Integrating soil health into contaminated land management

The ISLANDR project

Paul Drenning (Chalmers University), Jennifer Harris and Virginie Derycke (BRGM), Nazaré Couto and Vannessa Correia (NOVA), and many others in ISLANDR

Co-funded by the European Union

SOILveR Soil Health Webinar #2
April 4, 2025

ISLANDR objectives

Risk-based contaminated land assessment for the promotion of soil health

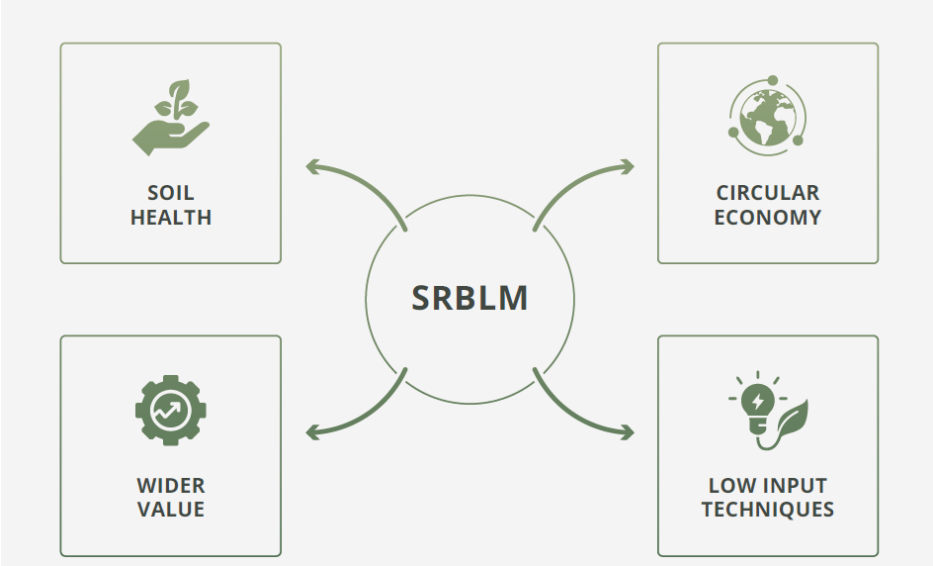
ISLANDR focuses on integrating existing knowledge on soil health into the decision-making process for sustainable and risk-based land management (SRBLM)

1) Combining Risk-based approaches and soil health to prioritize sites for contaminated land management

(Leader: NOVA | Partners: BRGM, CERTH, GD, IUNG, GTK; CHALMERS)

2) Extend risk management concepts to consider soil functionality as a receptor for risk management

(Leader: BRGM | Partners: R3, Chalmers, GD, IUNG, CERTH, NOVA)



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What does it mean to consider soil health in remediation and redevelopment projects?

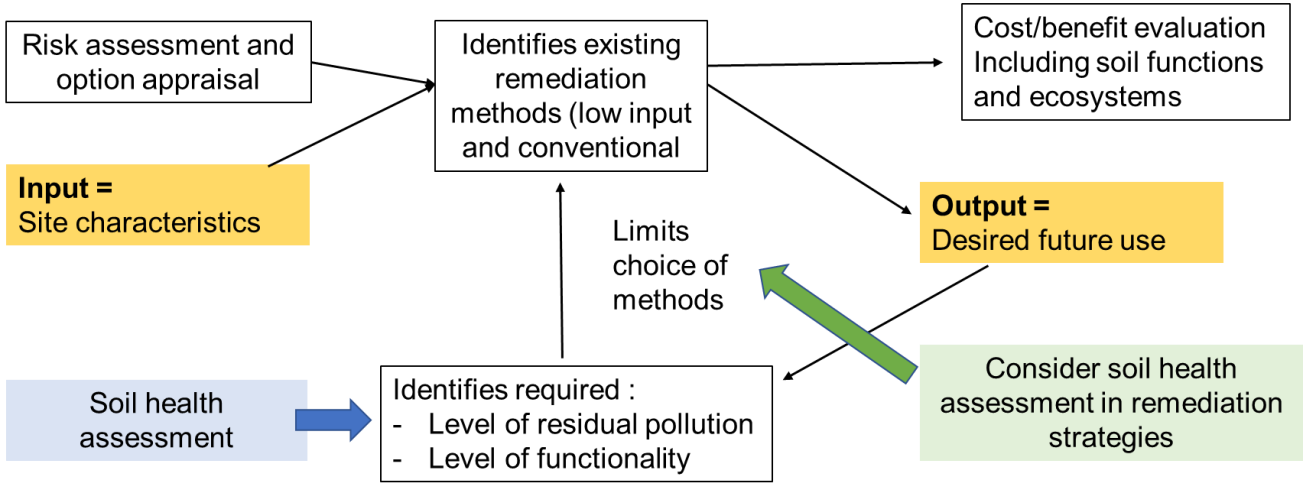
A risk-based approach to soil health focuses on maintaining or restoring soil functions while managing risks posed by contaminants or other stressors

