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Article

A Framework for Upgrading Contaminated Urban Land and Soil by Nature-Based Solutions: Demonstration with a Swedish Case

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Abstract: To move towards a circular economy and to meet the upcoming EU soil health legislation, both contaminated land and contaminated soil should be acknowledged as fragile and valuable resources to be restored and recycled to provide essential ecosystem services to humans. Underused, often contaminated land can be returned to beneficial use as urban greenspace (UGS) with the help of gentle remediation options (GROs). GROs are plant-, fungi-, bacteria-, and soil amendments-based risk management mechanisms that can also simultaneously improve soil functions and the provision of ecosystem services. This study (i) presents a framework including tools and methods for exploring opportunities for transforming brownfields to UGS using GROs to deal with soil contamination, (ii) demonstrates its application for a case study site in Gothenburg, Sweden, and (iii) presents stakeholders' views on the suggested framework. This framework can support the transition of brownfields to UGS while recycling both land and soil and increasing the market value of the site and its surroundings. Stakeholders found the suggested framework useful but identified some challenges for its practical implementation, mainly associated with financial aspects and the existing practice and level of knowledge. Stakeholders also identified the need for additional practical tools to (a) make predictions about the time required for GROs to reach acceptable risk levels, (b) monetize non-market benefits such as ecosystem services for communicating benefits to decision-makers, and (c) provide support for plant and soil amendment selection for various GROs and contaminants.

Keywords: brownfield; urban greenspace; gentle remediation options; circular land use

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1. Introduction

1.1. Background

Land, referring to the Earth's surface, and soils, as the natural resource underneath, are limited and fragile resources that are crucial for both humans and ecosystems [1–4]. In circular economy (CE) thinking, the waste of these limited and valuable resources must be minimized, and their circular use must be prioritized [1,2,4,5]. Policy incentives such as the proposed EU soil monitoring law [6], the EU Soil Strategy for 2030 [4], and the EU policy "No net land take by 2050" [7] aim to enforce such a circular perspective for soil and land and, thus, set a goal to eliminate exploitation of greenfields, i.e., previously unutilized land. However, the process of bringing previously utilized but presently obsolete land (i.e., brownfields) back into use is unfortunately extensive, expensive, and often complicated by the potential pollution from the previous on-site activities [8,9]. The prospect of a higher market value of the reclaimed land often drives the redevelopment of brownfields for residential, commercial, or industrial uses [10], rather than opting for softer uses such as urban greenspace (UGS). Although UGS provides a variety of ecosystem services [2,11,12], this type of land use may be less attractive to developers, as the current market valuation does not fully reflect all of the benefits provided by greenspaces.

Nevertheless, the demand for greenspaces in cities is growing, especially after the COVID-19 pandemic-related increase in use [13]. Retrofitting brownfields with greenspaces was common even before the pandemic, and in the UK, for example, over 19% of brownfields were transformed into greenspaces from 1988 to 1993 [10].

A healthy soil is not only a prerequisite for the maintenance of a UGS but can also be considered alive [6,14], as it sustains all terrestrial plant and animal life [15]. Well-functioning soils are fundamental to the provision of essential ecosystem services such as biomass provision, supporting biodiversity, storing and regulating water flows, recycling of wastes, and climate change mitigation [16–19]. Ensuring healthy, living soils is crucial for achieving the UN Sustainable Development Goals (SDGs), such as climate neutrality, biodiversity restoration, zero pollution, healthy and sustainable food systems, and a resilient environment [4]. The restoration of degraded soils and their circular use are important components of the EU Soil Strategy for 2030 [4], which paves the way for the soil monitoring law [6].

Gentle remediation options (GROs) are in situ plant- (phyto-), fungi- (myco-), bacteria-, and soil amendments-based remediation measures that both reduce the risks posed by contaminants to the environment and human health and, at the same time, restore degraded soils to a healthy state by improving their ecological functions and increasing the provision of ecosystem services [20–22]. The increased market value of land at the site and in the surrounding area is another significant benefit resulting from remediation measures in general [23,24]. Nature-based solutions (NBSs) are "actions that are inspired by, supported by, or copied from nature, designed to address a range of environmental challenges" [25]. As Alshehri et al. [26] suggested, NBSs provide the best trade-offs between managing contamination risks and the economic costs of remediation by providing environmental, social, and economic benefits and contributing to building resilience. GROs can consequently be seen as a subset of NBSs, although only some of them, i.e., phytoremediation and soil amendment technologies, are mentioned in the review of NBSs by Song et al. [27].

GROs have proven to be feasible for risk management on large sites with elevated levels of both organic and inorganic contaminants [20,21]. Rhizo- and phytodegradation of organic pollutants in soils has been shown to be effective and, under the right circumstances, can be fairly quick [28–30]. Phytostabilization and/or immobilization with soil amendments and, to some extent, phytoextraction have also been demonstrated to reduce the risks posed by organics and inorganics in the soil [28,31,32]. Certain herbaceous and grass species have been shown to either effectively extract—i.e., take up significant concentrations of organics in their biomass—or degrade them by fostering microbes that are beneficial for organic contaminants' degradation [30,33–35]. A drawback of phytoextraction of inorganic substances (and degradation of some persistent organic substances) is the long time required for contamination sources' removal [36,37]. Phytostabilization and immobilization of both organic and inorganic pollutants in the soil with amendments and plants, on the other hand, are rapid and effective GROs that make the soil risk-free for many land uses, albeit not pollutant-free [21].

When transforming brownfields to UGS, there is an opportunity to combine green land use with GROs to manage risks to human health and the environment [2,27,38,39]. Such a combination can ensure a circular use of both land and soil. However, in Europe and beyond, subsurface aspects in general, including contamination, are rarely considered in spatial planning processes until the implementation phase is reached [40–43]. The lack of consideration of subsurface issues in planning hinders the identification, assessment, selection, and realization of opportunities for such synergy, as these opportunities are only available if they are considered in the early planning phase [42,43]. If the development plan does not accommodate GROs in the early planning phase, conversion of a brownfield to UGS may favor short-term solutions such as excavation and disposal, and may result in a missed opportunity to undertake long-term nature-based measures. In this paper, we propose, exemplify, and examine a novel conceptual framework based on a set of previously developed tools and methods for exploring the opportunities of combining GROs with different types of UGS to sustainably manage the risk of soil contamination, improve soil functions and ecosystem services, and increase the market value of land.

1.2. Aim and Objectives

The aim of this study is to introduce, exemplify, and examine a proposed framework for exploring the opportunities of transforming brownfields to UGS with the help of GROs that manage risks posed by soil contamination. The specific objectives are as follows: (i) to introduce and explain the suggested framework, (ii) demonstrate the framework and the supporting tools and methods developed using a study site in Gothenburg, Sweden, and (iii) explore the challenges and possibilities for implementing such a framework in practice together with stakeholders.

2. Methodology

2.1. Framework Development and Supporting Tools and Methods

The framework development was based on a conceptualization of relevant concepts (circular land and soil use, sustainable remediation, UGS, GROs) in the existing literature offering a justification for the framework. The developed conceptualizations and the resulting framework are presented in the Results section. In order to facilitate the application of the proposed framework, the authors have compiled a comprehensive set of tools and methods developed in their previous research [21,44,45] and earlier studies [46]. These resources are listed below in the order of their intended utilization in the framework, along with brief descriptions of each.

2.1.1. The Bio-Based Land-Use Matrix

The bio-based land-use matrix was developed as part of the bio-based land-use framework presented by Chowdhury et al. [44] and further developed by Chowdhury [2]. The matrix supports the identification of various UGSs that can potentially be developed at a given site, based on a set of preconditions and basic conditions for the site. By defining the site's conditions, the matrix filters out impossible UGSs for the site from a list of 15 UGS types that were generally found to be relevant for brownfield redevelopment. It is used to provide a broad selection of possible UGSs for the site given minimal information at hand.

2.1.2. Methods for Stakeholder Analysis

To manage the differences in opinions, preferences, and resources of the stakeholders, whose involvement is essential to support an effective implementation of UGS on brownfields, a series of methods were developed by Chowdhury et al. [45] to (i) identify and categorize relevant stakeholders, (ii) highlight their preferences for UGS, (iii) map their resources and the challenges associated with the site, and (iv) match these challenges with the mapped resources over the timeline of a site's development as UGS.

2.1.3. Time-Intervention Diagram for UGS Development

As a component of the bio-based land use framework [44], a diagram was created to illustrate a timeline in terms of the time needed to realize a particular UGS and the interventions required to achieve this goal. In the time-intervention diagram, the 15 types of UGS as defined in the bio-based land use matrix, are arranged along a diagonal line representing a relationship between the required scale of intervention and the realization time of UGS. This tool thus introduces a temporal aspect to the planning and design of a site by sorting the UGS based on the time required for their realization and can support a better understanding and communication regarding time-intervention requirements for the feasible UGS at a site.

