THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

An Assessment of the Potential for Bio-based Land Uses on Urban Brownfields

SHASWATI CHOWDHURY

Department of Architecture and Civil Engineering

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2020

An assessment of the potential for bio-based land uses on urban brownfields

SHASWATI CHOWDHURY

Technical report series: Lic/Architecture and Civil Engineering/Chalmers University of Technology

Department of Architecture and Civil Engineering
Division of Geology and Geotechnics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Cover:
The suggested scatter diagram of future bio-based land uses on urban brownfields with provisional positioning of the icons; also Figure 11. Developed by Shaswati Chowdhury.

Chalmers Reproservice
Gothenburg, Sweden 2020

An assessment of the potential for bio-based land uses on urban brownfields
SHASWATI CHOWDHURY
Department of Architecture and Civil Engineering
Division of Geology and Geotechnics
Research Group Engineering Geology
Chalmers University of Technology

ABSTRACT

Circular Economy (CE) is expected to accelerate the emerging shift in resource consumption from finite to renewable, and plants are key in enabling the switch as industries would opt more and more for resources with a bio-based origin. Cities have an important role in the process not only as the main consumers of the resources but also because vegetation provides numerous tangible and intangible ecosystem services essential for the wellbeing of urban dwellers. But the urban lands are heavily burdened with present activities and ongoing urbanisation. Retrofitting obsolete and potentially contaminated brownfields within the urban periphery provides an opportunity to engage in bio-based land uses. At the same time, vegetation can be incorporated with Gentle Remediation Option (GRO), a possible alternative and more sustainable option over common 'dig and dump' remediation to manage risks due to contamination and restore soil health. The overall aim of this thesis is to identify bio-based land use opportunities on urban brownfields and to develop appropriate decision support to assess the potential for their realisation. This thesis presents a framework for assessing the bio-based land use potential on brownfields consisting of three practical tools: a conceptualisation of linkages between GROs and prospective Urban Green Space (UGS) uses, a scatter diagram for the realisation of 15 UGS opportunities on brownfields, and a decision matrix to analyse the requirements for UGS on brownfields. The decision matrix tool is applied to the case study site Polstjärnegatan in Gothenburg, Sweden, where six potential UGS uses are filtered out for the site. The assessment of bio-based land use potential on urban brownfields can be further improved by incorporating stakeholder planning and governance, decision support for the site-specific applicability of GRO and GRO selection, and land use specific risk management.

Keywords: Circular Economy (CE), Bio-based CE, Brownfields, Gentle Remediation Options (GROs), Bio-based land use, Urban Greenspaces (UGSs)

LIST OF PUBLICATION

This thesis contains the following publication appended to the thesis:

- Chowdhury, S., Kain, J.-H., Adelfio, M., Volchko, Y., & Norrman, J. (2020). Greening the Browns: A Bio-Based Land Use Framework for Analysing the Potential of Urban Brownfields in an Urban Circular Economy. *Sustainability*, *12*(15), 6278. https://doi.org/10.3390/su12156278

Division of work between the authors

The authors contributed as follows: Conceptualisation, J.-H. Kain, M. Adelfio., J. Norrman., Y. Volchko., and S. Chowdhury.; methodology, S.C., J.-H.K., M.A., J.N., and Y.V.; formal analysis, S.C.; investigation, S.C.; writing—original draft preparation, S.C.; writing—review and editing, J.-H.K., J.N., M.A., Y.V., and S.C.; visualisation, S.C.; supervision, J.-H.K., J.N., M.A., and Y.V.; project administration, J.N.; funding acquisition, J.N., J.-H.K., Y.V., and M.A.

Other work and publications not appended to the thesis:

- Chowdhury, S., & Norrman, J. (2020). Evaluating contamination exposure rates in different Urban Agriculture (UA) practices. Gothenburg, Sweden. Available at https://research.chalmers.se/en/publication/519874. Poster presented at Beyond2020 on-line conference, Nov 2-4.
- Drenning, P., Norrman, J., Chowdhury, S., Rosén, L., Volchko, Y., & Andersson-Sköld, Y. (2020). Enhancing ecosystem services at urban brownfield sites – what value does contaminated soil have in the built environment? In *Beyond 2020*. Gothenburg, Sweden: Chalmers University of Technology.
- Chowdhury, S. (2020). *Urban potential in Bio-based Circular Economy Literature review report*. Gothenburg, Sweden. Available at https://research.chalmers.se/en/publication/517806.
- Chowdhury, S. (2019). Opportunities for preparing urban contaminated land for bio-based production. Antwerp, Belgium. Available at https://research.chalmers.se/en/publication/519875. Poster presented at the AquaConSoil Conference, May 20-24.

TABLE OF CONTENTS

1 INTRODUCTION

The first chapter of the licentiate thesis provides a brief background of the research (which is further elaborated in chapter 2) and presents the research aim and the main objectives. It also lays out the scope of work followed by clarifying some limitations.

1.1 Background

The global economy has grown exponentially since the industrial revolution made mass production of goods possible (Prendeville et al., 2018; Winans et al., 2017). Current linear ‘take-make-use-dispose’ economy has seen the material consumption increase by 800% in the past hundred years and it is expected to triple in the next thirty years (Krausmann et al., 2009; Lieder & Rashid, 2016; Prendeville et al., 2018; UNEP, 2011; Winans et al., 2017). As studies like ‘Planetary boundary’ suggests, earth’s resources are stretched to its limit and will not be able to sustain such an economic system for long (Rockström et al., 2009). The concept of Circular Economy (CE) addresses these concerns by proposing an economic system that keeps finite resources in a closed material flow loop and promotes the usage of renewable resources wherever possible (Ellen MacArthur Foundation, 2013; Sauvé et al., 2016). Circular Economy (CE) has been widely regarded as a comprehensible concept targeting resource efficiency and wider sustainability issues such as climate change (Domenech & Bahn-Walkowiak, 2019; Mont et al., 2018). Various CE strategies are also being implemented at the policy level by governments; the European Union has enacted a ‘Circular Economy Action Plan’ in 2015 that proposes a combination of legislative and non-legislative measures for wider adoption of CE strategies (COM/2011/0571; European Commission, 2015).

