Phytomanagement to restore degraded sites and achieve wider benefits – the GREENLAND project

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Content

1. Context: Contaminated land, GROs, phytomanagement and soft re-use
2. Soft re-use and wider benefits
3. The GREENLAND project
4. The GREENLAND decision support framework
5. Concluding thoughts – from Brownfields to Green Fields

www.zerobrownfields.eu

These projects have received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreements No 265097 and 266124.

Historically, approaches to contaminated site risk management have focused on containment, cover and removal of contaminated soils to landfill

http://ferreiraconstructionsouthern.com/services/environmental-remediation/

Since the late 1990s, move towards treatment-based remediation strategies

Source: clu-in.org

Source: psdmud.co.uk

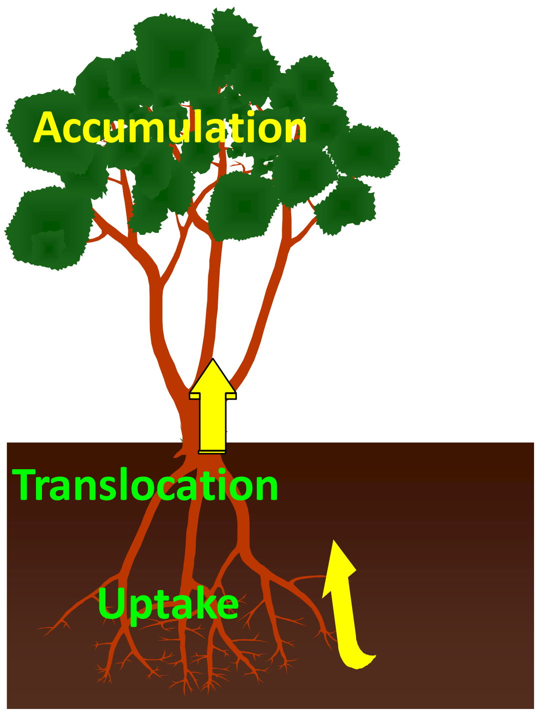
Source: Adventus Group

Number of these alternative technologies utilise an in-situ, less invasive/low impact approach whereby plants (trees, shrubs, native grasses etc) are used for managing site risk – phyto- or “gentle” remediation approaches (GRO)

GROs: risk management strategies or technologies that result in a net gain (or at least no gross reduction) in soil function as well as achieving effective risk management

Phytoremediation / phytomanagement – common GROs

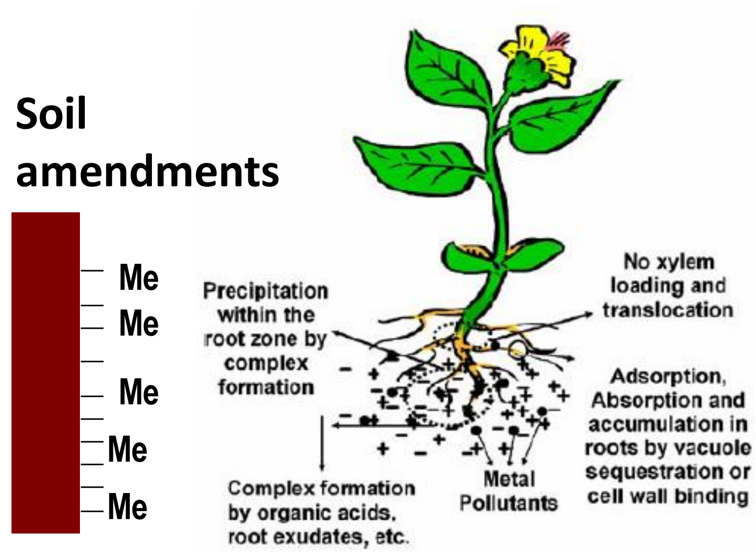
Phytoextraction



(+ phytomining applications for Ge, Ni, Au)?

In situ immobilisation
Aided phytostabilisation

Soil amendments



Phytoextraction is only part of the story……

Phytomanagement: the long term combination of profitable site use with GROs which leads gradually to the reduction of contaminant linkages and the restoration of ecosystem and other site services

Refers to a wider design and management strategy which, alongside risk management, places realisation of wider (including economic) benefits at the core of site design, and uses GROs as part of integrated site management strategies.

Intelligently applied GROs can provide **rapid risk management** via pathway control, through containment and stabilisation, coupled with a longer term removal or immobilisation of the contaminant source term, plus **wider economic, social and environmental benefits**.

Source → **Pathway** → **Receptor**

Source	Pathway	Receptor
Gradual removal or immobilisation of source term	***Reduction in labile pool, rapid reduction in flux of contaminants to receptors at significant risk***	***Using vegetation to manage receptor access to the subsurface***

Particularly useful in cases:

1. Where there are large treatment areas, particularly where contamination may be causing concern but is not at strongly elevated levels
2. Where biological functionality of the soil is required after site treatment
3. Where there are budgetary constraints
4. Where there are deployment constraints for land remediation process plant (e.g. as a function of area and location).

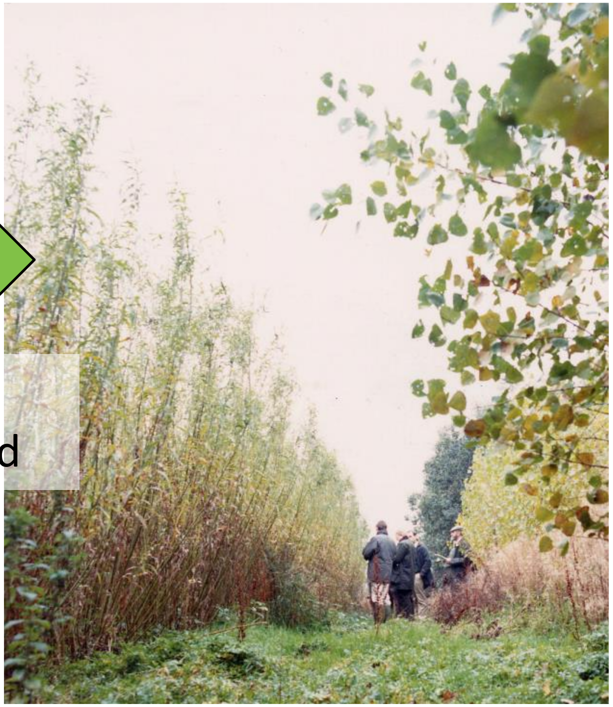
As the treated soil remains unsealed, GROs are highly applicable to soft-end use for a site........

What is soft re-use?