2.1.4. The SEPA Soil Guideline Value Model

The Swedish Environmental Protection Agency's guideline value model [46,47] is a model used in Sweden to determine safe levels of contaminants based on land use scenarios.

It is the basis for deriving the Swedish generic soil guideline values (These types of values are common in several countries and derived based on the same type of generic models, but typically differ somewhat due to different national assumptions regarding human exposure, acceptable risks, site conditions etc. [48]. Soil guideline values can be referred to as e.g., soil screening values or soil clean-up standards) for sensitive land use and less sensitive land use and indicates whether a detailed soil investigation and risk assessment is required at a site [46,47]. The SEPA model is used to derive site-specific soil guideline values and to identify the predominant risk, i.e., risks to human health or ecosystems, along with the most important human health exposure pathways. This information provides input to the GRO framework presented in the next section.

2.1.5. The GRO Framework

The GRO framework [21] was developed to support (i) communication about the different types of risk-reducing mechanisms GROs can provide (generic version), and (ii) identification of suitable GROs for specific sites (site-specific version). The site-specific version functions as a tool to demonstrate the range of possible applications of GROs for effective risk management that can be customized to fit different UGS. Each GROs would need further investigations, but the GRO framework supports early consideration of each option in the redevelopment of a site.

2.1.6. UGS & GRO Interventions over Time

The originally developed visualization of UGS and GROs intervention over time of the bio-based land use framework [2] is adapted in this study to visualize and communicate linkages between GROs application and UGS development over time for the study site.

2.2. Polstjärnegatan Case

The framework was applied and demonstrated using the case of Polstjärnegatan. The Polstjärnegatan site is located within the Lindholmen district in Gothenburg (Sweden). It is about 14,800 m^2 and part of a larger urban landscape undergoing rapid transformation (projected 2017–2028) in accordance with the detailed plan for large-scale development of housing and commercial facilities in the Karlastaden area (Figure 1, top). This site is currently surrounded by roads and a railway on all sides: Polstjärnegatan Street to the south, Karlavagnsgatan Street to the east, a petrol station and a fast-food restaurant to the west, and a railway along the Hamnbanan Road as well as a motorway (Lundbyleden) to the north (see Figure 1, top). In the detailed plan [49], the future land use of the study site is a park area designed to manage surface water runoff, with new roads being constructed around its perimeter. Due to the presence of the Hamnbanan Road, the north part of the site is in the risk zone associated with traffic with dangerous goods [49], whereas infrastructure is planned to reduce these risks. The park area in the northern part is planned to be designed without facilities that can encourage crowds to stay for a longer period of time [49].

Historically, most of the site has previously been used as a yard with loading and unloading operations for coal products, forming part of the Sannegårdshamnen harbor and its shipyard. The shipyard was in operation from the early 1900s to the 1980s–1990s. After the shipyard was closed, the site was turned into a golf course, with sludge brought in from Ryaverket (a sewage treatment plant) to model the surface. The golf course was closed in the early 2000s, and since then the site has remained unused. As the access to this abandoned site has not in any way been restricted, it has been subject to unauthorized use, e.g., illegal cable burning and metal reclamation at several places.

The previous use of the site has led to soil pollution. The results of the risk assessment indicate that there are several small hotspots from the illegal cable burning with high contamination levels, while lower but still elevated contamination levels are found in the rest of the area, primarily in the upper soil layer of 0–0.7 m [50]. The contaminants detected at the site are metal(loid)s (As, Cu, Pb, and Zn), petroleum products (primarily high-molecular-weight polycyclic aromatic hydrocarbons (PAH-H)), and persistent organic pollutants (polychlorinated biphenyls (PCBs), specifically PCB-7, i.e., 7 selected indicator PCBs (see Figure 1, bottom). There are two hotspots with metal concentration levels corresponding to Swedish criteria for hazardous waste, mainly due to illegal cable burnings at the site (Figure 1) [50]. However, the investigations also indicate that the rest of the site only has elevated levels of contamination in topsoil (Figure 1), which offers a possibility for GROs as an alternative to soil excavation and disposal.

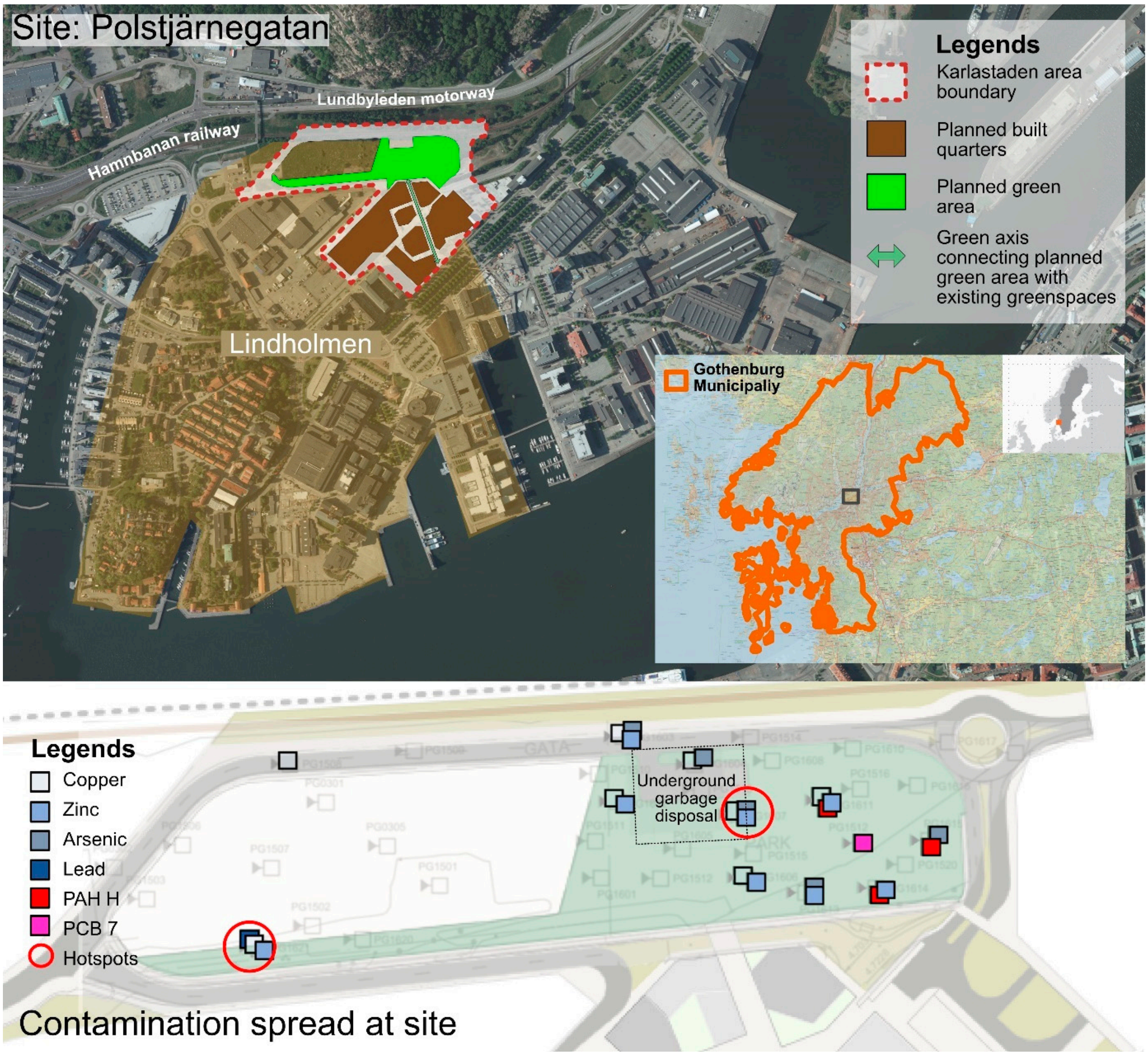

Figure 1. Top: Location map integrated with the concept plan of the Karlastaden development project, with the site area highlighted (Karlastaden plan redrawn from Göteborg stad [49] base map and orthophoto ©Lantmäteriet (https://www.lantmateriet.se/en/maps/, accessed on 20 February 2020), used under Creative Commons License CC BY 4.0). Bottom: Spread of contamination across the site based on the SWECO report [50]. The hotspots are circled in red. The grey square marks a future planned underground waste disposal construction.