While CE sets clear circular strategies for the usage of non-renewable resources such as metals, for some resources, such as soil, the direction is less obvious. Apart from being the source of most finite resources, Breure et al. (2018) define soil as a non-renewable material in itself due to its slow formation and recovery processes. Besides this, soil and land are essential for vegetation that is the main renewable alternative to finite resources (Breure et al., 2018). Products designed and made with bio-based resource alternatives are the driving force of changes in CE, which is likely to increase the pressure on fertile landscapes that are already overstressed in satisfying the primary need of food (Ellen MacArthur Foundation, 2013; European Commission, 2017, 2019). As centres for socio-economic activities and dense human settlements, cities see an even more concentrated and intensive use of land that is also likely to increase due to on-going urbanisation (United Nations, 2014; Wu, 2014). More than half of the world population is now urban and to support the growing influx of new inhabitants, cities expand spatially even faster, twice the times of their population growth rates on average (Angel et al., 2011; United Nations, 2014; Wu, 2014)(The World Bank, 2020). The land consumption of cities, however, is likely to be monitored under policy implementations, such as the 'No net land take by 2050' goal which was launched by the EU in 2011 (COM/2011/0571). But there remain pockets of urban land that are known as 'brownfields', lands that were once in use and are now derelict and abandoned but can be crucial in urban development under such situations (Ferber et al., 2006; Loures, 2015).

Brownfields can be considered as valuable waste from a linear land use system and a resource that provides multifaceted opportunities in a circular urban land use system (Loures & Panagopoulos, 2007). Bringing brownfields back in use is, however, both an expensive and complicated process due to real or perceived contamination related to previous uses (Reddy et al., 1999). Vegetation provides an opportunity to not only explore scopes of bio-based products in the urban periphery but also as a potential remediation strategy to reduce the ecological and human health risks (Dickinson et al., 2000; 2009; Diplock et al., 2010). Plant-based risk management, or phytoremediation, has been discussed as an alternative to the resource-intensive 'dig and dump' remediation technologies when redeveloping brownfields for green land use (Carlon et al., 2009; A. Cundy et al., 2015; EEA, 2014) For example, combining biofuel feedstock and other bio-based production with a phytoremediation process can potentially become a 'self-funding land management regime' for brownfields (Andersson-Sköld et al., 2014). Furthermore, vegetation guarantees the liveability of the city by providing numerous ecosystem services essential for its inhabitants' wellbeing (Wolch et al., 2014). Practising bio-based production on brownfields results in bio-based land uses which will increase the greenspaces in the urban fabric, thus contributing to the tangible and intangible services provided by the urban greenspaces. Such roles of brownfields and urban greens are yet to be discussed and explored in the context of bio-based CE.

1.2 Aim and objectives

The overall aim of this thesis is:

> *to identify bio-based land use opportunities on urban brownfields and to develop appropriate decision support methods to assess the potential for their realisation.*

To reach the overall aim, the thesis has the following specific objectives:

- To develop a bio-based land use framework consisting of different tools for practitioners and researchers in the brownfield domain to understand and assess the potential of different bio-based land uses on urban brownfields;
- To apply the tools on a case study to review its practicality;

- To identify issues that are urgent for realising bio-based land uses and needs further elaboration/investigation.

1.3 Scope of work

Achieving the objectives of the licentiate thesis require studying the intersection of CE, bio-based land us and urban brownfields using a multidisciplinary approach. To understand the relevant topics, the thesis starts with a theoretical background that elaborates and links these topics. The theoretical background is presented in Chapter 2. A more elaborate coverage on the topics can be found in the literature review report 'Urban Potential in Bio-based Circular Economy' (Chowdhury, 2020). Chapter 3 elaborates the methodology adopted to achieve the aim and objectives of the licentiate thesis and details out the specific tasks required. The subsequent tasks performed to achieve the specific objectives of the thesis are presented in Chapter 4 and have been elaborated as follows.

- Study on bio-based land use options and subsequent ecosystem services is performed to provide supporting material required for developing a bio-based land use framework development. The output is presented in Section 4.1
- The proposed bio-based land use framework is presented in Section 4.2. The framework consists of: a) a general conceptualisation of how the potential for bio-based production on brownfields is linked to soil contamination, gentle soil remediation options and time; b) a graphical representation to assess the potential for realisation of bio-based land uses on brownfields in relation to involved interventions and time spans; c) a decision matrix showing how site-specific brownfield conditions affect the potential for different types of bio-based land uses.
- The decision matrix tool of the framework has been applied to a brownfield site in Gothenburg, Sweden to test and evaluate it based on a real-world application. The output of the application along with the possibilities, strengths, limitations, and required adjustments are presented in Section 4.3.

The framework development and its application have been reflected upon, the issues that require further investigation have been identified, and ongoing work on the issues has been put forward. The process is summarised in Chapter 5. The thesis outcome is further discussed with the main conclusions summarised in bullets in Chapter 6.

1.4 Limitations

The limitations of the licentiate thesis are as follows:

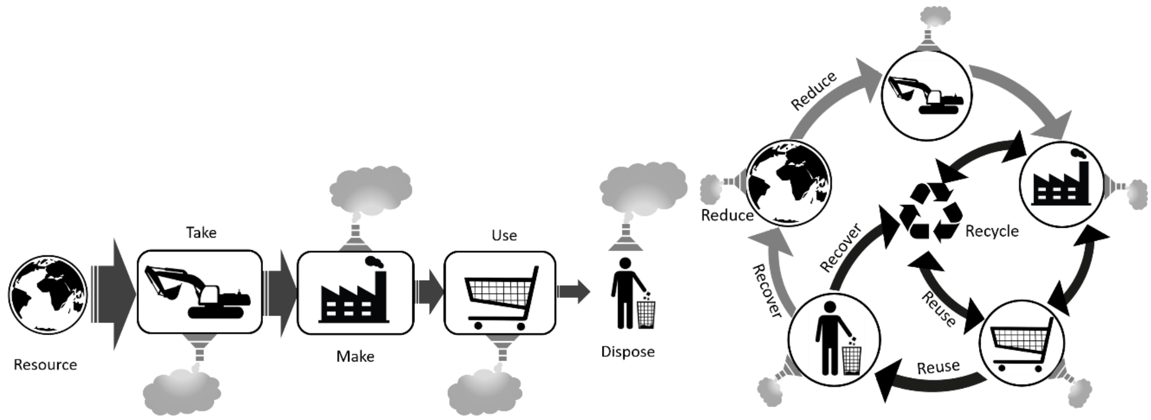
- As it is a multidisciplinary research, the focus has been put in linking different fields of interest rather than an in-depth exploration of each topic. Thus, the thesis provides a limited investigation but the possible extent of the research is outlined as ongoing work in Chapter 5.
- CE is a rather new and developing concept and the outlook of CE is constantly getting updated. Only discussions on CE published prior the writeup has been considered in this thesis.

2 THEORETICAL BACKGROUND

This chapter firstly explains different concepts related to the research, secondly connects them to provide the necessary arguments, and thirdly builds on the findings to elaborate the specifics of the research scopes.

2.1 Circular Economy (CE)

The present economic system is dominated by a linear ‘take-make-use-dispose’ model where virgin resources are extracted to create products that are destined for landfills after their end of usefulness (Ellen MacArthur Foundation, 2013; Franco, 2017; Pitt & Heinemeyer, 2015). This mode of consumption considers the nature’s resource as limitless but empirical evidence suggests otherwise (Franco, 2017). The impact of this relentless consumption coupled with explosive population growth has pushed planetary boundaries to their limits (Pengra, 2012; Sauvé et al., 2016).



Linear Economy   Circular Economy

Figure 1. Linear economy vs. Circular Economy. Adapted from Sauvé et al. (2016).

Circular Economy (CE) is a response addressing the limitations of the linear economic system. It takes place in a loop where resources are in circular movements within a system of production and consumption (Figure 1) to optimise the use of resources and reduce waste at each step by recovering, reusing, or recycling (Sauvé et al., 2016). Circular Economy (CE is considered a credible sustainability operationalising tool for balancing ambitions for both economic growth and environmental protection (Ghisellini et al., 2016; Kirchherr et al., 2017). One prominent concept of CE, Cradle to Cradle, distinguishes two material cycles within CE, biological and technical (Braungart EPEA, 2018). The Ellen MacArthur Foundation builds on that to create the CE systems diagram that is more commonly known as the ‘Butterfly diagram’ to map the flows and interconnections of the two material systems (Figure 2) (Ellen MacArthur Foundation, 2013).

The green cycles on the left side of the diagram represent the biological materials that are sourced from the biosphere and can safely re-enter the natural world (Ellen MacArthur Foundation, 2013, 2020). The blue cycles on the right side of the diagram, instead, represent the technical materials (Ellen MacArthur Foundation, 2013, 2020). These materials, such as metals and plastics, are finite resources and cannot re-enter the environment safely and thus, should continuously cycle through the system for maximising their value (Ellen MacArthur Foundation, 2013, 2020).

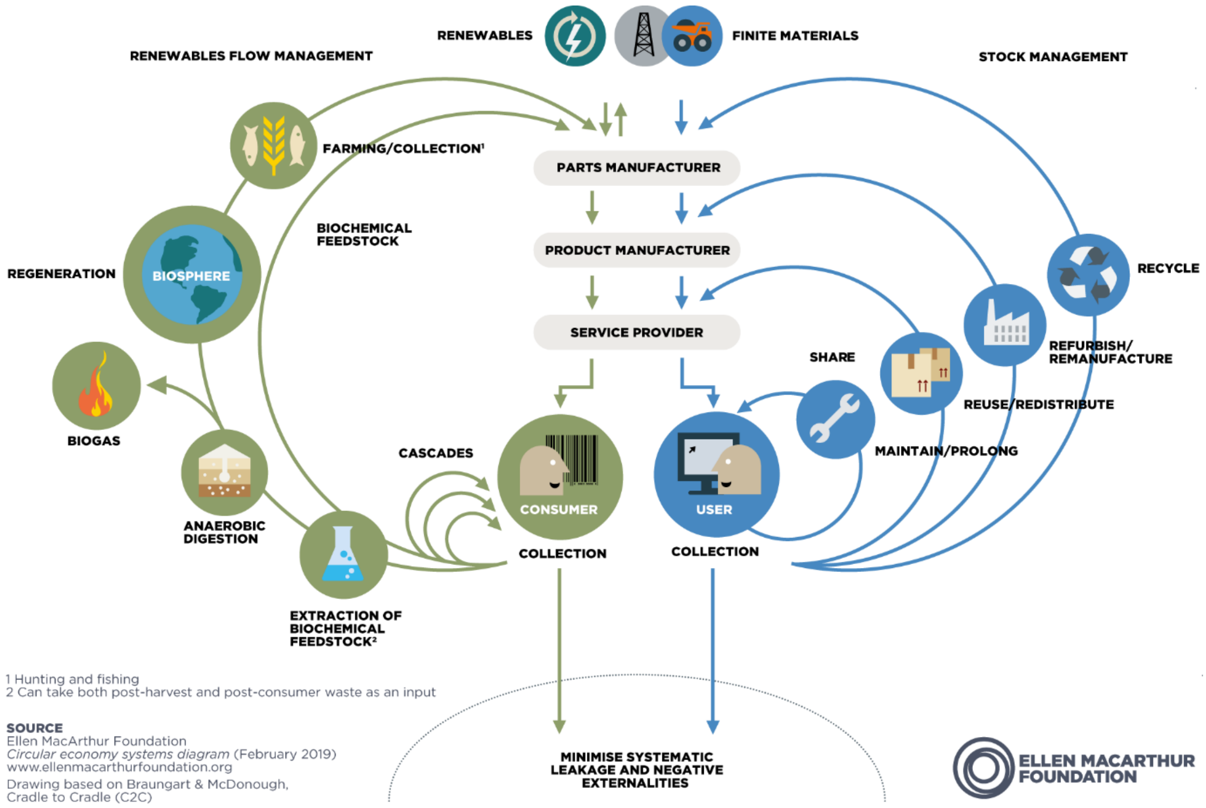


Figure 2. The Circular Economy systems diagram. From the Ellen MacArthur Foundation (2019).

