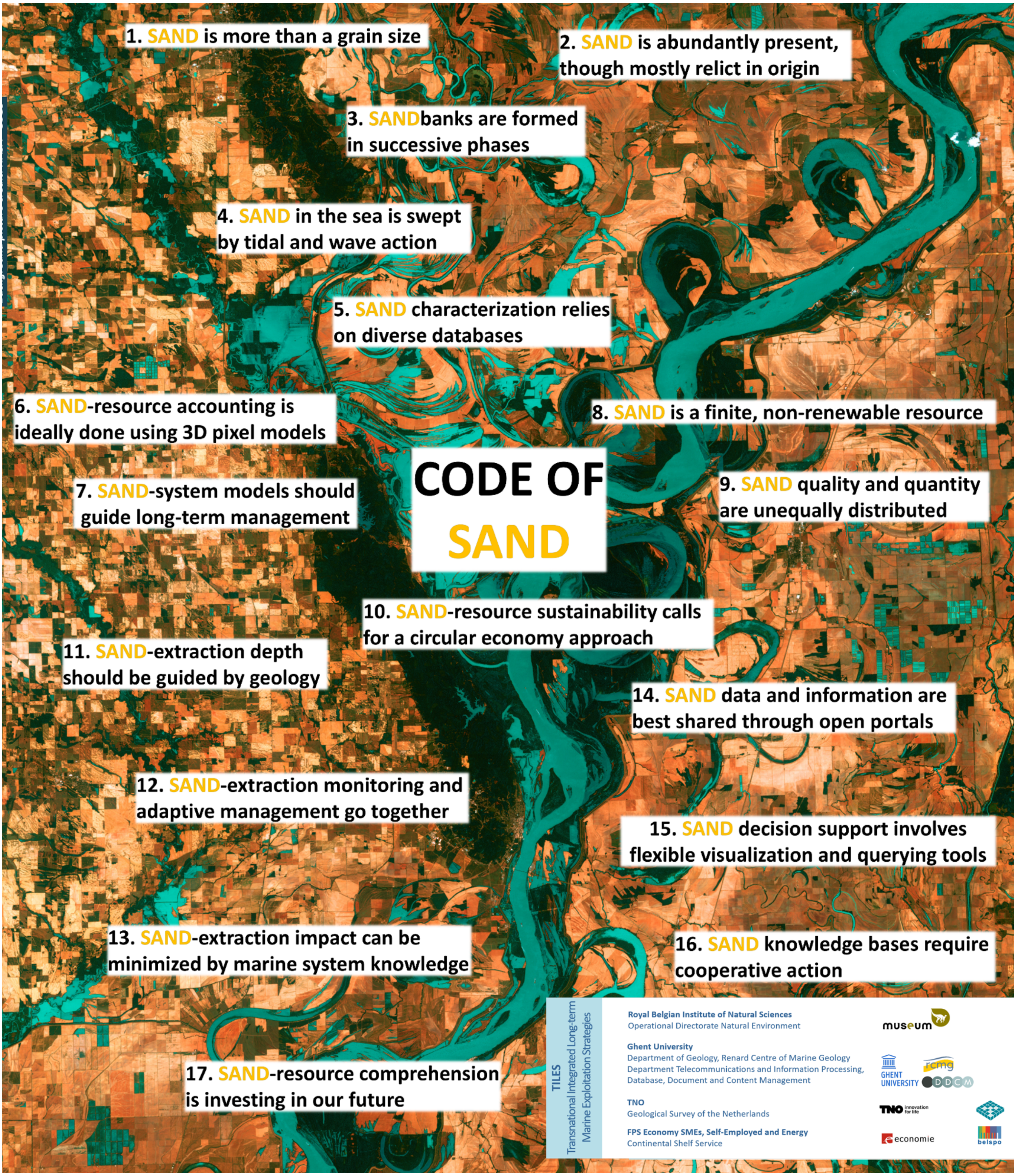
We thank the following colleagues for assisting, most professionally, in bringing awareness of marine sands to a wider audience: e.g., via photography and virtual reality demonstrations:

Pieter van der Klugt (BSc Laboratory for Soil Mechanics Delft) is a geological technician and borehole-description expert at the Geological Survey of the Netherlands. Aside from producing sample descriptions on the basis of visible characteristics, he has helped to modernize various techniques used in the borehole-description laboratory. He specializes in sand-sample photography (photomacrography), and produced the images for the TILES Code of Sand.

Peter-Paul van Maanen (PhD VU Amsterdam) is researcher and project manager at the Geological Survey of the Netherlands. As a computer scientist specializing in artificial intelligence, he has been instrumental in the Survey's work on quality control of geological voxel models using experts' gaze, the development of lithological interpretation of cone-penetration tests using neural networks, and subsurface-data visualization in Virtual Reality.

Rick Appleton (MSc Delft University of Technology) is owner, software engineering consultant and C/C++ Trainer at Daedalus Development. As an external consultant for TNO Defense, Security and Safety, he works on a selection of real-time visualizations in the Virtual Reality and Augmented Reality area.

Steven Ramaker (BSc Rotterdam University of Applied Sciences) is a 3D game art veteran and owner of Kuji Studios. He focusses on high-end digital experiences using Unity 3D, developing Virtual and Augmented Reality apps for architecture, consumer products, simulations and games. One of his clients is TNO Defense, Security and Safety.


1. SAND is more than a grain size
2. SAND is abundantly present, though mostly relict in origin
3. SANDbanks are formed in successive phases
4. SAND in the sea is swept by tidal and wave action
5. SAND characterization relies on diverse databases
6. SAND-resource accounting is ideally done using 3D pixel models
7. SAND-system models should guide long-term management
8. SAND is a finite, non-renewable resource
CODE OF SAND
9. SAND quality and quantity are unequally distributed
10. SAND-resource sustainability calls for a circular economy approach
11. SAND-extraction depth should be guided by geology
12. SAND-extraction monitoring and adaptive management go together
13. SAND-extraction impact can be minimized by marine system knowledge
14. SAND data and information are best shared through open portals
15. SAND decision support involves flexible visualization and querying tools
16. SAND knowledge bases require cooperative action
17. SAND-resource comprehension is investing in our future
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FPS Economy SMEs, Self-Employed and Energy
Continental Shelf Service
museum
GHENT UNIVERSITY
rcmg
DDCM
TNO innovation for life
economie
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