2.3. Investigating Challenges and Possibilities with Stakeholders

The challenges and possibilities of implementing the framework in practice were explored with stakeholders in a workshop using a SWOT (Strength, Weakness, Opportunity, and Threat) analysis. Stakeholders were consulted to (i) investigate challenges and possibilities for implementing the suggested framework with the supporting tools and methods in practice, and (ii) to discuss how the framework could be improved to facilitate its practical application. Stakeholders were selected based on the outcome of the survey carried out by Chowdhury et al. [45], where relevant departments from the city of Gothenburg, as well as a municipal urban development company, were identified. In addition, landscape architects were considered as important experts in the design of greenspaces and were included in the selection. These stakeholders were contacted through a formal personalized e-mail invitation. Six out of eleven contacted organizations returned positive responses and participated in the workshop. The persons accepting the invitation represented the following organizations and roles:

- The city of Gothenburg
  - Two representatives from the Real Estate Office: one with the role of managing investigations and potential remediation of contaminated sites for which the Real Estate Office is responsible, with expertise in contaminated sites, and one with a strategic role concerning the long-term management and planning of land development.
  - One representative from the Environmental Department, working strategically with environmental and green aspects in urban development, with expertise in biodiversity, ecosystem services, and green infrastructure.
  - One representative from the Recycling and Water Office, responsible for handling storm water, and with a specific interest in nature-based solutions such as rain gardens and bioswales.
- A municipal urban development company active close to the site
  - One project leader with financial responsibility for real estate development projects, with an architectural background.
- A small landscape architect consultant company with a special interest in slow and gentle urban development
  - One landscape architect, with a special interest in phytoremediation technologies.

A three-hour workshop was held on 13 June 2022, in Gothenburg, at Chalmers University of Technology. The workshop was bilingual (Swedish and English), with everyone speaking the language they felt most comfortable with and participants helping with translation when needed. The workshop agenda included the following main parts: (1) a short background to the research work and the purpose of the workshop; (2) one time slot for a presentation of the proposed framework, using the Polstjärnegatan site for demonstration of its application; and (3) two time slots for discussion in groups, followed by reporting back the main discussion points to the whole group.

The SWOT (Strength, Weakness, Opportunity, and Threat) analysis method [51] was used to facilitate stakeholders' discussion in groups during the workshop. A large A0 SWOT table (3 $\times$ 3 cells) was printed out and hung on the wall at the workshop venue (Table 1). Supporting questions (in Swedish) were formulated for all cells in the SWOT table to guide the discussions. In the first part of the discussion, each group of participants discussed the strengths and weaknesses of the proposed framework and the opportunities and threats for its practical application. In the second part of the discussion, each group of participants discussed the strategies for (i) taking advantage of the identified opportunities through identified strengths, (ii) taking advantage of the identified opportunities to minimize the identified weaknesses, (iii) counteracting the threats through the strengths, and (iv) counteracting the threats through the weaknesses. During the discussion, the participants were asked to place sticky notes with their comments in the corresponding cells of the SWOT table.

After the workshop, all documentation was collected, translated to English by the authors, and digitized. Miro's web platform (https://miro.com, accessed on 20 February 2020, San Francisco, USA, and Amsterdam, NE) was used to process and analyze the comments left by the participants on the SWOT table. Based on the input during the workshop, the suggested framework was improved and updated (see Section 3.1).

Table 1. The SWOT table used during the workshop with stakeholders, translated from Swedish to English.

Overall aim: To achieve a greener city by more sustainable and circular management of brownfields by integrating nature-based solutions in the early-stage planning process	**External** (legal, financial, political etc.)	**Helpful**	**Harmful**
Internal (the suggested framework)		Opportunities 1. What can support the proposed framework: existing policies, legislation, practices, political visions, trends, economic considerations, etc.? 2. What can the proposed framework contribute with?	Threats 1. What are the challenges today in being able to apply the proposed framework: existing policies, legislation, practices, political visions, trends, economic considerations, etc.?
Helpful	Strengths 1. What are the strengths of the proposed framework? 2. What are the most important components?	*Strategies to take advantage of opportunities through strengths:* What can the proposed framework contribute to today's way of working?	*Strategies to counteract threats through strengths:* How can the proposed framework change today's way of working?
Harmful	Weaknesses 1. What are the weaknesses of the proposed framework? 2. Which components or parts do you think are the weakest?	*Strategies to take advantage of opportunities to minimize weaknesses:* What can be improved in the proposed framework?	*Strategies to counteract strengthening threats through weaknesses:* Which of today's challenges are not captured in the proposed framework? What challenges have not been discussed in today's workshop?

3. Results

3.1. Conceptualization and the Suggested Framework

The EU Soil Strategy for 2030 [4] calls for (1) prioritizing recycling or some other form of recovery of contaminated land and soil rather than landfilling, and (2) detoxifying and restoring soils whenever possible at reasonable costs.

In the context of CE [52] and linear economy, soil and land use can be conceptualized in three scenarios (Figure 2): In Scenario 1, the "linear" land and soil use implies that land and soil are abandoned and form unrecycled waste, whereas "greenfields" are instead used for development. Scenario 2 (Figure 2) depicts a common situation where the land is being recycled but the soil is still treated as waste, being dumped and replaced by virgin materials. Such non-circular treatment of the soil may result in an immense loss of ecosystem services that the soils might supply if detoxified and restored. In Scenario 3 (Figure 2), not only are brownfields repurposed for new uses, but contaminated soils are also regarded as valuable resources and recycled.

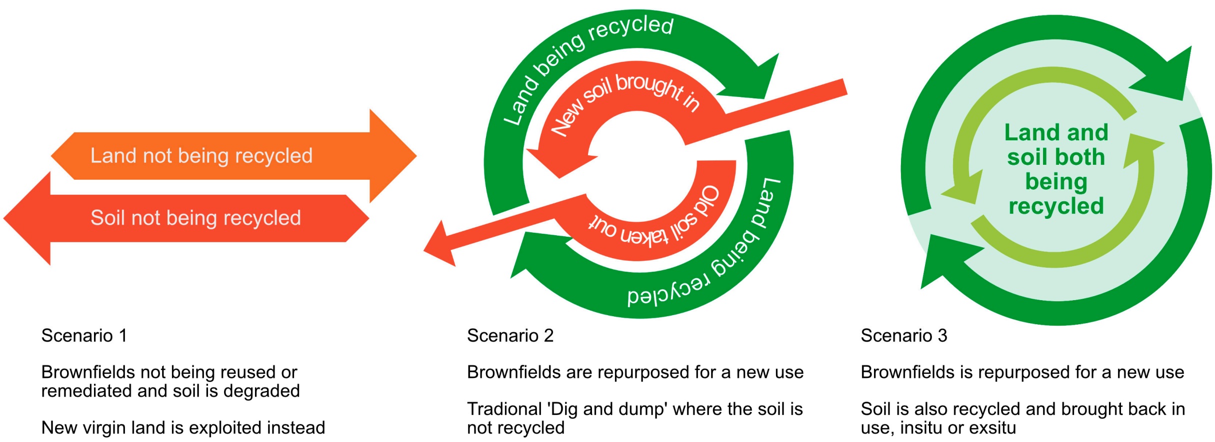

Figure 2. Conceptualizing brownfields in linear vs. circular soil and land management.

The contaminated soil can be repurposed in two ways: ex situ, where soil is excavated and treated on-site or off-site before being safely reused for other purposes (e.g., construction), and in situ, where soil is treated using remediation technologies in situ.

Traditional remediation measures, however, often focus on meeting the safe contaminant concentration targets in soils rather than restoring soil health. In contrast, GROs can offer an overall sustainable low-input in situ remediation alternative, e.g., no fossil fuels for excavation and transport, fewer soil resources for backfilling, less air emission and waste generation, and significantly lower remediation costs compared to traditional excavation and disposal methods [53]. Although GRO strategies are time-consuming and require regular maintenance, in combination with appropriate UGSs, they have the potential to return contaminated sites to use much earlier, as they can provide multiple benefits in the form of ecosystem services during ongoing remediation. In addition, the remedial action itself, in combination with UGS, may increase the market value of land on the site and in the surrounding area.

The proposed framework for upgrading contaminated urban land and soil in Sweden is presented in two ways: as a conceptualization (Figure 3), and as a schematic diagram (Figure 4). Notably, this framework can be generalized for application in other countries. Conceptually, the proposed framework suggests brownfield redevelopment based on two main principles: (1) *space*—at the surface level, the site is repurposed for use as greenspace, while at the subsurface level, contamination risk is managed and soil health is improved; and (2) *time*—the changes at the surface and subsurface levels occur incrementally over time (Figure 3). The transition of a brownfield is conceptualized to take place in three successive phases: (1) abandonment and underuse, i.e., becoming a brownfield; (2) temporary use as greenspace; and (3) long-term use as greenspace. This sequence may be repeated several times in a land-use cycle. The temporal use combines UGS and GROs to simultaneously remediate the site, improve soil function and ecosystem services, and increase the land value on the site and in the surrounding area. The gradual reduction in risk over time allows for more user-intensive and more sensitive UGS, which is associated with stricter safety requirements.