2.2 The biological cycle of Circular Economy

The biological cycle of CE will provide biodegradable alternatives, such as biofuel and bioplastics, and is considered to be the main driver in cutting CO_2 emission and fossil fuel consumption (Ellen MacArthur Foundation, 2013; European Commission, 2019; Kirchherr et al., 2017; Pimentel & Patzek, 2006). The dominating bio-based product by far is food crops and the growing global population would likely need that production output to be maintained if not increased (Figure 3) (European Compost Network, 2019; Vermeulen, Campbell, & Ingram, 2012). After the food products, biofuel is potentially the bio-based product most explored. Interest in biofuels as fossil fuel alternatives came to the forefront during the 1970s fuel crisis (Hansen et al., 2005). Biofuel feedstock in the early days was made of edible food crops that gave rise to the 'fuel vs. food' debate (Marlair et al., 2009). This debate prompted the production of biofuel using biowaste and, presently, work is ongoing to produce biofuel entirely from algal biomass (Lee & Lavoie, 2013; Marlair et al., 2009). Apart from food crops and biofuel, several products from different domains of consumptions use resources of bio-based origin (e.g. paper, wool) and many are now shifting towards bio-based alternatives (e.g. bioplastics).

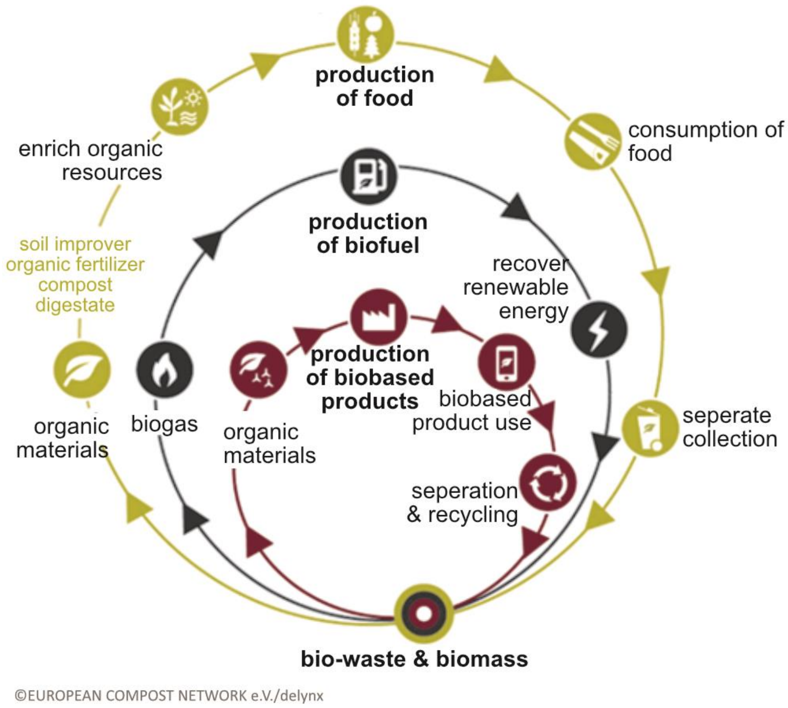


Figure 3. The biological cycle in the Circular Economy (CE). From the European Compost Network (2017).

2.3 Soil and land in a Circular Economy - a case for Urban Brownfields

The role of soil and land in CE is multidimensional as they are important common pool resources (Priyadarshini & Abhilash, 2020). CE is progressively becoming the most commonly used discourse to address sustainability issues in land-use intensive industries (D'Amato, Korhonen, & Toppinen, 2019). Breure et al. (2018) explain that soil in itself can be considered a non-renewable resource due to its extremely slow formation and recovery processes in the CE systems. Soil also acts as a medium containing other finite resources of the technical cycle, such as metals, fossil fuels, and groundwater (Breure et al., 2018).

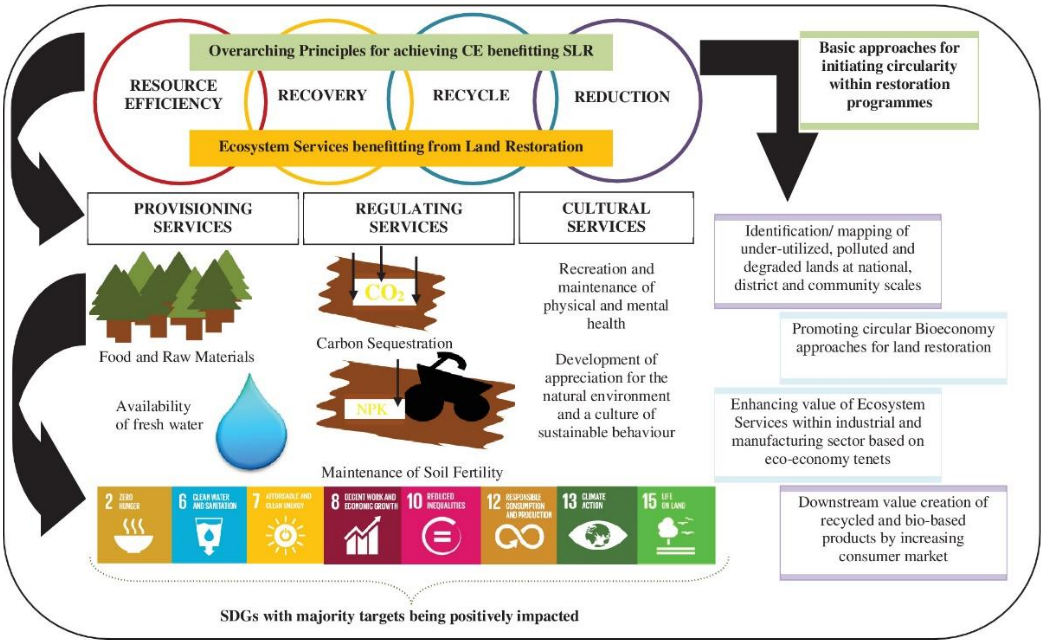


Figure 4. Bio-based CE in soil and land restoration (SLR) enabling the protection of related ES and the SDGs. From Priyadarshini and Abhilash (2020).