- Matching the land use suitability for different risk classifications and soil functionality requirements

→ Connecting soil contamination – remediation – land use

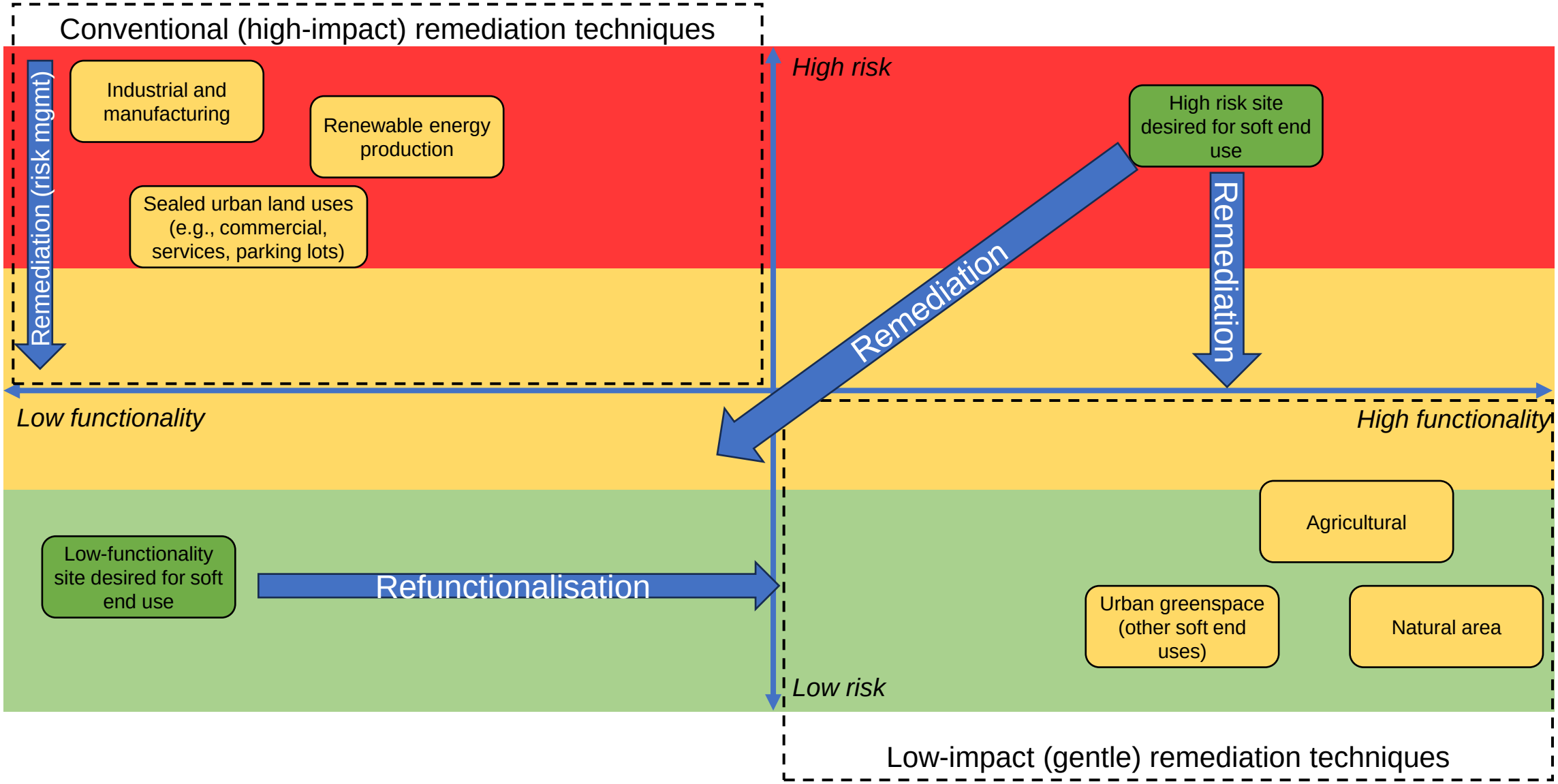
In the decision-making process, **balancing**:

1) The level of soil health required for a future land use
2) The level of decontamination (for risk management) required
3) Avoiding further degradation of soil functions



Land use suitability for different risk classifications and soil functionality requirements

(*Risk assessment x soil health assessment*)



How to integrate soil health in contaminated land management?

Today: Legislation primarily focuses on human health risk and exposure when defining future land use – remediation often legally mandated when trigger values are exceeded

- While not "**healthy**", contaminated soils can still perform functions to deliver ecosystem services
- Remediation techniques can have **negative impacts** on soil functionality

There are two (interconnected) contexts in which soil health needs to be considered in contaminated site remediation:

1) Looking at soil health as a "receptor" in the context of managing risks
→ Impacts on soil health (providing ES) itself as a **risk** – not only the health and ecological risk

2) The impacts (positive or negative) of the remediation process itself on soil health

In **SRBLM**, soil health can be iteratively added in the steps of site management →

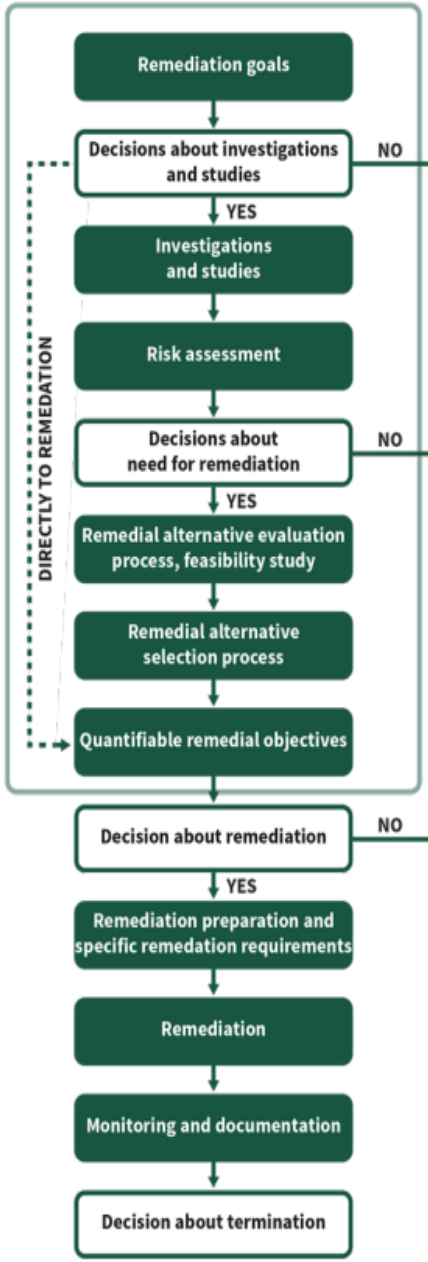


Figure 4. A schematic illustration of the remediation proces

SEPA, 2021

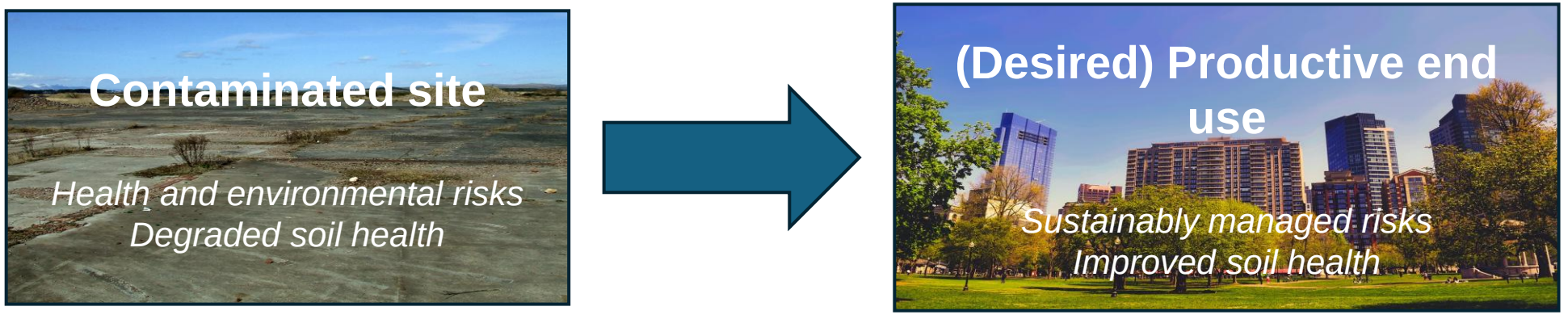
ISLANDR approach to soil health

Step-wise approach to including soil health in the decision-making process:

1. Site investigation – soil health and risk assessment
2. Evaluate remediation alternatives
3. Future land use
4. Required soil functions and indicators for future land use
5. Consider impacts of remediation alternatives on soil functions
6. Refine choice of remediation option and site design

Harmonized with Soil Monitoring Law and coming ISO standards!