The schematic diagram (Figure 4) outlines the types of assessments suggested and the tools and methods that can support an exploration of a site's potential. Some tools and methods support an investigation of the UGS potential at the site, while others support the investigation of the GRO potential at the site. In combination, they can support the process of exploring the opportunities for creating a GRO-integrated UGS design at a site for one or more temporary land uses towards more long-term land use. During the temporary phases of land use at the site, it is recommended to regularly monitor (1) the soil with respect to GROs' performance in mitigating risks and improving soil health, (2) the ecosystem services, and (3) the needs and preferences of site users. If monitoring indicates that changes in risk management are needed to achieve the long-term strategy, or that a new land use is required, this information will inform the development of a new UGS design with integrated GROs that better meets the needs of the users, while at the same time managing risks.

The exploration part of the framework precedes a GRO-integrated UGS design and contains three main parts: (1) an investigation of the UGS potential of the site, (2) an investigation of the GRO potential at the site, and (3) the combination of GROs and UGS over time.

As a first step for investigating the UGS potential, the bio-based land-use matrix [2] (Section 2.1.1) can be used to screen potential UGS with minimal information on the physical properties or contamination situation at the site. The potential UGS options can be further analyzed by investigating stakeholder preferences [45] (see Section 2.1.2). Finally, the time–intervention diagram [2] (see Section 2.1.3) can be used to better understand and communicate the timeline for the identified potential UGS.

To analyze the GRO potential in the Swedish context, soil guideline values for the identified potential UGS can be derived using the SEPA risk assessment model [46,47] (see Section 2.1.4). Such a risk assessment model provides information on the nature of the risk situation (human health or ecological receptors, dominating exposure pathways for humans) and can be combined with soil contamination data from the site to calculate risk quotients [21]. The GRO framework [21] (see Section 2.1.5) can then be used to support the identification of potential GRO measures to manage contamination risks.

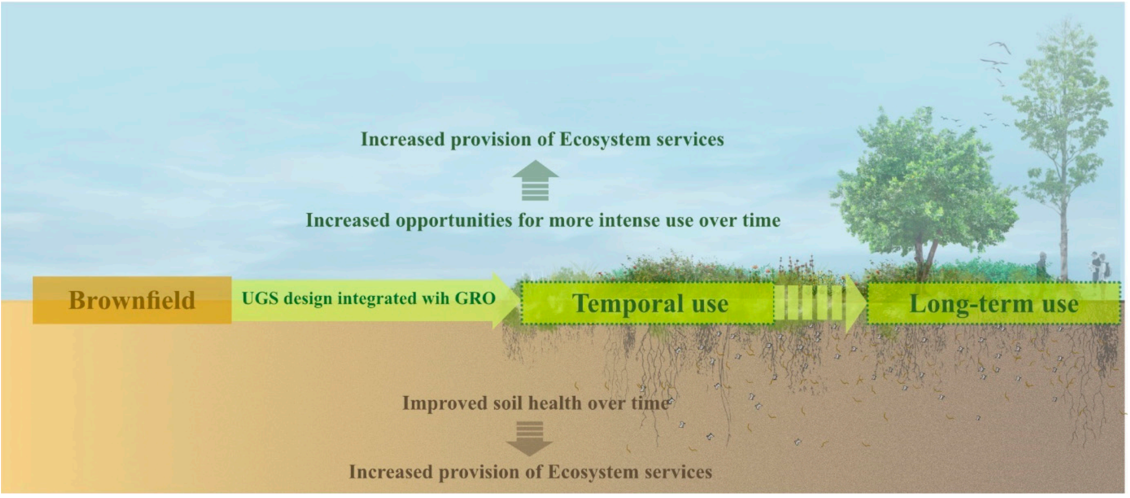

Figure 3. Conceptualization of the regeneration of brownfields over time using a combination of UGS and GROs.

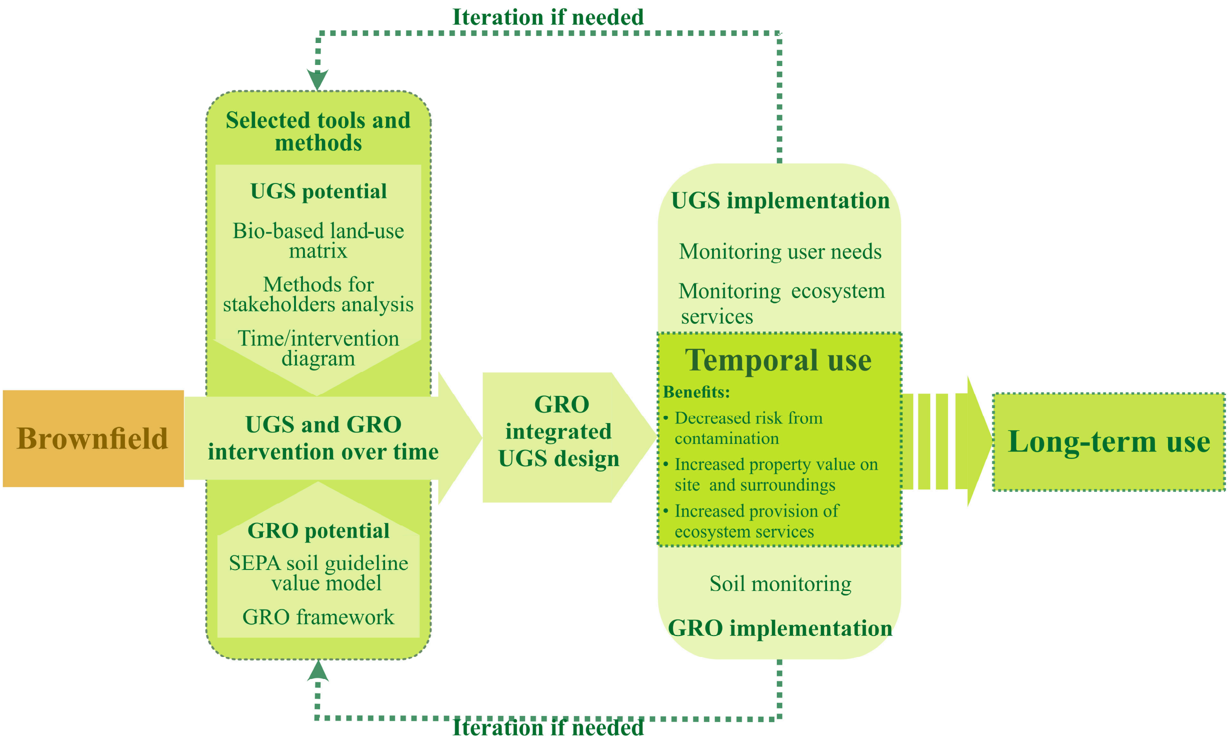

Figure 4. Schematic diagram of the suggested framework: Suggested tools and methods for the exploration of the site's potential are listed. The implementation of a UGS combined with GROs suggests monitoring to follow up on progress and potential changes. Dotted arrows indicate the possibility for iterations if needed, should conditions or user needs change over time.

The results of the previous steps provide insight into how potential development occurs over time, along with a visualization of GRO and UGS interventions over time (adapted and updated from Chowdhury et al. [44]). Section 2.1.6 ties the output of the other tools together and helps to illustrate and communicate this potential development of the site over time. The final design of the GRO-integrated UGS on the site needs to be carried out with experts on GROs together with landscape architects, and preferably also including experts responsible for the maintenance of the site.

This framework is most useful when a planning and design process is initiated early, before formal detailed plans are made, and when there is still sufficient time for GRO implementation. It is intended to support dialogue between planners, real estate developers and economic experts, remediation experts, landscape architects, experts in biodiversity and green infrastructure, and experts in greenspace maintenance to explore the possibilities of combining UGS and GROs on a particular site.

3.2. Demonstration of the Framework's Application

The Polstjärnegatan site was selected as an example to demonstrate the application of the suggested framework for exploring the possibilities of upgrading the land and soil though gentle remediation options and establishing greenspaces. For a comprehensive report detailing the sequential application of all of the tools and methods of this framework for the study site, the reader is directed to the Supplementary Materials (SM). The primary objective of Section 3.2 is to provide a concise summary of these findings, which are spread across the authors' earlier publications, while being compiled, structured, and enriched in this study in a coherent manner.

3.2.1. Investigation of the UGS Potential

The bio-based land-use matrix: Chowdhury et al. [44] elaborated on the application of the bio-based land-use matrix on the study site to identify the potential UGSs. The site fulfils the criteria for eleven UGSs: (1) bioswale; (2) urban park, (3) neighborhood greenspace, (4) allotments, (5) community gardens, (6) grassland, (7) meadow orchard, (8) biofuel production, (9) horticulture, (10) shrubland, and (11) spontaneous vegetation.