When it comes to the biological cycle, soil supports the terrestrial nature inherent in sourcing bio-based resource input (Breure et al., 2018). The value of soil and land in supporting nature and society is better explored in the term of Ecosystem Services (ES), where an array of services (prominently provisioning services, but to a large extent also regulating, supporting, and cultural services) have been investigated highlighting their indispensable role (Jónsson & Davídsdóttir, 2016; Masi et al., 2018). The importance of protection and restoration of soil and land resources is well reflected in several UN Sustainable Development Goals (SDGs), both directly (SDG 2 – Zero Hunger, SDG 15 – Life on land), and indirectly through different indicators and targets (SDG 6 - Clean water and sanitation, SDG 7- Affordable and clean energy, SDG 8 – Decent work and economic growth, SDG 12 – Sustainable cities and communities, SDG 13 – Responsible consumption and production) (Priyadarshini & Abhilash, 2020; United Nations, 2020). The notion of CE can be helpful in threading the existing sustainability paradigms (e.g. SDG, waste hierarchy) to bring forward policies enabling the protection and restoration of soil and land resources (D'Amato et al., 2019; Goh, 2020; Priyadarshini & Abhilash, 2020). Priyadarshini and Abhilash (2020) outline the need for an integrated adoption of bio-based CE for soil and land restoration (SLR) that would help protect the ES provided and thus help to attain the SDG goals related to soil and land (Figure 4).

Urban land is getting increasingly burdened as the urban population is expected to grow from the current 3 billion to 6 billion by 2050 (Bučienė, 2003; European Commission, 2017;

United Nations, 2014). Apart from supporting the influx of the growing population, urban land will also have an important role in the CE. To accommodate such growing needs, land in the cities needs to be utilised to the maximum. The abandoned, barren, underutilised, and often contaminated land commonly known as 'brownfields' can potentially provide the opportunity to meet the increasing need. Brownfields can be defined as sites that 'have been affected by former uses of the site or surrounding land, are derelict or underused, are mainly in fully or partly developed urban areas, require intervention to bring them back to beneficial use, and may have real or perceived contamination problem' (Dixon et al., 2007; Ferber et al., 2006). Given the context of CE, brownfields can be conceptualised as valuable waste resulting from the 'linear' land use, lands that were previously useful but now lays to waste (Figure 5) (Breure et al., 2018; Loures & Panagopoulos, 2007). In the circular land use system, brownfields are considered as a resource in the transition from abandonment to redevelopment and reuse (HOMBRE, 2014).

Figure 5. A conceptualisation of the Circular Urban Land use system.

Much like all the other resources, cities are the biggest consumers of bio-based products although the production mostly takes place in the agrarian landscapes outside the urban periphery (UNEP-DTIE, 2012). Even with three-quarter of the population living in urban areas, many cities in Europe are still expanding both spatially and in the population (United Nations, 2014). Such expansion results in the loss of fertile farming land in two ways: land encroachment due to urban sprawl (EEA, 2018), and abandonment because of lack of maintenance due to rural population loss (Bučienė, 2003). As the urbanisation process will continue to surge, the EU region is set to lose another 2.5 million hectares of land by 2030 (European Commission, 2017). To sustain the growing urban population with decreasing agrarian land, pressure on cities will mount for sourcing bio-based products from within. Brownfields can provide the opportunity for engaging a bio-based CE in cities given the lack of space in the dense urban fabric otherwise.

2.4 Bio-based production in Brownfields

Brownfields in the cities are often centrally located due to being previously used (Frantál et al., 2012). Hence, brownfields are the potentially lucrative location for future development but the main detriment of these lands remaining abandoned is the possibility of the actual and potential contamination (Coffin, 2003). Bio-based production in such undervalued locations not only provides opportunities for CE integration within the cities but also scope for providing much-needed vegetation in the often dense urban fabric (Loures & Panagopoulos, 2007; Loures, 2015). Contamination, proven or alleged, can also be limiting for certain types of bio-based production, such as food crops, but guidelines are being developed for safe practices (Hahn, 2013; US EPA, 2011). Other types of bio-based production, like cultivating biofuel feedstocks, can now even take place directly on contaminated soil (Enell et al., 2016).

Bio-based production will inevitably result in bio-based land uses and the urban context carries the possibility to heighten and diversify their purpose and necessity. Bio-based land uses in cities can be understood as Urban Greenspaces (UGSs), i.e. basically vegetated open spaces that provide an array of ES essential for maintaining the health and wellbeing of the urban dwellers and the urban environment (Perino et al., 2011; Ståhle, 2010). Urban Agriculture (UA) can be categorised under the UGS typology and in itself represents a selection of land uses with a different purpose and user intensity. UGS and UA are described briefly in the following sections.

2.4.1 Urban Greenspaces

The importance of UGS as an indicator of liveability has come to the forefront during the 19th century when the cities started to grow spatially and in population (Swanwick et al., 2003). With time, UGS in the cities have been growing both in number and variety. The wide variety of greenspaces that can be observed in European cities has been identified and categorised by Green Surge, a pan-European research collaboration of 24 institutes of 9 countries funded by European Union (Haase et al., 2015). Green Surge developed an inventory of 44 UGS elements that are further categorised in 8 categories (Cvejić et al., 2015). The study used existing pan-European data sets, the Urban Atlas, and Corine land use/land cover (CLC) to create the inventory (Copernicus EU, 2020a, 2020b; Cvejić et al., 2017). Brownfields can be considered listed as the UGS element 33: an abandoned, ruderal and derelict area (Cvejić et al., 2015). The inventory is summarised in Table 1.