Sustainable and risk-based land management (SRBLM)



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Pollutant	Possible remediation methods	Future use considered?	Required functions for each future use	Impact of remediation methods on soil functions

Contaminated site

1

- Metals
- Chlorinated solvents
- Hydrocarbons
- BTEX
- …..

2

Conventional
Thermal treatment
Soil washing (ex-situ)
Soil flushing (in-situ)
ISCR/ISCO (in-situ)
Electrokinetic treatment (in-situ)
Multi-phase extraction (in-situ)

Low impact
Bioremediation (in-situ/ex-situ)
Phytoremediation (all, in-situ)
Natural attenuation/NSZD (in-situ)
Immobilisation with amendments (organic, in-situ)
Immobilisation with amendments (inorganic, in-situ)
Mycoremediation (in-situ)

3

- Agricultural
- Urban
- Industrial
- Artificial land
- Cropland
- Woodland
- Shrubland
- Grassland
- Bareland
- Water
- Wetland

Support for Plant Growth	Nutrient Cycling	Water Storage and Regulation	Water Filtration	Carbon Sequestration	Biological Habitat	Erosion control	Buffering pH
Soil organic carbon, Nitrogen in soil, Soil acidity, Extractable phosphorus, Bulk density in topsoil, Soil texture, Earthworm density	Soil organic carbon, Nitrogen in soil, Extractable phosphorus, Microbial biomass, Soil basal respiration	Soil water holding capacity, Bulk density in topsoil, Soil texture, Soil erosion rate	Soil organic carbon, Soil texture, Soil acidity, Concentration of heavy metals in soil, Concentration of a selection of organic contaminants	Soil organic carbon, Bulk density in topsoil, Fauna, Microbial biomass	Earthworm density, Above ground biodiversity, Fauna, Macroinvertebrates	Soil erosion rate, Soil texture, Bulk density in topsoil	Soil acidity, Soil organic carbon
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Indicators and how to measure/interpret them ongoing in T2.4