Stakeholder analysis: Chowdhury et al. [45] demonstrated the following methods for stakeholder analysis: identification and categorization of stakeholders, identification of their preferences for UGS and their resources (*money*, *knowledge*, *time*), and identification of challenges related to *governance*, *land*, *finance*, *design*, and *sustainability* for realizing preferred UGSs at the Polstjärnegatan site. The municipal government plays a strong role in site development: the Parks and Nature Administration, the Recycling and Water Office, the Environmental Administration, the City Planning Authority, and the Real Estate Office, along with a municipal urban development company. The three most preferred UGSs according to the stakeholders' order of preference were as follows: (1) urban park, (2) bioswale, and (3) community garden, but the stakeholders also wished that the site should offer a variety of functions and activities. Financial support is mainly expected to come from the landowner of the site (the Real Estate Office). The other relevant municipal departments (as well as the municipal company) would contribute with *knowledge* (planning and project management, maintenance of the completed park, etc.) and *time* (human resources in the form of working hours). The local residents suggested their contribution of time as their available resource for using the future greenspace. Examples of challenges identified for realizing the three top-ranked UGSs at Polstjärnegatan include the following: (i) coordinating the planning process and ensuring maintenance (*governance*), (ii) the derelict site conditions and the railway and high-traffic motorway that border the site (*land*), (iii) general lack of financial resources to develop greenspaces (*finance*), (iv) the nearby high-rise buildings and associated shadow and technical design of bioswales (*design*), and (v) risk associated with land uses with more immediate profit, e.g., car parking (*sustainability*).

The time–intervention diagram: For illustrative purposes, all 11 identified feasible UGSs from the bio-based land-use matrix, along with the requirements that need fulfilment to realize them, are highlighted using the time–intervention diagram (Figure 5). The diagram plots each UGS based on the time and the extent of intervention (i.e., resources) required to realize them, helping to understand the prospective permanency of the UGSs based on that. Grassland and shrubland would potentially require less time and interventions to be realized on the site than an urban park or bioswale. If constructed vertically, allotments could potentially be realized in less time than the urban park, but they would require more interventions to ensure acceptable risks to human health and safety due to soil contamination. Biofuel production is expected to require the most time and intervention among the possible UGSs on the site, as it would be necessary to ensure a setup for the biomass to be sold for the production of biofuel. Spontaneous vegetation, on the other hand, is the present UGS on the site and would require no time to realize and minimal maintenance to move forward.

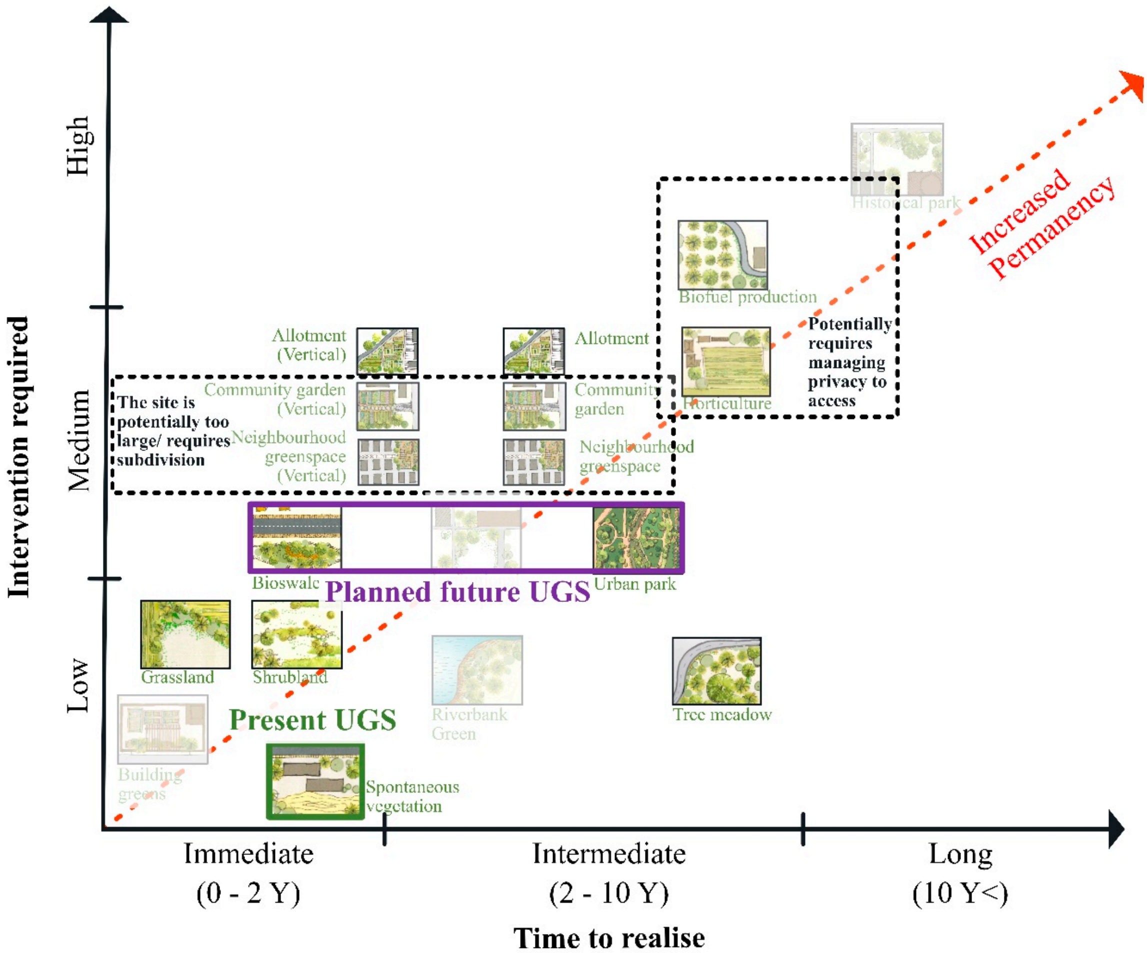

Figure 5. The time–intervention diagram [2] applied to the Polstjärnegatan site in this study.

3.2.2. Investigation of the GRO Potential

The SEPA soil guideline value model: The Swedish guideline value model [46,47] was used in this study to determine soil guideline values (SGVs) for the three top-ranked UGSs at the site (Section 3.2.1). The resulting soil guideline values for these UGSs were calculated to provide input to the GRO framework (see Table 2). For input to the GRO framework, risk quotients (RQs), calculated as the mean contaminant concentration divided by the SGV [47], were derived for all soil contaminants. A potential risk is indicated by an RQ > 1. The bioswale UGS is not relevant to consider in the SEPA model, as its construction implies replacement of the contaminated soil with layers of new clean material that would effectively allow for the infiltration and retention of storm water, as well as filtering out runoff contaminants.

The GRO framework by Drenning et al. [21] was applied in this study to investigate the potential GRO strategies for soil contaminants at the site for the three top-ranked UGS scenarios; a summary can be seen in Table 2. The concentrations of Cu and Zn present at the site pose a potential risk to the soil ecosystem in all three UGS scenarios. The concentration of As at Polstjärnegatan is in line with naturally occurring concentrations in Swedish soils;

thus, the RQ is equal to 1 in all three UGS scenarios, indicating no risk to humans and the environment. Still, caution has to be taken when establishing sensitive land uses assuming the intake of plants grown at the site. Furthermore, although the RQ for Pb is acceptable (RQ < 1) for human health in all three top-ranked UGS scenarios at Polstjärnegatan, the mean concentration of Pb in the shallow soil is close to the SGV for the community garden scenario (RQ = 0.9), which calls for caution when planning this UGS.

Table 2. Potential GRO strategies for soil contaminants that pose risks to human health and the environment at the site in different UGS scenarios. Potential GRO strategies based on Drenning et al. [21] and OVAM [32].

Contaminant (RQ)	**Risk Object (*Important Exposure Pathways*)**	**Potential GRO Strategy**	**Approx. Time of Risk Reduction**
Land uses: Spontaneous vegetation, urban park, and community garden			
As (1.0)	Human health (*plant intake/soil intake*)	Stabilization with plants and/or amendments	Immediate
		Secondary effects of vegetation cover	Immediate
		Phytoextraction	>10 years
Land use: Community garden			
PCB (2.8)	Human health (*plant intake*, *soil intake*)	Stabilization with plants and/or amendments	Immediate
		Rhizodegradation	>10 years
PAH-H (1.1)	Human health (*plant intake*, *soil intake*)	Stabilization with plants and/or amendments	Immediate
		Phyto/rhizodegradation	>10 years
Land uses: Spontaneous vegetation, urban park, and community garden			
Cu (*1.5*) and Zn (*1.1*)	Soil ecosystem	Stabilization with plants and/or amendments	Immediate
		Phytoextraction	>10 years

To reduce the risk posed by Cu (RQ = 1.5) and Zn (RQ = 1.1) to the soil ecosystem, GRO strategies involving stabilizing soil amendments are of interest. GRO strategies involving stabilization imply that the contaminants remain in the soil but become less bioavailable to humans, plants, and soil-dwelling organisms. Stabilization can also be considered to be a viable option for As and PAH-H. However, an important aspect is that As typically behaves differently than many other metals and other substances, and soil amendments that may stabilize Cu, Zn, and PAH-H can potentially mobilize As and, thus, need to be carefully selected.