Table 1. The UGS elements inventory. Adapted from Cvejić et al. (2015).

UGS categories	List of UGS elements
Building greens	UGS elements 1-6 Balcony green; Ground-based green wall; Facade based green wall; Extensive green roof; Intensive green roof; Atrium; Bioswale.
Private, commercial, industrial UGS, and UGS related to grey infrastructures	UGS elements 7-12 Tree alley, street tree, and hedge; Street green and green verge; House garden; Railroad bank; Green playground; School ground.
Riverbank green	UGS element 13 Riverbank green.
Parks and recreation	UGS elements 14-23 Large urban park; Historical park/garden; Pocket park; Botanical garden/arboreta; Zoological garden; Neighbourhood green space; Institutional green space; Cemetery and churchyard; Green sports facility; Camping area.
Allotment and community greens	UGS elements 24-25 Allotments; Community gardens
Agricultural land	UGS elements 26-30 Arable land; Grassland; Tree meadow/orchard; Biofuel production/agroforestry; Horticulture
Natural, semi-natural, and feral areas	UGS elements 31-37 Forest (remnant woodland, managed forests, mixed forms); Shrubland; Abandoned, ruderal and derelict area; Rocks; Sand dunes; Sandpit, quarry, pen cast mine; Wetland, bog, fen, marsh
Blue spaces	UGS elements 38-44 Lake, pond; River, stream; Dry riverbed, Rambla; Canal; Estuary delta; Sea coast

2.4.2 Urban Agriculture

Urban Agriculture (UA) is instrumental in instilling a degree of self-sufficiency in food production necessary for a resilient and sustainable city (Barthel & Isendahl, 2013) and can simply be explained as growing food crops within the city. It is practised by around the world by about 800 million people where most urban farmers grow food largely for self-consumption (FAO, 2019; Mougeot, 1999). UA varies in size, intensity and practice – from backyard vegetable patches to large allotment gardens with thousands of plots under city administration – all falling within the boundary of UA. From the Green Surge UGS inventory, 6 most commonly practised form of UA can be identified among the UGS elements: roof garden (UGS elements 4 and 5), house garden (UGS element 10), neighbourhood greenspace

(UGS element 19), allotment garden (UGS element 24), community garden (UGS element 25), and meadow orchard (UGS element 28), (Cvejić et al., 2015). Figure 6 below presents examples of such UA types.

Figure 6. Examples of different types of UA: a. Community garden in Toledo, Ohio; b. Allotment garden in Salinas, California; c. Private garden (house garden) in Toledo, Ohio; d. Easement garden (neighbourhood greenspace) in Melbourne, Australia; e. Rooftop garden in New York City; and f. Urban orchard (meadow orchard) in San Jose, California. Photos courtesy of P. Bichier (a, b, f), P. Ross (c), G. Lokic (d), and K. McGuire (e). From Lin et al. (2015).

2.5 Managing risks on urban brownfields

One of the biggest challenges for retrofitting brownfields in green land uses is the probable soil contamination of urban soils. Previous, ongoing, or even adjacent uses can result in continuous accumulation of contaminants on urban soil (Debolini, Valette, François, & Chéry, 2015; Luo, Yu, Zhu, & Li, 2012; Yousaf et al., 2017). Kennen & Kirkwood (2015) provide a classification of contaminants and the associated activities that can be a source of the pollution, summarised in Table 2. Contamination present in soil can be also transported to other environmental media (e.g. groundwater, surface water, air) and these contaminated sites pose a potential threat to human health and the environment (Luo et al., 2012; Öberg & Bergbäck, 2005; Scullion, 2006).

Table 2: Type of contaminants and typical source activities. Adapted from Kennen & Kirkwood (2015). The same grouping of the contaminants and colour coding is maintained in Figure 8.

Organic pollutants	
Contaminant group	**Typical source activities**
Petroleum	Fuel spills, leaky storage tanks, railway corridors, industrial activities
Chlorinated solvents	Dry cleaners, military activities, industrial activities
Explosives	Military activities, munition manufacturing and storage
Pesticides	Agricultural and landscape applications, railway and transportation corridors, residential spraying for pests
Persistent Organic Pollutants	Agricultural and landscape applications, former industry, atmospheric deposition
Other organic pollutants of concern (Glycols, pharmaceuticals, etc.)	Wastewater, embalming fluids, aircraft de-icing fluids
Inorganic pollutants	
Contaminant group	**Typical source activities**
Plant macronutrients	Wastewater, stormwater, agriculture and landscape application, landfill leachate
Metals	Industrial uses, mining, agricultural applications, roadways, landfill leachate, piments, lead paint, emissions
Salt	Agricultural activities, roadways, mining, industrial uses
Radioactive isotopes	Military activities, energy production

Humans might be risking exposure to contamination through various pathways such as dermal contact with contaminated media, ingestion of contaminated soil, consumption of food grown on contaminated soil, and inhalation of dust or vapours, etc. (Figure 7) (Scullion, 2006; SEPA, 1996). To ensure the safety of human health and ecosystems, ‘critical soil contamination’ or ‘guideline value’ are developed by national or international environment protection agencies to indicate contamination levels that do not pose an unacceptable risk to humans or ecosystems (SEPA, 1996). The Swedish Environment Protection Agency (SEPA), for example, provides generic soil guideline values and a calculation sheet to develop site-specific contaminated site remediation goals (SEPA, 1996, 2016).