- “Hard Re-Use”
- “Soft-Re-Use”

Building or infrastructure

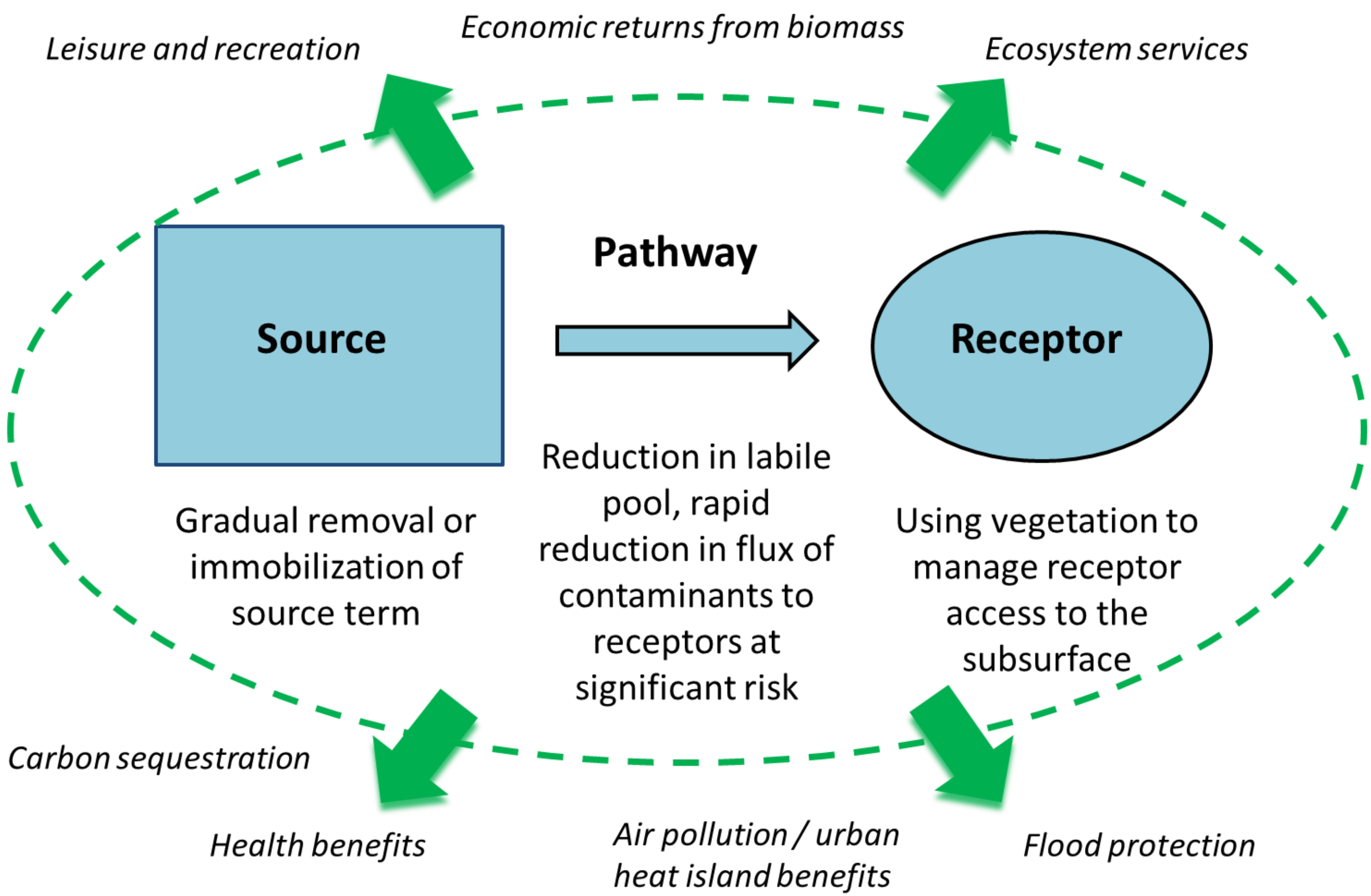
Often combined



Unsealed soil

Potential services from soft re-use

- Site value uplift / value uplift of surroundings / framing built development
- Renewable energy generation
  - Biomass based
  - Geothermal
  - Wind
  - Solar
- Renewable material generation
- Greenhouse gas mitigation (carbon offset revenue?)
- Synergies with waste processing and re-use, leachate management
- Shielding / sound-scaping
- Flood management – link with SUDS
- Amenity and leisure
- Urban climate management (such as mitigation of urban heat island effect)
- Air quality management
- Habitat and conservation
- Improved soil and water resources
- Improved health and well-being
- Opportunities for education
- Community involvement
- *Ecological system services*



Cundy et al., 2016

These services provide value

€	Revenue Generation Opportunity
	Natural Capital
	Cultural Capital
$	Economic Capital - tangibles
	Economic Capital - intangibles

GRO – more sustainable remediation?

Opportunity to use GROs to support potentially self-funding land management for brownfield and degraded areas unsuitable for built developments, such as former landfills, industrial sites and agricultural land damaged by diffuse pollution

Economic leveraging for site redevelopment with wider benefits…….

Soft re-use and benefits - examples

Beam Parklands, Dagenham, London

53 ha functional flood prevention area.
The Land Trust secured funding from a number of sources to enhance the space and to sustainably manage it as an attractive multi-functional community asset, alongside the Environment Agency's flood defence improvement works.

Land Trust ownership model allowed transfer of land and associated liabilities on long term lease to the Trust
Provides significant community benefits and is helping regenerate a deprived area.
http://www.thelandtrust.org.uk/business/sites.html?SID=beamparklands

Soft re-use and benefits - examples

Betteshanger, Kent

Former coal mining site of 120 ha. Regenerated between 2002 and 2011.

New use: Country Park with provision for walking, cycling, horse-riding and wildlife observation, plus warehousing, office and industrial space (inc parkland, “soft cover” and wetlands).

Betteshanger Colliery 1933 (Dover District Council)

Complexity and profile of site meant need for long-term and extensive stakeholder collaboration, e.g. masterplan for regeneration revised significantly in response to public consultation

http://www.peterbrett.com/projects/betteshanger-colliery-kent.php

BUT

Despite widespread use of "green" technologies such as landscaping, application of green cover, reedbeds and constructed wetlands in remediation and urban / industrial regeneration, application of phytoremediation/GRO as a practical site risk management tool is still in its relative infancy

http://thesmalleningworld.com/maltaremembrances/786

So why are GRO not widely applied as practical site solutions?

The main barriers to widespread GROs application, in Europe and more widely, derive from a general focus of the remediation sector on remediation for critical risks, or to rapidly return smaller urban brownfield sites to productive use e.g. for housing

Standardmarketing.com

So why are GRO not widely applied as practical site solutions?