Phytoextraction of As, Cu, and Zn is a potential option to achieve risk mitigation by source removal. The slightly elevated levels of Zn at the site could potentially be extracted in fewer than 10 years if an efficient hyperaccumulator is identified [32], but this is likely to take much longer for Cu (and As). However, the drawbacks of phytoextraction, apart from the expected (long) time, also include the handling of the biomass waste in the meantime. Any land use involving spontaneous vegetation (and and urban park) enhanced with GROs directed at phytoextraction should avoid using edible plants that can potentially take up As, PAH-H (RQ = 1.1), or PCBs (RQ = 2.8), as this may increase the risks to humans (and grazing animals).

Relying only on stabilizing strategies for mitigating the human health risks posed by PCBs in soils is not the best option for the community garden scenario, because the concentration of PCBs is almost three times higher than the SGV (RQ = 2.8). Instead, PCBs can potentially be phytoextracted by various pumpkin species [54,55], but since the biomass waste needs handling, rhizodegradation may be more interesting to investigate further as a possible remediation solution [32,56]. If starting up a GRO strategy to rhizodegrade PCBs in an early phase of the development of the site, the source could potentially be decreased enough to allow for more sensitive uses—such as a community garden—later in the site development process. However, continuous monitoring and adaptive management of this (and any other) GRO strategy is needed to make sure that the targets are reached over time.

Further detailed investigations on suitable plants and potential stabilizing soil amendments are needed to design any selected GRO strategy, in combination with the visions for the site regarding the functions it should fulfil in the city and for the citizens.

3.2.3. UGS and GRO Intervention over Time—A Basis for Site Design

UGS and GRO intervention over time: Based on the exploration of the site's potential, the suggested consecutive land uses, starting with the current spontaneous vegetation, are to add bioswales and to transition parts of the site (or the rest of the site) to an urban park. The suggested timeline, with combinations of UGSs and GROs, is illustrated and visualized in Figure 6. This visual representation is an advancement of the graph suggested by Chowdhury et al. [44], utilized for the study site in this paper, to better illustrate (i) the preferred UGSs over time and (ii) the management of risks posed by the different contaminants using GROs at different time intervals.

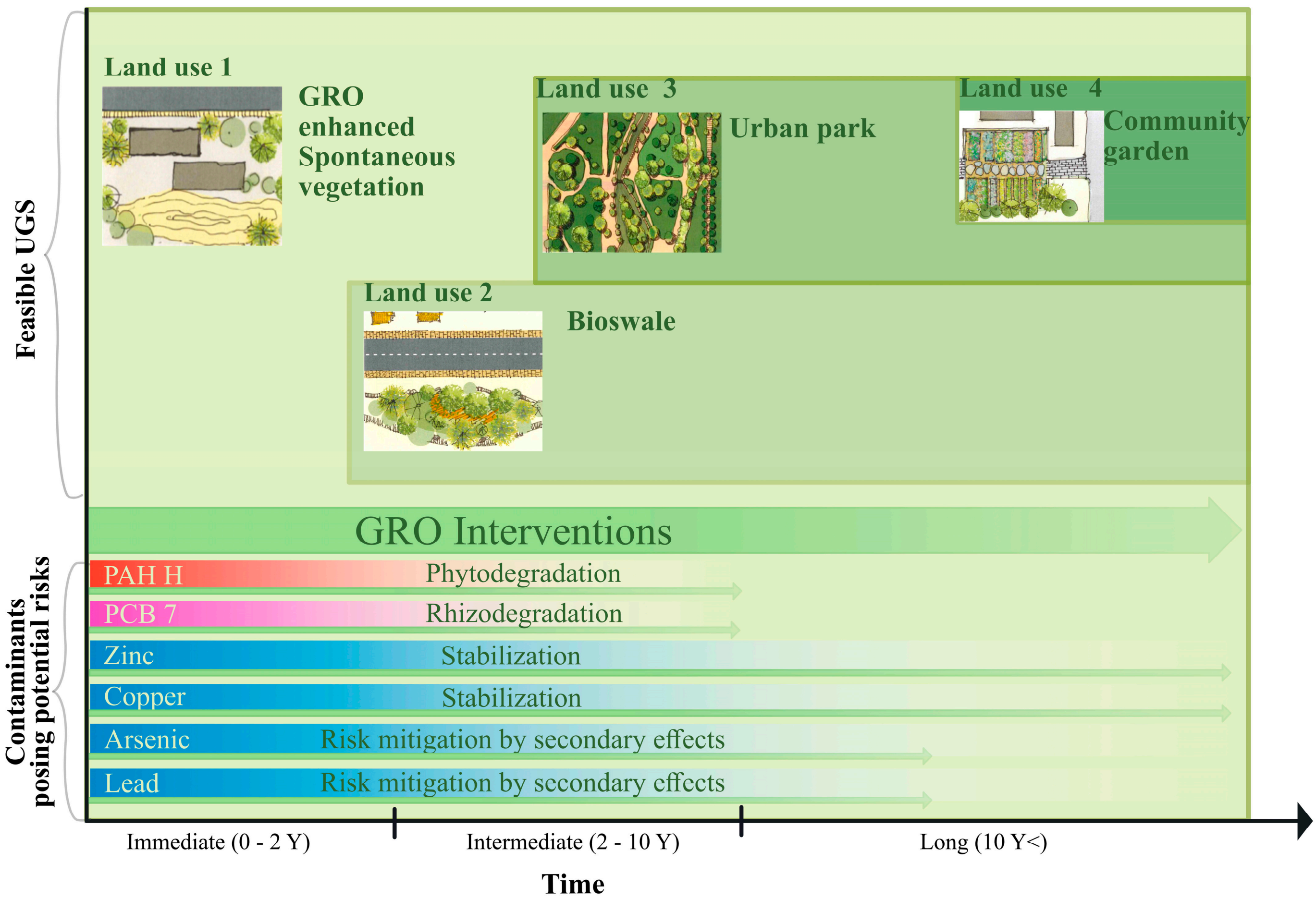

Figure 6. Illustration and visualization of potential combinations of UGSs and GROs for the Polstjärnegatan site.

Using the land as an urban park will potentially lower the risk for users compared to spontaneous vegetation, as plants that are grown are supposed to be managed, whereas edible plants can be avoided. Community gardens can potentially be implemented over time if the PCB and PAH-H concentrations are reduced enough to allow for more sensitive land use. To achieve this, methods for the stimulation of rhizo- and phytodegradation of PCBs and PAH-H should be investigated further for immediate implementation (Figure 6). As the RQ of PCBs is high (2.8) and PCBs are difficult to degrade, the time required is likely to be (potentially very) long, but it should continue until the site is safe for more sensitive land use (Figure 6). An alternative way to manage risks for a community garden scenario, if the concentration levels in the soil are not low enough, would be to implement vertical practices (i.e., bringing in clean soil and placing it in boxes on top of the current soil), to implement restrictions on growing certain types of plants (i.e., avoiding edible plants altogether, or at least any edible plants that are likely to take up existing contaminants), or to provide instructions on wearing protective gear and careful washing of body parts and crops (so-called Best Management Practices, US EPA [57]).

Risks posed to the soil ecosystem by metals at the site are suggested to be investigated further to better understand their current bioavailability and, if needed, to implement stabilizing measures with plants and/or amendments to reduce the risk. Stabilization strategies, aside from protecting the soil ecosystem, can also prevent the uptake of contaminants in edible plants at the site. Monitoring of the soil, as indicated in the framework, is needed to ensure that the selected GRO is effective and to ensure safe soil conditions for more sensitive land use in the future.

To further increase the possibility of achieving acceptable contaminant concentrations in the soil over time, the design of the site should also consider the contamination situation. The detailed plan indicates the construction of an underground waste storage facility (Figure 1), which requires the excavation of soil. Such a facility, as well as the bioswales, should ideally be located where the soil contamination is most complex and/or at its highest levels, since these constructions require excavation and off-site handling of the excavated masses anyway. For example, the underground waste storage facility could potentially be located in the southeastern part of the area (Figure 1, bottom), where the soil contaminant levels exceed generic soil guideline values for PAH-H and PCBs, as well as for metals. Such placement could potentially elongate the green axis implied in the detailed plan, suggesting the connection of the existing greenspaces on the other side of Karlastaden with this green area (Figure 1, top). GROs, on the other hand, should be applied at parts of the site where soil contaminant concentrations are at low or medium levels. A more detailed soil investigation to map contamination could support such detailed planning and decrease the need for GROs, as well as decreasing the time needed for implementing more sensitive land uses.