5

4

Example

Impacts of remediation techniques → on soil functions ↓		Conventional techniques (tec
Function	Sub-functions & -indicators/descriptors	Thermal treatment (in-situ/ex-situ*)	Soil washing (ex-situ*) or flushing (in-situ)	ISCR/ISCO (in-situ)
Organic matter storage, transformation and recycling	Decomposition	Combustion of SOM		Degradation of SOM
	-soil microbial biomass	– or +/-	– or +/-	– –
	-feeding activity	– or +/-		– –
	-organic matter mineralization in soil			
	Resource reallocation			
	-soil organic carbon (SOC)	– –		– –
	Biochemical transformation			
	-soil organic carbon (SOC)			
	-microbial basal respiration (carbon mineralization)			
	-microbial catabolic activities (MSIR, enzymes)			
	-functional diversity/genes			
Water regulation, retention and release	Biological retention by plants?		Impaired due to loss of fine particles	Decreased retention, pores can be clogged by residual precipitates
	Water retention			
	-soil texture			
	-water holding capacity (retention)		– or +/-	–
	-soil organic carbon (SOC)			
	Infiltration and percolation			
	-infiltration/permeability			
	-bulk density			
	-effects on macrofauna (earthworms)	– or +/-		– –

Full matrix in progress

6 Refined choice of decontamination method

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Site investigation and remediation option appraisal

Risk assessment (validation, fit-for-use) →

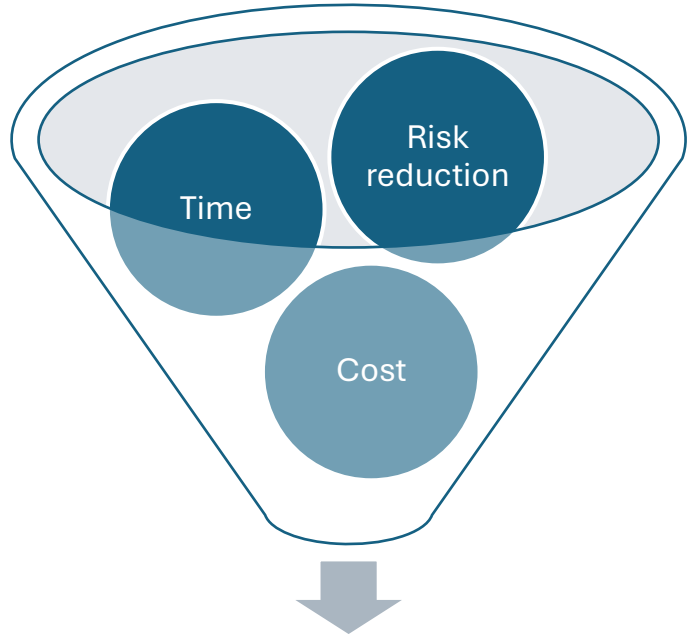
- Source-pathway-receptor linkages
- Risk to humans and ecosystems
- Ecotoxicology and residual contamination
- Ecological risk assessment – **TRIAD**

+

Soil health assessment (iterative, management)

- Soil capacity to provide ecosystem services
- Required soil functionality according to future land use
- Physical, chemical and biological indicators

→ Emphasis on **low-impact remediation techniques**



Most viable remediation option

Considering future land use → indicators and soil functions

Participation in the **NICOLE & COMMON FORUM Joint Spring Workshop 2024 in Brussels** : ISLANDR led the "**What Does Soil Health Mean on Industrial and Urban Land?"** session aimed to foster a holistic understanding of soil health