+

- Effective performance on large field scale (up-scaling) remains to be consistently demonstrated
- Management routes for potentially contaminated plant biomass need to be tested
- Decision support tools do not sufficiently consider GRO (Onwubuya et al, 2009)
- At metal contaminated sites, the success of GRO is mostly reflected by changes in contaminant bioavailability rather than in total concentration, which is currently not sufficiently considered by legal frameworks
- **Stakeholders and decision makers are not well informed, or have negative perceptions, about GRO as practical site solutions**

GREENLAND – Gentle remediation of trace element contaminated land*

The GREENLAND project has adopted a transparent and simple plan of action to address these impediments. It has:

1. co-ordinated data collection from a range of long-duration GRO pilot projects at contaminated sites across Europe,
2. evaluated standard protocols and methods for site monitoring, and
3. developed a set of specific design aids (for use when GRO appear to be a viable option) to promote the appropriate use of gentle remediation options and encourage participation of (and inform) stakeholders

* FP7-KBBE-266124; 2011-2014

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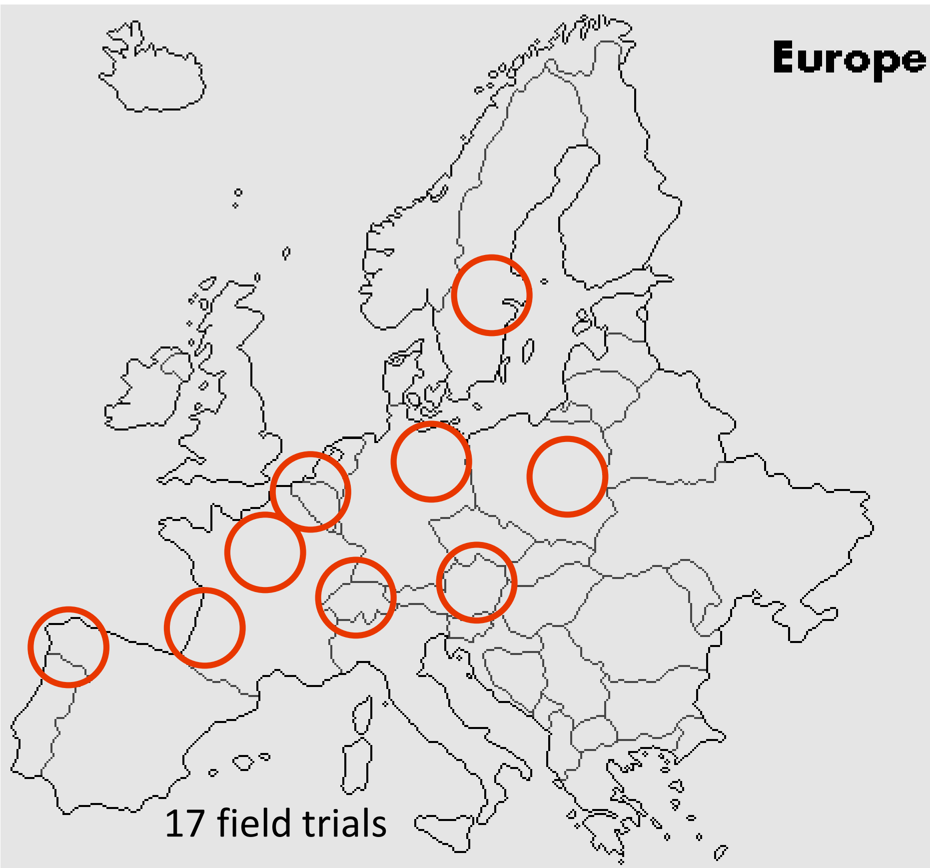
GREENLAND – Gentle remediation of trace element contaminated land*: Project Objectives



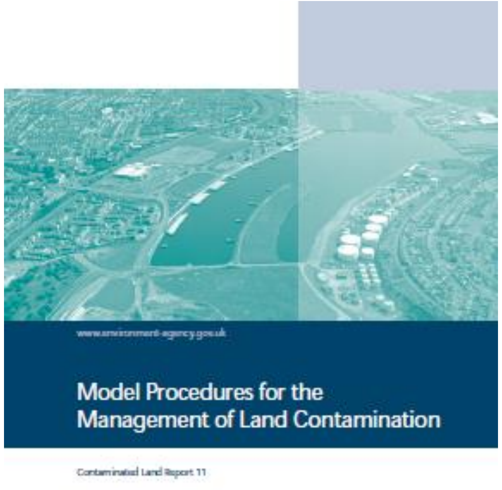
- Assess the efficiency tested in long-term (> 5 year duration) field trials
- Test the possibilities for biomass valorisation
- Evaluation of a set of soil tests to assess GRO performance
- Enhance the efficiency of GRO (e.g. by selection of most effective plants, microbes, and soil amendments)
- Development of a decision support system, stakeholder engagement guidance, and publication of a guide for practical application

* FP7-KBBE-266124; 2011-2014

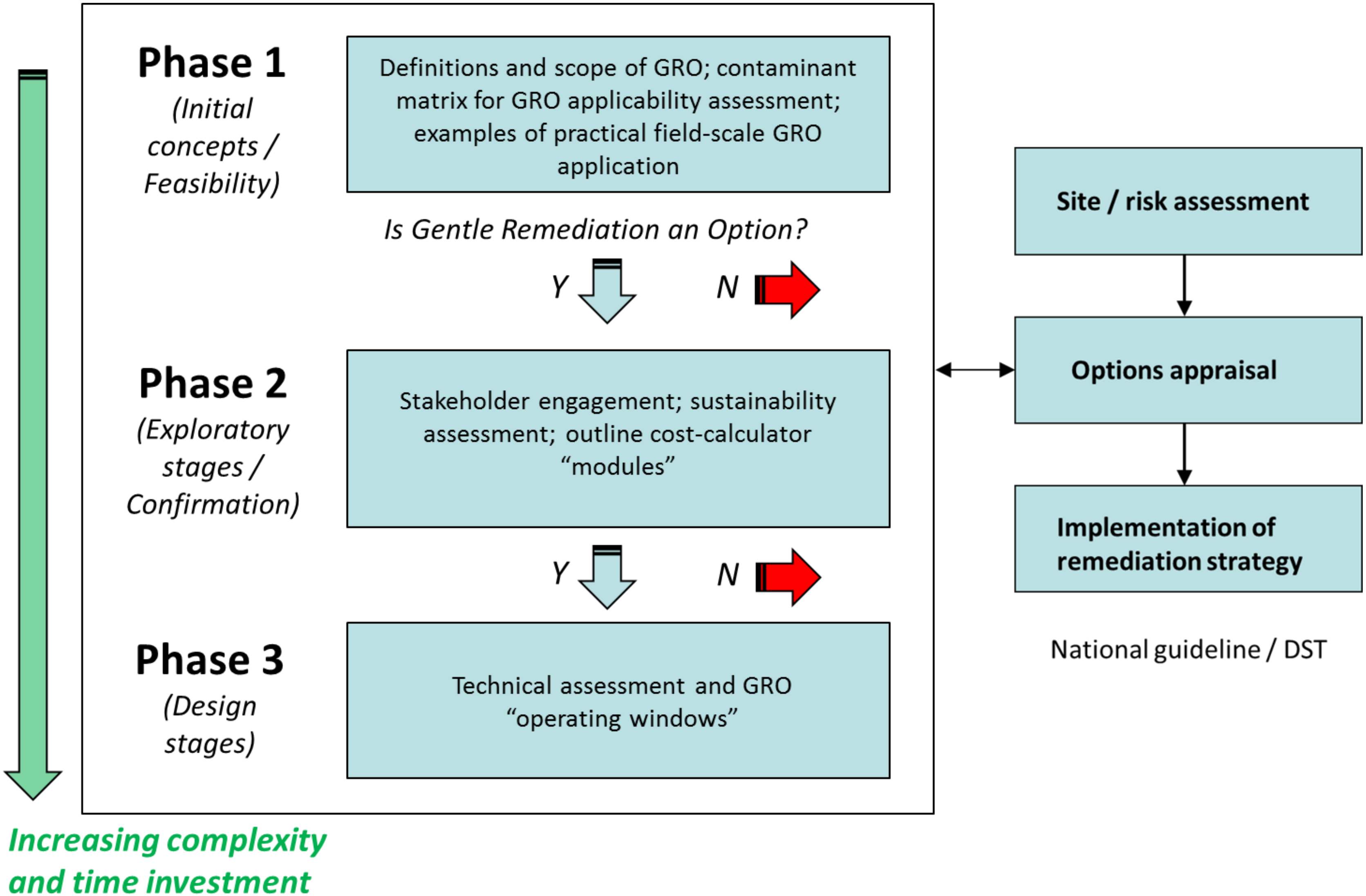
Key output of the GREENLAND project is to develop and trial / evaluate practical decision support tools (based on Greenland and other case studies), focussed on GRO, which