3.3. Possibilities and Challenges of the Framework

A summary of the stakeholders' feedback during the SWOT analysis of the suggested framework at the workshop is presented in Appendix A.

3.3.1. Possibilities

Stakeholders considered the suggested framework to be useful for supporting the planning of larger sites, where sections/parts of the site are developed over time. The framework could also support the formulation of long-term goals for a brownfield and demonstrate the potential for a brownfield to be brought back into beneficial use instead of lying derelict. This illustrates the increased market value of the brownfield over time as a result of its remediation and temporary use as UGS, providing a better understanding of the opportunities for combining UGSs and GROs on brownfields. The upcoming major restructuring of the municipality was identified as a more specific opportunity for implementing the framework in the city of Gothenburg, as the new organization is intended to recruit experts from different sectors to work together in different phases (e.g., planning, implementation, maintenance) and, thus, facilitate better collaboration between knowledge fields. The long-term strategic planning carried out at the municipal level is also in line with the long-term planning suggested by the framework. Communication of international success stories as reference projects for GRO applications, e.g., in Germany and the Netherlands [58,59], may inspire and pave the way for implementation initiatives in Sweden and beyond. Regarding identified threats, many of them are related, but not limited, to financial aspects of redevelopment projects and existing knowledge gaps. The workshop participants suggested several strategies for further actions and studies that could support and counteract the identified external threats (see Section 3.3.2 and Appendix A) for practical implementation of the framework.

Increasing knowledge: Make international (and national) reference projects better known using various dissemination channels, and start local small-scale GRO applications as prototypes that can demonstrate and make the benefits more visible.

Applying financial and economic analysis methods: Make financial and economic calculations with estimated costs and benefits, which may (i) better relate to the practice of how investments are made and (ii) show the generation of benefits from the site over time in monetary terms.

Investigating the benefits on a city scale: Investigate on a larger scale how many areas are underused in the municipality, why they are underused, and whether they have the potential to provide UGS benefits.

Development of tools: Develop practical tools for (i) estimating the time requirements of GROs, (ii) selecting relevant plants and amendments for potential GROs and specific contaminants in a Swedish context (e.g., climate), and (iii) monetization of the provision of ecosystem services by UGSs and GROs for inclusion in economic analyses.

Relating the framework to local sustainability goals: The framework relates well to EU strategies [4,7], but these strategies often have limited local impact unless it is required by law. Relating the framework to and clarifying how it contributes to local sustainability goals will increase its relevance and accessibility. The upcoming EU soil monitoring law can stimulate the use of GROs.

3.3.2. Challenges

The stakeholders indicated that there are more external threats to practical implementation of the suggested framework than there are external opportunities. Consequently, the participants identified several challenges for a practical implementation of the framework in Sweden.

Economy and finance: Long-term economic planning is only possible to a limited extent (or even not at all) for municipal landowners, as public actors often only have limited budgetary resources at their disposal. This was instead recognized as an opportunity for private actors, but on the other hand, it was noted that the existing financing strategies of private landowners do not fit well into the framework. They have a strict financial perspective, while the framework requires an economic perspective that also includes externalities such as the benefits of ecosystem services. As a result, the redevelopments suggested by the framework are likely to be perceived only as a cost and not as a good investment. In addition, it is difficult to ensure stable ownership of the site over such a long-term time horizon, leading to uncertainties for long-term plans and remediation strategies.

Politicians and the political system: The workshop participants suggested that some politicians find the concept of ecosystem services to be fuzzy, i.e., that the benefits of combining UGS and GROs are not clear or are not perceived as real (financial) benefits. Additionally, even if the benefits of combining UGS and GROs and implementing the framework to support the planning processes can be convincingly presented to a group of politicians, new elections every 4 years may bring new political visions and new budget priorities. This challenge is a threat, but it can also be an opportunity if the political vision favoring the implementation of the framework does not change over time. For example, at present, there is a municipal intention to increase the share of green spaces and green infrastructure in the city, although there is no legal support to demand this from private developments.

Preference for "business as usual": Today, there is a low level of knowledge about GROs among landowners and a strong preference to carry out remediation "as usual" using excavation and disposal, because this is perceived as a safe and quick practice. Furthermore, early detailed soil investigations on future green spaces that are needed for GRO-based UGS implementations are not carried out in practice today.

4. Discussion

The identified weaknesses of the framework and advice from stakeholders on strategies to minimize them helped to improve the final version of the framework (Section 3.1). Three important updates were included in the final version of the framework: (1) the benefits that accrue during temporal land use when combining UGS and GROs to redevelop brownfields were clarified in the framework (Figure 4), (2) an improved description of when and how to use the framework was included (Section 3.1), and (3) a demonstration of the complete suite of tools and methods included in the framework was presented. The results from the exploration of opportunities for the study site and the proposed GRO and UGS strategies are detailed in Section 3.2, Figure 6, and the Supplementary Materials.

The participants were very engaged in the discussions and related the ideas of the framework to their roles. Although the workshop was well attended, some representatives were absent as they did not respond or did not have time to participate. For example, as there were discussions about how the maintenance of the site should be handled (in terms of responsibility and funding), a representative from the municipality's Parks and Nature Administration could have contributed further to this discussion. The municipality's Environmental Department, which acts as the controlling environmental authority, was also not represented at the workshop. This department is responsible for approving sampling plans, risk assessment reports, and the selection of remediation measures for contaminated sites, for example, and could thus provide valuable input. The workshop was held in both Swedish and English. The main reason for this was to make the discussions as simple as possible. The downside, of course, was that parts of the discussion were not fully accessible to all participants. However, this is not expected to have had a negative impact on the final results of the workshop discussions.

The framework includes several tools and methods developed to support the circular use of both land and soil in brownfield regeneration for GRO-based UGS, but additional needs for supporting tools were identified at the workshop. Ecosystem services provided by different greenspaces in cities can be both specified (e.g., [44]) and quantified (e.g., [60]), but the workshop participants highlighted the need for methods to monetize such added values for a more practical adaptation of the framework. The Ecosystem Services Valuation Database (ESVD, https://www.esvd.net/, accessed on 20 February 2020) has long been established to produce value estimates based on the TEEB database [61]. However, this database lacks indicators for urban areas (only 4 out of 1310) to support the valuation of ecosystem services provided by UGSs. Greenspaces in cities are providers of complex and integrated suites of ecosystem services that are difficult to monetize [62]. Therefore, the use of non-monetary parameters to quantify benefits is the predominant method for urban ecosystem evaluations [63]. However, there are examples of monetizing ecosystem services provided by UGSs, such as the hedonistic valuation of ESs provided by New York's Central Park by approximating the estimated real estate value of the area covered [62], or the contingent valuation for urban forests in Puerto Rico by willingness to pay (WTP) for their preservation [64]. The suggested framework, however, combines GROs' implementation with greenspaces for brownfield regeneration, and such combined ecosystem-based adaptations can help to capture the provided benefits more efficiently [65]. Valuation of soil ecosystem services [66] can potentially be utilized to capture the benefits that GROs can offer through the restoration of soil health. The Brownfield Opportunity Matrix (BOM) [67] is built around similar principles to the proposed framework but focuses on remediation strategies. The BOM helps to explore the benefits that can arise from these remediation technologies [68], and it can therefore support the suggested framework in communicating these benefits to stakeholders.

A key area of the framework that needs further development, as identified at the workshop, is the GRO technologies. A comprehensive database for the selection of plants suitable for a particular climate zone is one of the aspects required for the implementation of GROs in practice. This is also potentially a key tool for planners and landscape architects in linking GROs with UGS development. Several studies on plant selections have been conducted (e.g., [69,70]) and can be used as stepping stones to start the construction of a database of plants for GROs. Furthermore, although the GRO framework includes a relative risk reduction time mainly based on the work of Kennen and Kirkwood [29] and OVAM [32], it is generic. However, during the workshop, the need for more specific time estimation was identified. This is challenging, since the estimated time differs for different GRO strategies, for different contaminants, for different plant species, and for many other site-specific conditions, including climate. The available literature on GRO strategies reflects these limitations and mostly revolves around field experiments (e.g., [71,72]), but the topic is of continued interest, and there are studies [30,73,74] that summarize the results of different field trials. Based on this, it is possible to establish a database that can be used to create more reliable time estimates for GROs.