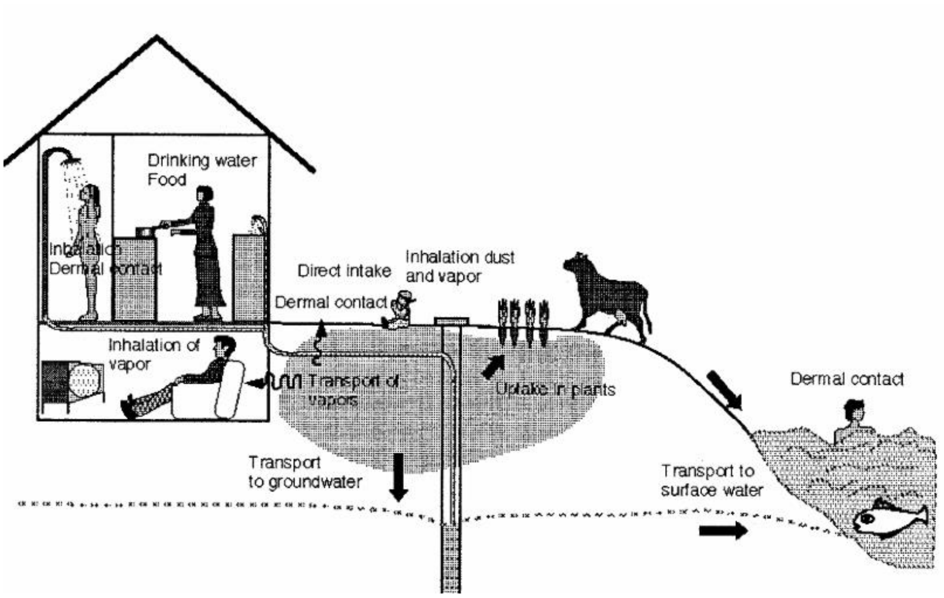


Figure 7: Possible contamination transport and exposure pathways for a brownfield. From SEPA (1996).

The management and decisions concerning retrofitting urban brownfields would require an in-depth assessment of the risk posed by the contamination present at the site (Öberg & Bergbäck, 2005). Risk assessments on brownfields essentially evaluate the risk of adverse effects on receptors, humans or ecosystems, as a result of exposure to the contamination present on the soil (Carlon et al., 2009). A tiered approach is often applied in contaminated site risk assessment, going from a simplified assessment to a more in-depth assessment of risks. The tiered approach for exposure risk assessment proposed by World Health Organization /International Programme on Chemical Safety (WHO/IPCS) (Meek et al., 2011; Silins et al., 2011) is briefly described below:

- Tier 1 assessment – Point estimates of generic exposure scenarios are used as a measure of risk to determine whether further assessment is necessary. These estimates are commonly based on broad, conservative scenarios addressing a range of somewhat similar uses with limited numbers of parameters being included.
- Tier 2 assessments – Risk assessment with better defined and specific scenario estimates with the incorporation of increasing amounts of measured data. Risk models can be used to synthesise data and compare with the estimates which are still considered conservative, but they are believed to be more realistic.
- Tier 3 assessments – Risk assessment with estimates of exposure factors or measured data that are probabilistic in nature This approach requires detailed information on exposure for the scenarios of interest for the relevant populations.

2.6 Bio-based remediation of Brownfields: Gentle Remediation Options

Apart from the widely discussed necessities and benefits of UGS, vegetation on brownfields is also a low-cost and effective solution to bring the derelict lands back in use (French et al., 2006). But most importantly, vegetation can also potentially provide effective remediation strategies for reducing the ecological and human health risks potentially posed by a contaminated brownfield (Kennen & Kirkwood, 2015). Plant-based remediation options are discussed as sustainable alternatives of the resource-intensive ‘dig and dump’ remediation (Carlon et al., 2009; EEA, 2014). The use of plants to manage the risk for human health and environment (i.e. phytoremediation) is part of the broader category ‘Gentle Remediation Options’ (GROs) that also includes remediation technologies using fungi and/or bacteria (Bardos et al., 2008; Onwubuya et al., 2009). Cundy et al. (2013) defined GROs as risk management strategies that result in a net gain (or at least no gross reduction) in ecological soil functions, as well as achieving effective risk management. Some common examples of GROs are briefly presented in Table 3. Plant-based remediation technologies are proven to be efficient for both contaminated soil and water, under specific circumstances, and at the same time helps to maintain the ecological functions (Cundy et al., 2013; Juwarkar et al., 2010).

Table 3. Examples of Gentle Remediation Options (GROs). Adapted from Cundy et al., (2016).

GROs	Descriptions
Phytodegradation/ phytotransformation	Use of plants (and associated microorganisms) to uptake, store and degrade or transform organic pollutants.
Phytovolatilisation	Use of plants to remove pollutants from the growth matrix, transform them and disperse them (or their derived products) into the atmosphere.
Phytoextraction	The removal of metal(loid)s or organics from soils by accumulation in the harvestable biomass of plants. When aided by the use of soil amendments (e.g. EDTA or other mobilising agents), this is termed ‘aided phytoextraction’.
Phytostabilisation	Reduction in the bioavailability of pollutants by immobilisation in root systems and/or living or dead biomass in the rhizosphere soil.
Rhizodegradation	The use of plant roots and rhizosphere microorganisms to degrade organic pollutants.

GRO technologies are best applicable for ‘green’ or bio-based reuse of a site, such as parks, biofuel production, and UA (Cundy et al., 2016; Erdem & Nassauer, 2013; Evangelou et al., 2012; 2015; Fässler et al., 2010; HOMBRE, 2014; Huang et al., 2011; Tripathi et al., 2016). The remediation potential for GRO, however, varies greatly based on the type of contaminant and GRO technology used across different time scales. Considering time constraints, promising phytoremediation applications are phytostabilisation, degradation of chlorinated solvents and petroleum products and evapotranspiration by phytovolatilisation (Figure 8) (Kennen & Kirkwood, 2015; OVAM, 2019). GROs, if properly implemented, can have a significantly lower deployment cost than conventional remediation techniques. Brownfields that are deemed unfit for development can thus still be beneficial, e.g. by harvesting the vegetation while simultaneously managing the risks posed to human health and the ecosystem.