(a) can be integrated into existing, well-established and utilised (national) DSTs / decision-frameworks, to ensure ease of operation and wide usage;

(b) can be used to inform and support remediation option selection by wider stakeholders (consultants, planners etc)



GREENLAND decision support framework



Additional tools supporting Phase 1 (Feasibility)

Definitions

Scope and risk management capability (High Level Operating Windows)

Practical examples

Contaminant matrix

GRO	Definition
Phytoextraction	The removal of metal(loid)s or organics from soils by accumulating them in the harvestable biomass of plants. When aided by use of soil amendments, this is termed aided phytoextraction.
Phytodegradation / phytotransformation	The use of plants (and associated microorganisms such as rhizosphere bacteria) to uptake, store and degrade organic pollutants.
Rhizodegradation	The use of plant roots and rhizosphere microorganisms to degrade organic pollutants.
Rhizofiltration	The removal of pollutants from aqueous sources by plant roots and associated microorganisms.
Phytostabilisation	Reduction in the bioavailability of pollutants by immobilisation in root systems and / or living or dead biomass in the rhizosphere soil – creating a milieu which enables the growth of a vegetation cover. When aided by use of soil amendments, this is termed aided phytostabilisation.
Phytovolatilisation	Use of plants to remove pollutants from the growth matrix, transform them and disperse them (or their degradation products) into the atmosphere.
In situ immobilisation / phytoexclusion	Reduction in the bioavailability of pollutants by immobilizing or binding them to the soil matrix through the incorporation into the soil of organic or inorganic compounds, singly or in combination, to prevent the excessive uptake of essential elements and non-essential contaminants into the food chain. Phytoexclusion, the implementation of a stable vegetation cover using excluder plants which do not accumulate contaminants in the harvestable plant

Additional tools supporting Phase 1 (Feasibility)

Definitions

Scope and risk management capability (High Level Operating Windows)

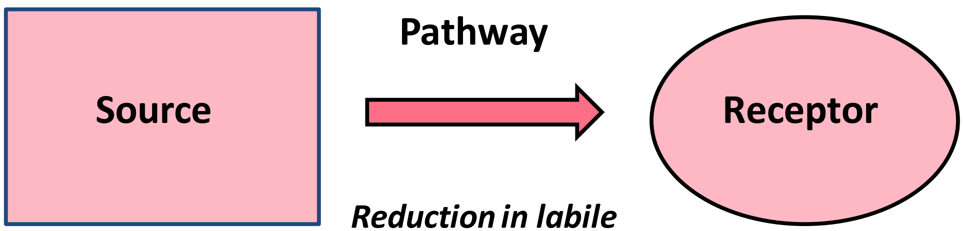
Practical examples

Contaminant matrix

Quick reference: Are GRO applicable to your site?

Key questions:	**If YES, are GRO potentially applicable?**
Does the site require immediate redevelopment?	**Unlikely** (except immobilisation / phytoexclusion which can show immediate positive effects)
Are your local regulatory guidelines based on total soil concentration values?	**Unlikely** for phytoextraction but possibly for some other GRO

Considers wider GRO-based <u>risk management</u> strategy, tailored along contaminant linkage model.



Gradual removal or immobilisation of source term

Reduction in labile pool, rapid reduction in flux of contaminants to receptors at significant risk

Using vegetation to manage receptor access to the subsurface

GREENLAND

SEVENTH FRAMEWORK PROGRAMME

Additional tools supporting Phase 1 (Feasibility)

Definitions
Scope and risk management capability (High Level Operating Windows)
Practical examples
Contaminant matrix

Site name	Freiberg/Halsbrücke	GRO type	Phytoextraction / -stabilization
Location	Freiberg, Germany	Origin of soil contamination	Geogenic and smelter emissions over centuries
Site type	Contaminated arable land	Implementation of field trial	start: 2005 – 2019
Current land use	Short rotation coppice (SRC)	Lifetime	Up to now: 9 years
End land use	Arable land/ grassland/SRC	Surface area	Regional scale, 2 ha test site
Objective	Reduction of pollutant linkages, bioenergy production, reduce total and mobile TE		

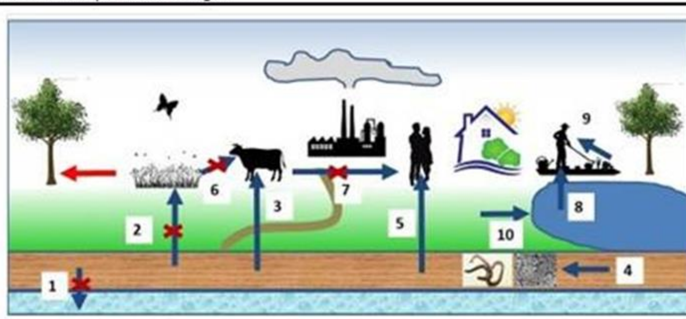
Soil characteristics	Initial values	After best GRO	Initial labile pool* mg/kg	Labile pool after best treatment§ mg/kg
pH	5.7	5.2		
Sand, silt, clay (%)	sandy loam			
Organic C (%)	1,4			
CEC	7.5			
As (mg/kg)	118	95.9	**(0.13) 0.03 ± 0.01	0.03 ± 0.01
Cd (mg/kg)	3.2	2.6	0.17 ± 0.06	0.17 ± 0.06
Cr (mg/kg	42.4		0.002 ± 0.001	< LOD
Cu (mg/kg)	24.3		n.d.	n.d.
Pb (mg/kg)	374		0.37 ± 0.11	0.37 ± 0.18
Zn (mg/kg)	179.5		1.7 ± 1.2	1.8 ± 1.0

* NH_4NO_3; § after 8 years; ** adjacent arable land

Halsbrücke

Core stakeholder	Function	Remark	Main site operators
Farmer	Site owner and harvest logistics		LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE; Freistaat SACHSEN
SMUL, LfULG	Saxon Ministry and its scientific authority	Scientific driven praxis field trial	