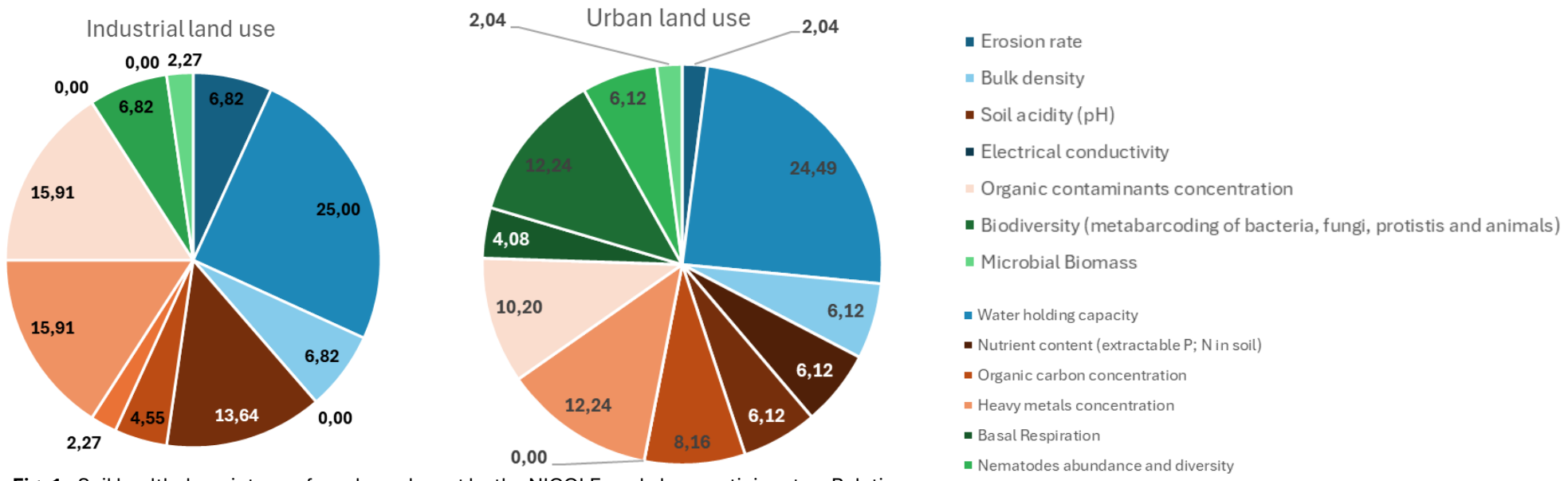
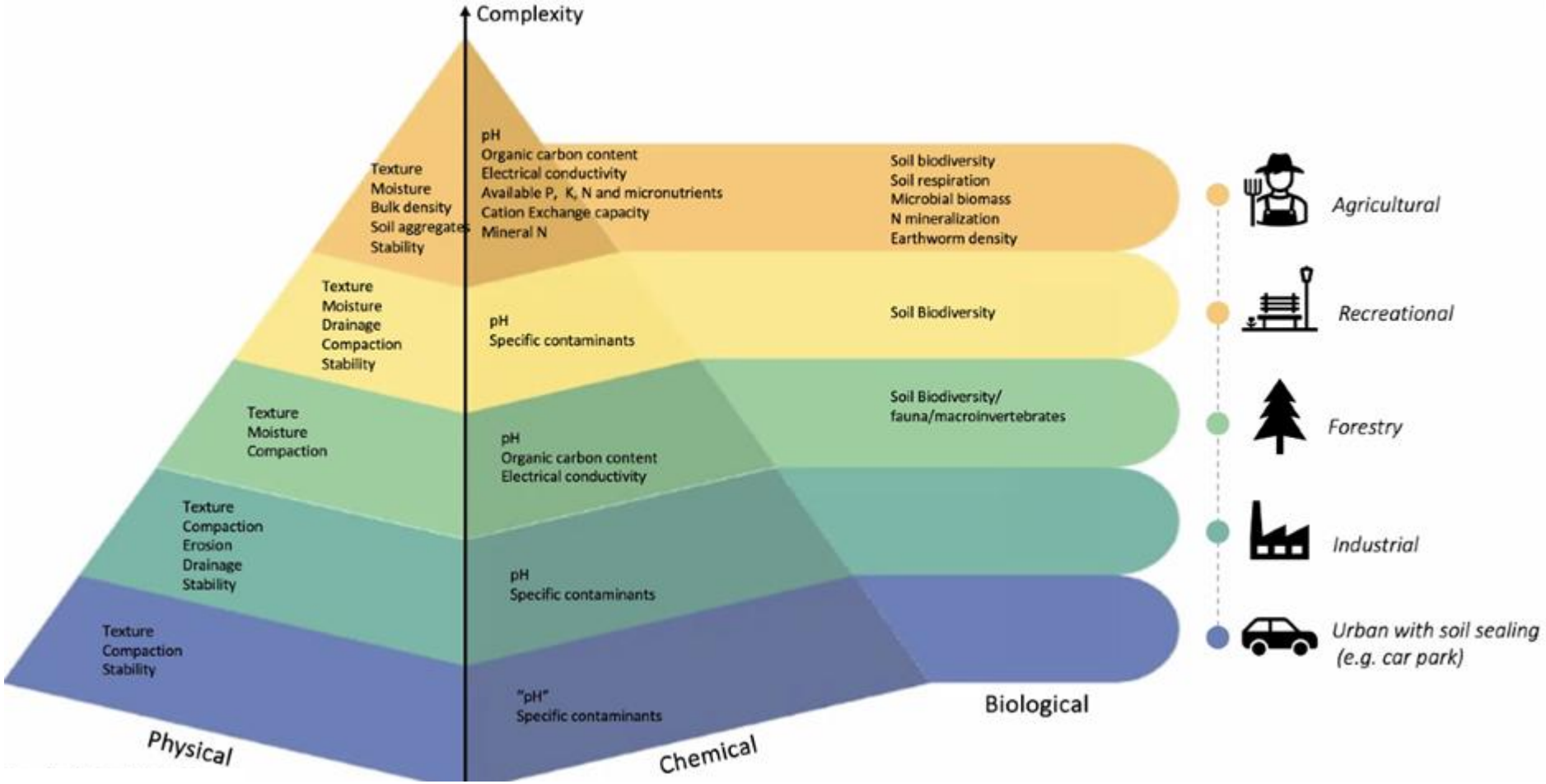