Apart from the identified need for additional specific tools to support the suggested framework, another limitation of this study that requires further exploration is its exploration in different settings. The complete suite of tools and methods presented would benefit from being tested together with stakeholders in real-life applications to further improve them. This framework has the potential to be adapted in European case studies with the progressive push by the EU for NBSs, as identified by Bona et al. [75]. Bona et al. [75] presented a compilation of NBS applications and highlighted how most of the case studies used the various ecosystem services brought by the NBSs to promote their use and application. Aghaloo et al. [76] provided a summary of 582 empirical studies to show that the prominent NBSs in urban settings are associated with greenspaces (i.e., sustainable urban drainage systems, green infrastructure, sponge cities, blue–green infrastructure). Preston et al. [77] exemplified Greater Manchester, UK as a case study location to demonstrate the hidden potential of brownfields as greenspace, citing that more than half of the area covered by brownfields is vegetated. Our framework builds on this potential and provides tools to accommodate NBSs to remediate brownfields. With the acceptance and application of NBSs now evidenced in the Global South [78], this framework could potentially be adapted to the specific needs of developing nations.

The framework presented in this paper proposes bringing brownfields back into beneficial use slowly but safely, ensuring not only the well-being of the people, in the form of reduced health risks and increased provision of ecosystem services, but also the well-being of the soil ecosystem, in the form of improved soil functioning. The framework is a response to the need to better incorporate soil contamination issues [42] and accommodate nature-based solutions for brownfield remediation [27] in land-use planning and design. This combined exploration for land and soil is in direct contrast to the current practice of brownfield development, where the compiling of information on soil contamination is left aside until the implementation phase of the planned land use is reached, preventing remedial measures other than excavation and disposal. Song et al. [27] pointed to the need to involve landscape architects in urban planning when designing NBSs for the remediation and redevelopment of brownfields in cities. Fernandes and Guiomar [79] pointed to the need for strong and reliable engineering approaches for designing NBSs (in general). Dorst et al. [65] pointed out the need for holistic and participatory governance and planning approaches for the implementation and realization of NBSs (as well as green infrastructure and ecosystem-based adaptation), as "all three approaches aim at delivering social, environmental and economic benefits simultaneously" [65], which increases the risk of a fragmented governance and implementation process. As demonstrated in this study, the implementation of GROs, as a subset of NBSs, is expected to challenge the current system, where different interests are partially handled in silos. There were some expectations among stakeholders that the new organization in the city of Göteborg could improve opportunities for collaboration across these silos. However, it is likely that ideas and concepts will also need to change, and not just among a few interested persons. As Fernandes and Guiomar [79] stated, "NBS imply a radical paradigmatic change in societal, individual, administrative and technical terms: to trust plants and living organisms in the same way one trust concrete, steel or glass to handle the use of plants in managed contexts in the same way and demanding the same degree of technical reliance as when using traditional technics and materials" [79]. Similarly, trusting GROs as strategies for handling contamination and effectively reducing risks to humans and ecosystems will likely require a shift in the mindset of environmental authorities and practitioners.

5. Conclusions

The framework suggested in this study and its associated tools and methods may support a transition of brownfields to UGSs while recycling both land and soil, thus contributing to a more circular use of urban land and soil. This assumes the monitoring of changes over time and, if needed, an iterative process to adjust UGS and GRO strategies based on changes in site conditions and/or stakeholder preferences over time. The demonstration of the framework, with its associated tools and methods, to explore the Polstjärnegatan site suggested the following:

- To the current spontaneous vegetation, bioswales can be added and an urban park can be established on parts of the site (or the whole site) without any health risks, and when risks to humans reach acceptable levels for more sensitive use, a community garden can be added.
- The expected risks posed by PCBs and PAH-H to humans in the community garden scenario are suggested to be managed by rhizo- and phytodegradation, initiated as early as possible to enable the establishment of a future community garden.
- Potential risks posed by Cu and Zn to the soil ecosystem should initially be confirmed by an investigation of their current bioavailability. If confirmed, the risks are suggested to be managed by stabilization, potentially also generating positive effects on Pb, PAH-H, and PCBs, but the effects will need continuous monitoring.
- Special attention is required for managing levels of As when selecting a specific soil amendment, since arsenic can potentially be mobilized by some of these stabilizing additives.
- Bioswales and the planned future underground waste storage should preferably be located where the highest concentrations of contaminants are present. Since excavation is needed for the construction, this creates an opportunity to remove masses with high contents of contaminants from the site.
- The framework should preferably be applied early in the process (at least before the design of a detailed plan) to make better use of opportunities for combining UGSs with GROs on brownfields.
- Although the framework was developed within the Swedish context, it can be extended to applications in other countries by replacing the risk assessments with those specific to each country.

The framework was analyzed using a SWOT analysis in a workshop with diverse experts and stakeholders. Overall, the workshop participants responded positively to the framework and recognized the opportunities of developing long-term goals for a site and communicating the site's potential and the benefits that it could provide if brought back into use as UGS. However, they also identified challenges and needs for its practical implementation:

- The main challenges were primarily associated with financial aspects such as the estimation of costs and benefits over time, monetization of ecosystem services, changes in ownership of sites over time, and limited possibilities for long-term economic planning. Moreover, the challenge lies in existing customary practices and levels of knowledge, e.g., the preference for business as usual, detailed soil investigations too late in the process, limited awareness about GROs, and limited involvement of other experts in earlier stages of the planning process.

- The set of tools and methods included in the framework should be complemented with methods, tools, or databases to (i) make predictions of time requirements and, thus, cost estimates of GROs to reach acceptable risk levels; (ii) make quantitative, preferably monetary, valuations of non-market benefits such as ecosystem services associated with GROs to communicate benefits to decision-makers; and (iii) support the selection of plant and soil amendments for various GROs and contaminants in a Swedish setting.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/urbansci8040198/s1.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Strengths, weaknesses, opportunities, and threats identified by the workshop participants.

Strengths	Weaknesses
Useful for planning of larger sites Shows the potential of the site instead of sitting idle awaiting redevelopment Highlights the increased land value over time Helps to formulate long-term goals for the site Provides a better understanding of the opportunities at a site	Difficult to understand when and how the suggested framework should be used Lacking methods for monetization of the provided ecosystem services and calculations of realization costs of UGSs and GROs to be able to show the long-term economy of the site's redevelopment Lacking clear decision support and clarification on how the site can be remediated Lacking a tool for selection of specific plants for specific GROs and contaminants
Opportunities	**Threats**
Possibilities for similar regulatory requirements for the soil as for ecological zoning of a local river Reference projects in other countries (DE, NL) Long-term strategic planning is possible for both municipal and private landowners Long-term economic planning is possible for private landowners Upcoming reorganization of the municipality, where they expect to work less in silos New election every 4th year: new political visions, new budget priorities	Little knowledge about GROs/NBSs among landowners and a preference to do business "as usual" Tradition/practice of not conducting early detailed soil investigations in future green spaces Difficulty of ensuring stable ownership of the site over time Difficulties in communicating risks to people involved in urban food production (e.g., allotments, community gardens) Central parts of the city often require fast redevelopment—no room for GROs Existing financing strategies used by private landowners do not fit with the framework—there is a challenge in comparing or mixing financial and economic analyses Such redevelopment is perceived as a cost and not as an investment (no legal requirements today on the amount of green spaces, etc.) Politicians think the concept of ecosystem services is fuzzy Often limited budget time for public actors Long-term economic planning is limited or even impossible for municipal landowners New election every 4th year: new political visions, new budget priorities

Table A2. Strategies identified by workshop participants.

Strategies to Take Advantage of Opportunities Through Strengths	Strategies to Counteract Threats Through Strengths
A holistic design is needed to plan a redevelopment and place functions that require excavation where excavation is necessary/best suited for remediation The framework can provide economic incentives for long-term planning Make existing reference projects where similar practices are implemented more known Associations for urban agriculture may also benefit from this thinking Work together with associations for urban agriculture—is it possible to apply restrictions on crops that may take up soil contaminants?	Creating local prototypes (funded by tax money) would be good to be able to display the value that they add and generate more knowledge about possibilities and risks, starting with small-scale GRO applications Use financial analysis methods to relate better to practice (of how investments are usually made) Use economic analyses to show the generation of benefits from the site over time in monetary terms Allow actors responsible for long-term maintenance of the site to be involved in the design process Give economic incentives for long-term planning
Strategies to Take Advantage of Opportunities to Minimize Weaknesses	**Strategies to Counteract Strengthening of Threats Through Weaknesses**
Clarifying how the framework contributes to local sustainability goals can help its practical implementation Economic and financial analyses can help convince decision makers to wait "18 years" for profits and benefits Provide evidence for the benefits generated at a site and undertake studies to better understand citizens' willingness to pay for such redevelopments Provide a comparison of strategies instead of only discussing one strategy Explain more clearly when the framework is useful and if it should be adapted for specific situations	Translate EU strategies to the Swedish municipal level to better understand how they link to local goals Develop tools for estimating time requirements of GROs to reach acceptable risk levels and for choosing plants/amendments Investigate on a larger scale (e.g., by MSc thesis projects) how many areas are underused in the municipality, why they are underused, and whether they have the potential to provide UGS benefits

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