Conceptual model and relevant pollutant linkages



Representing long-term in situ stabilization /phytoexclusion studies (Arnoldstein, AT); phytoextraction (Freiburg, GE); aided phytostabilisation (Fresnes-sur-Escaut, FR)

Additional tools supporting Phase 1 (Feasibility)

Definitions
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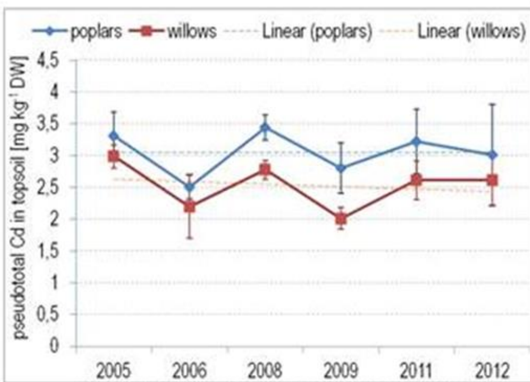
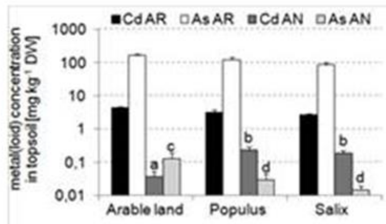
Practical examples
Contaminant matrix

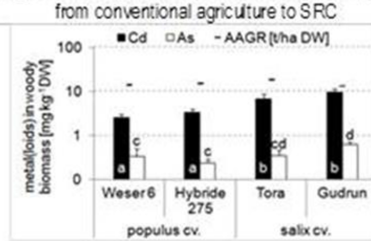
Specific achievements	Description
Reduction of total metal (Cd, Zn, Pb) pools in the soil	Compared to adjacent arable land mobile As could be reduced by ~ 90 %
Mitigate TE transfer into food or forage, bioenergy production	SRC with poplars and willows is a suitable alternative to conventional agriculture, average biomass production was 15 t/ha/DW per year



Changes in pseudo-total (aqua regia) Cd over time (data 2005 – 2009 from Dietzsch et al. 2011)



Changes in mobility of Cd and As due to land change use from conventional agriculture to SRC



Element uptake into wood of poplar and willow clones and biomass production (annual average growth rate)

Key progresses over time

Representing long-term in situ stabilization /phytoexclusion studies (Arnoldstein, AT); phytoextraction (Freiburg, GE); aided phytostabilisation (Fresnes-sur-Escaut, FR)

Such pilot-scale applications of effective GRO strategies (i.e. “success stories”) are key in providing robust technical and practical data for GRO implementation and in engendering confidence in stakeholders, both in terms of illustrating the long-term risk management potential of GRO but also in showing how wider economic, environmental and societal benefits can be realised.

Pilot sites can also be pivotal in education and training as demonstrator sites, both for specialists (e.g. regulators, contaminated land consultants) and nonspecialists

Additional tools supporting Phase 1 (Feasibility)

Definitions
Scope and risk management capability (High Level Operating Windows)
Practical examples
Contaminant matrix

GRO / Contaminant	Phytoextraction (stripping of bioavailable metal(loid))	Phytostabilisation (including aided phytostabilisation)	In situ immobilisation / phytoexclusion
Arsenic	✓✓*	✓**	✓**
Cadmium	✓✓	✓✓	✓✓
Chromium	-	✓	✓✓
Copper	✓✓	✓	✓✓
Lead	✓	✓	✓✓
Nickel	✓✓	✓✓	✓✓
Zinc	✓✓	✓	✓

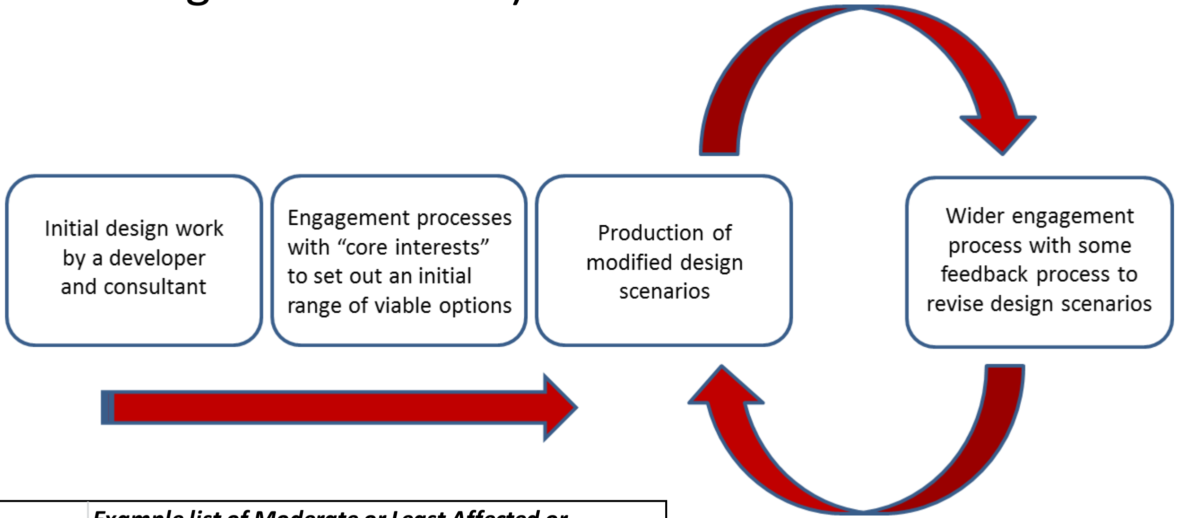
Number of tick marks in the table represents degrees of confidence, using data from the GREENLAND site network. Supporting data can be found in the individual site descriptions in Appendix 7 of the GREENLAND best practice guidance document (www.greenland-project.eu).
For Arsenic: * some hindrances if the soil is contaminated with Cu; **Aided phytostabilisation & in situ immobilisation : As sorption can reverse due to ageing and/or building of organic litter

GREENLAND

SEVENTH FRAMEWORK PROGRAMME

Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:
Stakeholder engagement (models for engagement, principles of stakeholder engagement and GRO, criteria for the identification of different stakeholders categories / profiles, and list of e.g. stakeholders)



Example list of Most Affected or Affecting ("Core") stakeholders	***Example list of Moderate or Least Affected or Affecting ("Non-Core") stakeholders***
	Local community
Developer (i.e. the individual or organisation seeking to develop the land area for alternative use)	Investors
Site Owner (i.e. the legal owner of the site)	Insurers
Regulator (i.e. the local, regional or national body responsible for…..)	Campaigning groups
Planner (……)	Future site users
Service provider (i.e. the contractor or consultant providing the remediation or regeneration service)	Local and regional press
Current and future site users (e.g. biomass producers)	Conservation bodies
Local authorities as owner, financer, regulator	Biomass / bioproduct users
	Recreational users
	Scientific community

From: Cundy A.B., R.P.Bardos, A.Church, M.Puschenreiter, W.Friesl-Hanl, I.Mueller, S.Neu, M.Mench, N.Witters and J.Vangronsveld, 2013. Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: the European context. *Journal of Environmental Management*, **129**, 283-291.

Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:
Sustainability assessment (economic, environmental and social benefits, linking to the HOMBRE project DST, and links to SURF-UK indicator sets)

SERVICE

Examples……

INTERVENTION

Examples

	Intervention **strongly contributes** to delivery of this service
	Intervention **contributes some and/ or indirect benefits** in delivering this service
	Intervention **may contribute or be detrimental** to delivery of service depending on site specific circumstances including management/design
	No influence - ***potential to apply complimentary intervention with further services and added value as output***
	Intervention **may be detrimental to** delivery of this service if not managed/designed appropriately
!	In the event a brownfield site/part of a brownfield site is classified by a regulator as contaminated - appropriate risk mitigation must form part of the redevelopment strategy for the borwnfield site
^	Negative influence/s could be negated with appropriate management/design

Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

- The HOMBRE Brownfield Opportunity Matrix plots Soft Re-use INTERVENTIONS against SERVICES that an Intervention may provide in order to demonstrate the VALUE of applying the Interventions either on their own, or in synergy with other interventions.
- The goal is to encourage redevelopment of Brownfield land so that it re-enters the land-use cycle.

Soft re-use	Service 1	Service 2
Intervention 1		
Intervention 2		

- HOMBRE was funded by FP7, www.zerobrownfields.eu

Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

SERVICE

Examples……

INTERVENTION

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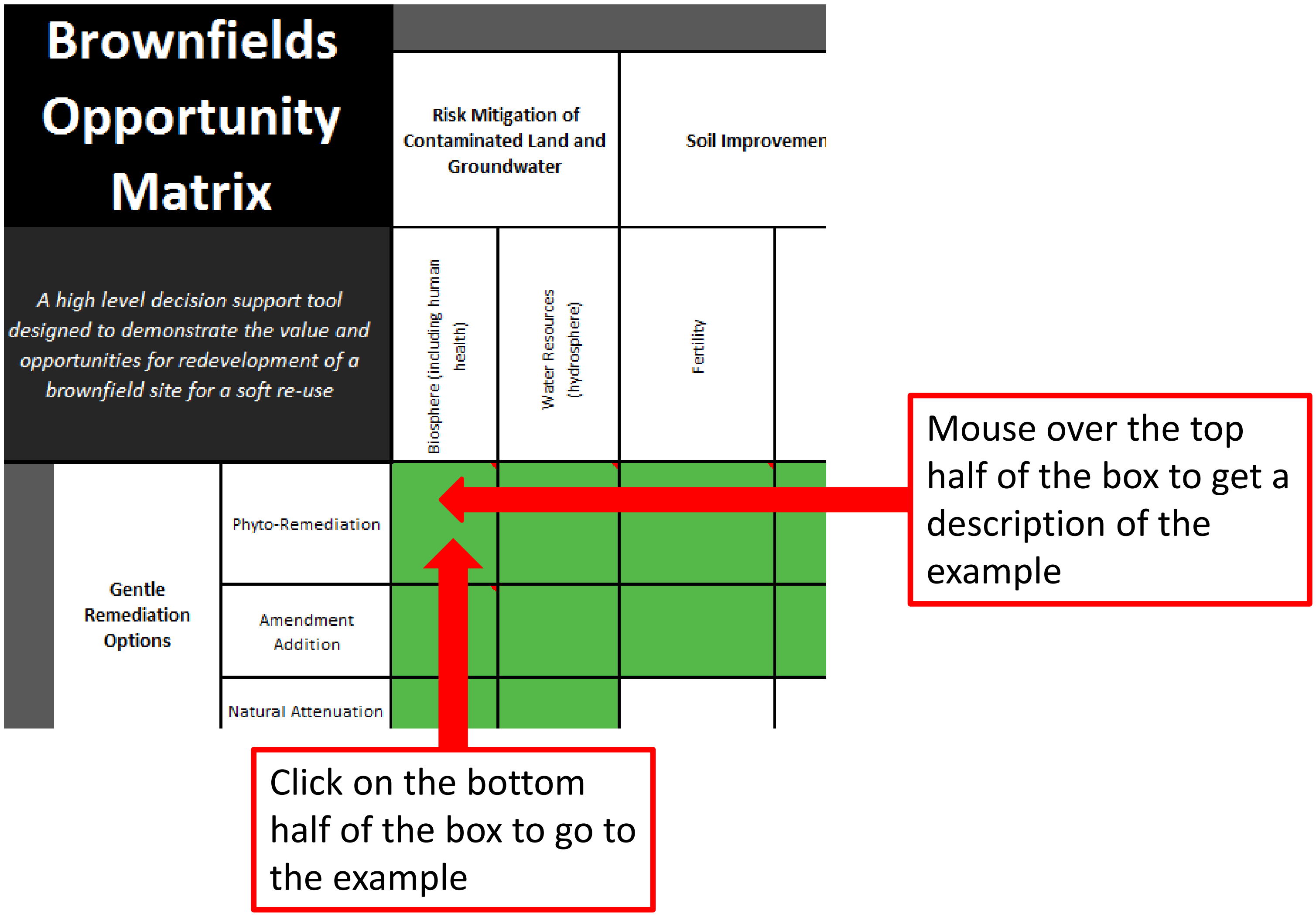
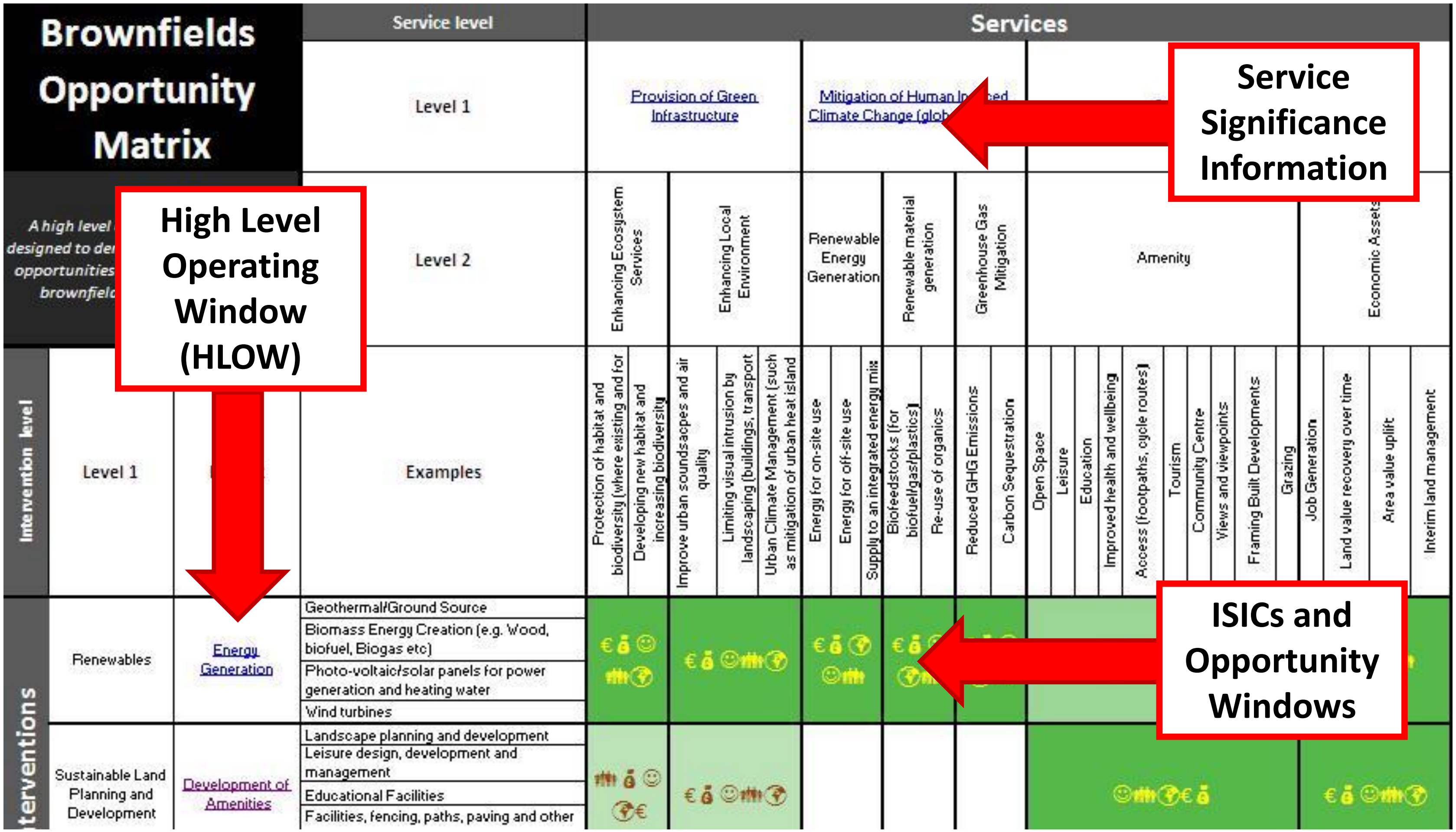
Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Simple format



Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Informational format



Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Sustainability assessment module (Onwubuya 2013)

Sustainability Elements	Source Parameters	Information Sources	Key Decisions
Environment	**Procedure 1** Use SURF framework and retrieve headline indicators	Procedure 1. SURF-UK: indicator descriptions	**Procedure 1** In order to establish and consider possible impacts that a remediation option (s) may have on the environment, a semi-quantitative assessment approach can be utilised in form of a Multi Criteria Analysis (MCA). Sustainability indicators (as detailed in the SURF indicator) should be identified using the information source (weblink) provided. The indicators to be considered can then be ranked in form of greater or lesser importance (e.g. 3 - High /2-Medium/1-Low weighting), and then scored (out of 5). A ranking order can then be established accordingly to show most suitable to least suitable technology.
	Procedure 2 Outline various parameters that may be considered in a typical LCA procedure. Information will be retrieved from source which will be highlighted in the 'information sources' column. Utilises EPA sponsored website LCAccess which provides abundance information regarding Life cycle inventory data sources. The primary focus of this source is on LCI databases and LCI data providers. Follow link provided in the 'information sources column	Procedure 2 http://www.epa.gov/nrmrl/std/lca/lca.html	**Procedure 2** This step can be considered in tandem with Procedure 1 or afterwards if additional information is deemed necessary. A more complicated LCA quantitative assessment can be carried out. An LCA inventory should be collated using any of the applicable sources outlined in the web address provided and full life cycle analysis carried out. This, however, is a resource hungry process and requires huge time investment . **Following the review of the indicators, all applicable indicators should be considered during DST selection.**

Similar produced for Economic and Social indicators – utilises SuRF sustainability indicators (semi-quantitative ranking system, Procedure 1) followed by web-links to more resource-hungry quantitative analysis (LCA etc for “Environment” and “Economic” indicators) as needed

Additional tools supporting Phase 2 (Exploratory stages / Confirmation)

Includes modules on:
Outline cost calculator (user-entered cost data – allows estimation of economic value proposition of GRO). Module "calibrated" using data from GREENLAND sites - used to test the cost calculator and give input examples

General Site Information		
Name of site		
Country		
Site type		
Site coordinates		
Distance to crop supplier		km
Distance to biomass processor		km
Size of site		m^2
	0	ha
Depth of contamination		m
Density soil		ton/m^3
Total weight per ha	0	ton
Discount rate	4	%

General contamination information		
Extraction (0) or stabilisation (1)?	1	
Define metal(s):		
Concentration in soil	1	
Concentration in solution		
Start:		
Start concentration		mg/kg soil
Contamination in soil	0	kg/ha
stabilisation for how long?	15	years

General Plant Information		
Plant used		
Rotation speed of crop	1	year
Remediated surface/plant		m^2/plant
	0	ha/plant
Kg of dry mass per harvest per ha		Kg DM/ha
Of which ...% is in		
Plant part 1	plant part 1	
% of total biomass plant part 1	100	
Plant part 2	plant part 2	
% of total biomass plant part 2		
Plant part 3	plant part 3	
% of total biomass plant part 3		
Plant part 4	plant part 4	
% of total biomass plant part 4		
Plant part 5	plant part 5	
% of total biomass plant part 5		
Extraction in mg/kg DM per harvest per part, only for extraction		
plant part 1		mg/kg DM
plant part 2		mg/kg DM
plant part 3		mg/kg DM
plant part 4		mg/kg DM
plant part 5		mg/kg DM