Fig. 1 - Soil health descriptors referred as relevant by the NICOLE workshop participants - Relative percentage of each descriptor

Minimum data set of soil health indicators per type of soil land use



Matrix to support selection of key soil descriptors for different land uses

What: Matrix to support stakeholders track key soil descriptors considering land use and soil functions

How. Matches land uses (e.g., agriculture, industrial) with soil functions (e.g., water filtration, carbon sequestration)

Color-coded. Green (high relevance), yellow (medium), red (low) for prioritizing soil health indicators

Dynamic monitoring. Adjust soil monitoring based on current or intended land use

Land uses
Agricultural
Urban
Industrial
Artificial Land
Cropland
Woodland
Shrubland
Grassland
Bareland
Water
Wetland

Soil Functions
Support for Plant Growth
Nutrient Cycling
Water Storage and Regulation
Water Filtration
Carbon Sequestration
Biological Habitat
Erosion Control
Buffering pH

LAND USE	SOIL FUNCTIONS					
	Support for Plant Growth	Nutrient Cycling	Water Storage and Regulation	Water Filtration	Carbon Sequestration	Biologic
Agricultural	Soil organic carbon, Nitrogen in soil, Soil acidity, Extractable phosphorus, Bulk density in topsoil, Soil texture, Earthworm density	Soil organic carbon, Nitrogen in soil, Extractable phosphorus, Microbial biomass, Soil basal respiration	Soil water holding capacity, Bulk density in topsoil, Soil texture, Soil erosion rate	Soil organic carbon, Soil texture, Soil acidity, Concentration of heavy metals in soil, Concentration of a selection of organic contaminants	Soil organic carbon, Bulk density in topsoil, Fauna, Microbial biomass	Earthwor Above biodiversi Macroinv
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Industrial	Soil organic carbon, Soil acidity, Extractable phosphorus, Bulk density in topsoil, Soil texture, Concentration of heavy metals in soil	Soil organic carbon, Microbial biomass, Soil basal respiration, Nitrogen in soil	Soil water holding capacity, Bulk density in topsoil, Soil texture, Soil erosion rate	Soil texture, Soil acidity, Concentration of heavy metals in soil, Concentration of a selection of organic contaminants	Soil organic carbon, Bulk density in topsoil, Microbial biomass	Earthwor Above gr biodiversi Macroinv
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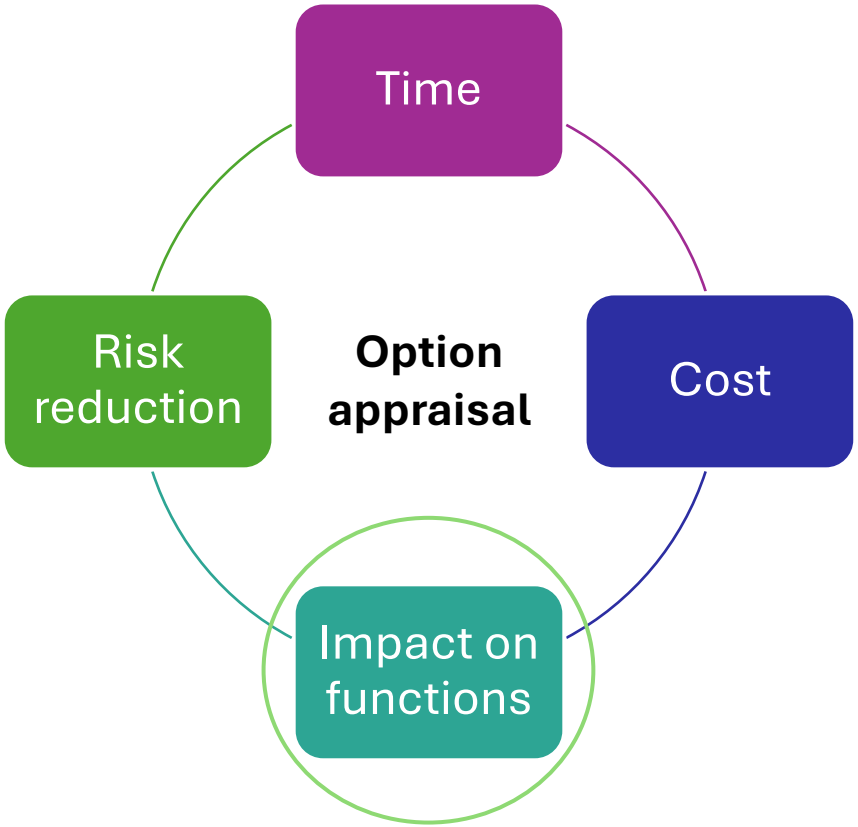
Consider remediation option impact on soil functions

(based on literature review)



Soil functions ↓ / Soil remediation techniques →		*Physical remediation techniques*					*Chemical remediation techniques*		