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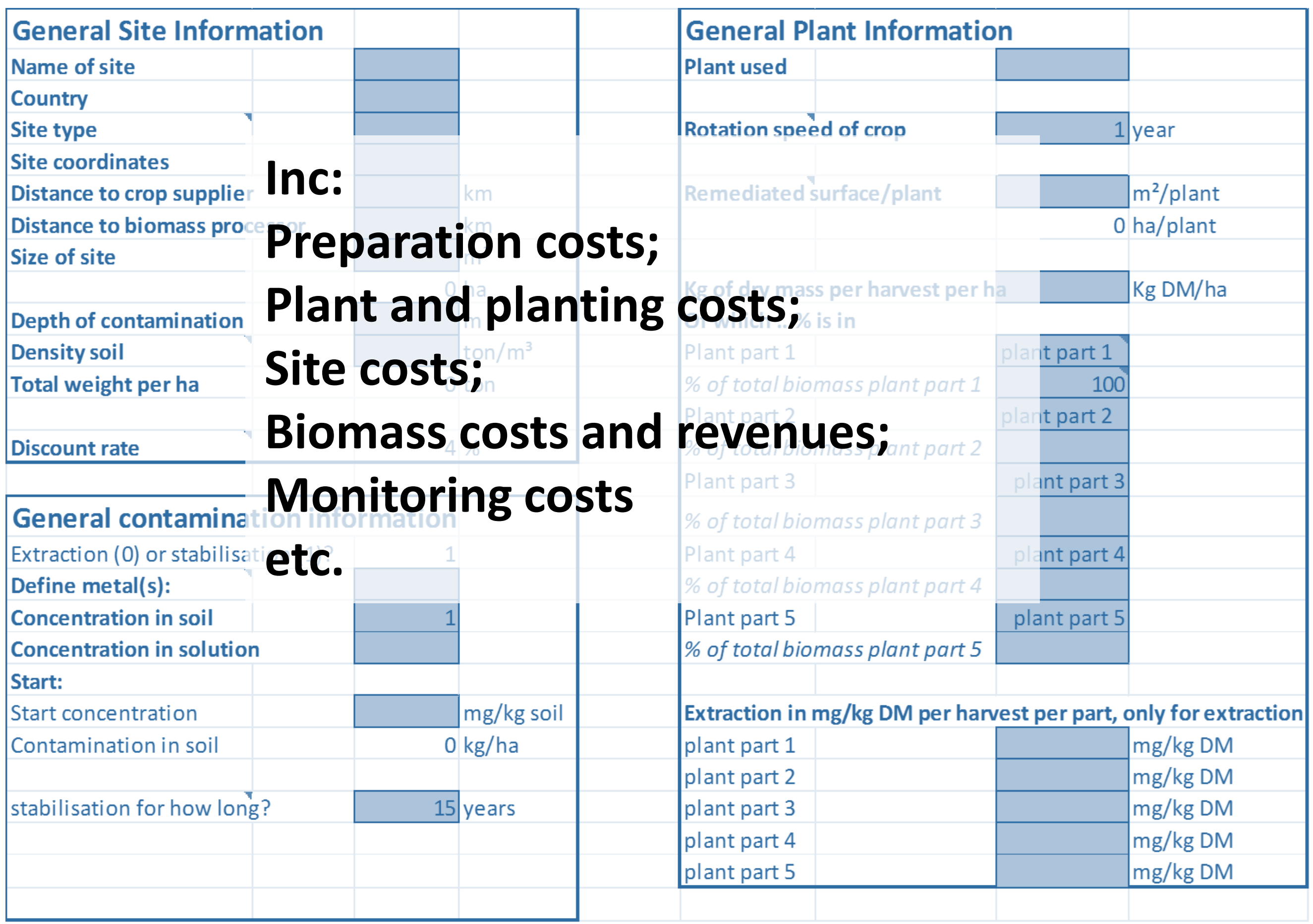

Inc:
Preparation costs;
Plant and planting costs;
Site costs;
Biomass costs and revenues;
Monitoring costs
etc.

Additional tools supporting Phase 3 (Design Stages)

Detailed operating windows *(optimal soil, pH, depth of contamination etc)*

For each category, choose only 1 of the 3 options by writing "Yes". Examples are shown

What is the typical soil pH range at your site?	pH
5 - 8	yes
4 - 5 / 8 - 9	
2 - 4 / 9 - 11	

What is the relative diversity and density of current plant species present on your site?	Plant Community
Diversity and density of plant species are similar to surrounding areas (on non-contaminated soil)	yes
Diversity and density of plant species is visibly less/different to surroundings (non-contaminated soil)	
No plant species are growing on the contaminated site	

What is the overall climate of the region in which your site is located?	Climate
Arid	
Semi-Arid	
Humid/Temperate	yes

What is the typical soil type / composition on your site?	Soil Type
Clay	
Loam	
Sand	yes

What is the typical soil depth to which contaminants of concern are present?	Depth of contamination
Top Soil (0-30 cm)	
Sub Soil (30-90 cm)	
Deep Soil (> 90 cm)	yes

Recommendation

Expert advice and plant toxicity tests are recommended

Additional tools supporting Phase 3 (Design Stages)

Technical datasets *(cultivars and amendments, safe biomass use, indicators of success and methods, stakeholder engagement guidance)* and design / implementation guidance

GREENLAND: FP7-KBBE-266124

Appendix 6: Stakeholder engagement guidelines for application of "gentle" remediation approaches (GROs).

Introduction

Definitions and key concepts

Stakeholder engagement is a broad inclusive and continuous process between a project and those potentially affected by it. The World Bank (2012) describes the aims of stakeholder engagement as building up and maintaining an open and constructive relationship with stakeholders and thereby facilitating a project's management of its operations, including its environmental and social effects and risks. Effective stakeholder engagement is also seen as reducing key remediation project risks, for example failure to gain acceptance and delays due to antagonistic relationships; and also as means of reducing project management costs and timescale (RESCUE 2005; REVIT 2007).

Need for stakeholder engagement when applying GRO.

Stakeholder involvement has been identified as a key requirement for the optimal application of sustainable remediation strategies (CL:AIRE, 2011), and in site regeneration more widely (REVIT, 2007; RESCUE, 2005). Effective and sustained stakeholder engagement is critical to the acceptance of GROs, particularly for larger

A practical, usable tool to interface with existing DSTs (e.g. HOMBRE) and national guidance.......

Aims to communicate the potential wider benefits and risk management capabilities of GRO, supported by information on large-scale examples of successful GRO application, presented in a robust and non-technical way

The guidance can be used to support site planning, options appraisal, stakeholder engagement and consideration of initial design scenarios, and wider education of the potential risk management capacity and economic, environmental and societal benefits of GROs.

Available at: www.greenland-project.eu

Concluding thoughts

The GREENLAND guidance promotes a refocus from phytoremediation to wider phyto-management-based approaches which place realisation of wider benefits at the core of site design, and where gentle remediation technologies can be applied as part of integrated, mixed, site risk management solutions or as part of “holding strategies” for vacant sites.

Combination of GROs with renewables, for biomass generation but also with technologies such as wind and solar power, can provide a range of economic and other benefits, and potentially support the return of low-level contaminated sites to productive usage.

Combining GROs with urban design and landscape architecture, and integrating GRO strategies with sustainable urban drainage systems and community gardens/parkland (particularly for health and leisure benefits), has large potential for triggering GRO application and in realising wider benefits in urban and suburban systems.

Quantifying these wider benefits and value (above standard economic returns) will be important in leveraging funding for GRO application and soft site end-use more widely at vacant or underutilized sites.

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http://thelandtrust.org.uk/space/port-sunlight-river-park/

THANKYOU

ANY QUESTIONS?

Key references:

Cundy A.B., R.P.Bardos, M.Puschenreiter, M.Mench, V.Bert, W.Friesl-Hanl, I.Mueller, X.N.Li, N.Weyens, N.Witters, and J.Vangronsveld (2016) Brownfields to green fields: Realising wider benefits from practical contaminant phytomanagement strategies. Journal of Environmental Management, 184, 67-77.

GREENLAND project outputs, including Decision support and case studies on gentle remediation can be found at: http://www.greenland-project.eu

HOMBRE project information: www.zerobrownfields.eu

Brownfield Navigator: http://bfn.deltares.nl