Function	**Sub-functions & *-indicators/descriptors***	**Thermal treatment (in-situ/ex-situ*)**	**Soil washing (ex-situ*) or flushing (in-situ)**	**Electrokinetic treatment (in-situ)**	**Liquid layer removal (in-situ)**	**Air sparging, vapor extraction (in-situ)**	**Chemical oxidation, ISCO (in-situ)**	**Chemical reduction and reduction-oxidation (redox) reactions, ISCR (in-situ)**	**Pump and treat of groundwater (remove?)**
Organic matter storage, transformation and recycling	**Decomposition**	Combustion of SOM					Degradation of SOM		
	-soil microbial biomass	– or +/-	– or +/-	–			– –		
	-feeding activity	– or +/-					– –		
	-organic matter mineralization in soil								
	Resource reallocation								
	-soil organic carbon (SOC)	– –					– –		
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	Water retention								
	-soil texture								
	-water holding capacity (retention)		– or +/-				–		
	-soil organic carbon (SOC)								
	Infiltration and percolation								
	-infiltration/permeability								
	-bulk density								
	-effects on macrofauna (earthworms)	– or +/-					– –		

CHALMERS

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Mycoremediation (in-situ)

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- Woodland
- Shrubland
- Grassland
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- Water
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Indicators and how to measure/interpret them ongoing in T2.4

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	Resource reallocation			
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	Infiltration and percolation			
	-infiltration/permeability			
	-bulk density			
	-effects on macrofauna (earthworms)	– or +/-		– –

Full matrix in progress

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Deliverable to be finalized in January 2026!

Take-home messages and future work in ISLANDR

Integrating broader soil health assessments into contaminated land management is essential for better decision-making → **Recycling brownfields**

'Fit-for-use' should cover both risk and soil functionality for future land use

ISLANDR is working to:

- Select indicators/descriptors based on intended land use and soil functions
- Consider impacts on soil functions during selection of remediation options
- Include soil health in different steps of the decision-making process
- Value soil health to include in cost-benefit analysis

→ Soil Health as an important building block in the **ISLANDR Roadmap**

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