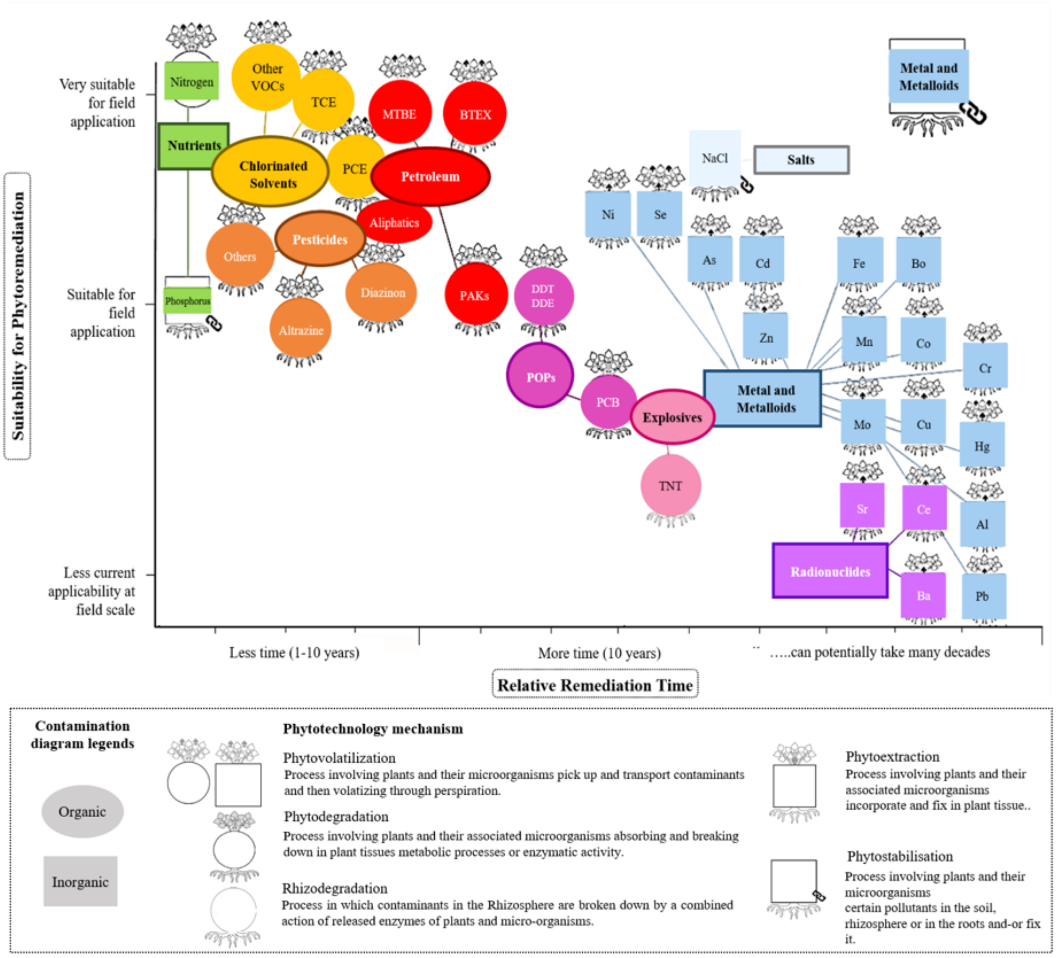


Figure 8: Overview of the phytoremediation potential of some contaminants and associated phytoremediation mechanism. From OVAM (2019)*; and Kennen & Kirkwood* (2015)*with a slightly adapted legend.*

2.7 Stakeholders involved in realising bio-based land use on urban brownfields

Immediate financial incentives often motivate the redevelopment of brownfields by turning them into residential, commercial, or industrial land use, but the recognition of green land use as an alternative end-use is growing (De Sousa, 2003, 2006). For example, over 19% of brownfields were retrofitted as greenspaces in the UK in the years between 1988 to 1993 (De Sousa, 2003). As greenspaces provide an array of services that are essential for city dwellers and the urban environment, a wide range of stakeholders are involved in greening the brownfields. Here, stakeholders can simply be defined as 'any individual or group of individuals who may have influence, or be influenced, on the realisation of the purpose of an organisation' (Freeman & McVea, 2005). Azadi et al. (2011) classify the relevant stakeholders for urban greenspace development and performance in three groups namely: state-all types of government from local to national level; private – includes banks, enterprise, manufacturers contributing to greenspace development; and society – ranging from an individual (e.g. philanthropists, residents) to groups (non-governmental organisations, community-based organisations, academic institutions). After investigating 42 urban greenspaces across the globe, Azadi et al. (2011) identify 'society' and 'state' to be of particular importance in urban greenspace performance as many get realised as public greenspaces.

Government, municipal or state, plays an important role in the realisation and later, the performance of the brownfields retrofitted as greenspace (Azadi et al., 2011; Doick et al., 2006). In a study analysing 12 examples of turning brownfields into greenspace in Toronto (Canada), De Sousa (2003) found all redevelopment projects to be carried out by the public sector, with the majority being attended by the parks department of the municipal government. Involvement of the stakeholder group, 'society', is also key in realising urban greenspaces as they are designed to serve the public (Azadi et al., 2011). The increased involvement of NGOs in public place development across Europe and the USA can be attributed to the dissatisfaction with regulatory planning failures (Azadi et al., 2011). Public participation in the planning process can stabilise future use by creating collective awareness (Azadi et al., 2011; Erickson, 2006). It can be also argued that increased public involvement in urban greenspace development and management can increase the sense of ownership, sense of belonging, and willingness to maintain urban greenspaces among the public (Azadi et al., 2011; Erickson, 2006).

Considering the potential of using greening as a medium for managing the risks posed to human health and the environment by the contamination of the brownfields, the involvement of additional groups of stakeholders becomes necessary. For instance, regulatory authorities monitoring the safety of the brownfield site and experts in the phytoremediation technologies are needed if bio-based remediation is to be considered in the brownfield redevelopment (Cundy et al., 2013).

3 METHODOLOGY

This chapter provides the methodology adopted to achieve the research objectives. It is divided into four phases: framework support, realisation, application, and reflection. The phases are outlined with steps taken to reach the phase target.

The process for developing a bio-based land use framework, the application of the framework in cases, and reflections on future work is structured into nine different steps divided into four methodological phases, see Figure 9.

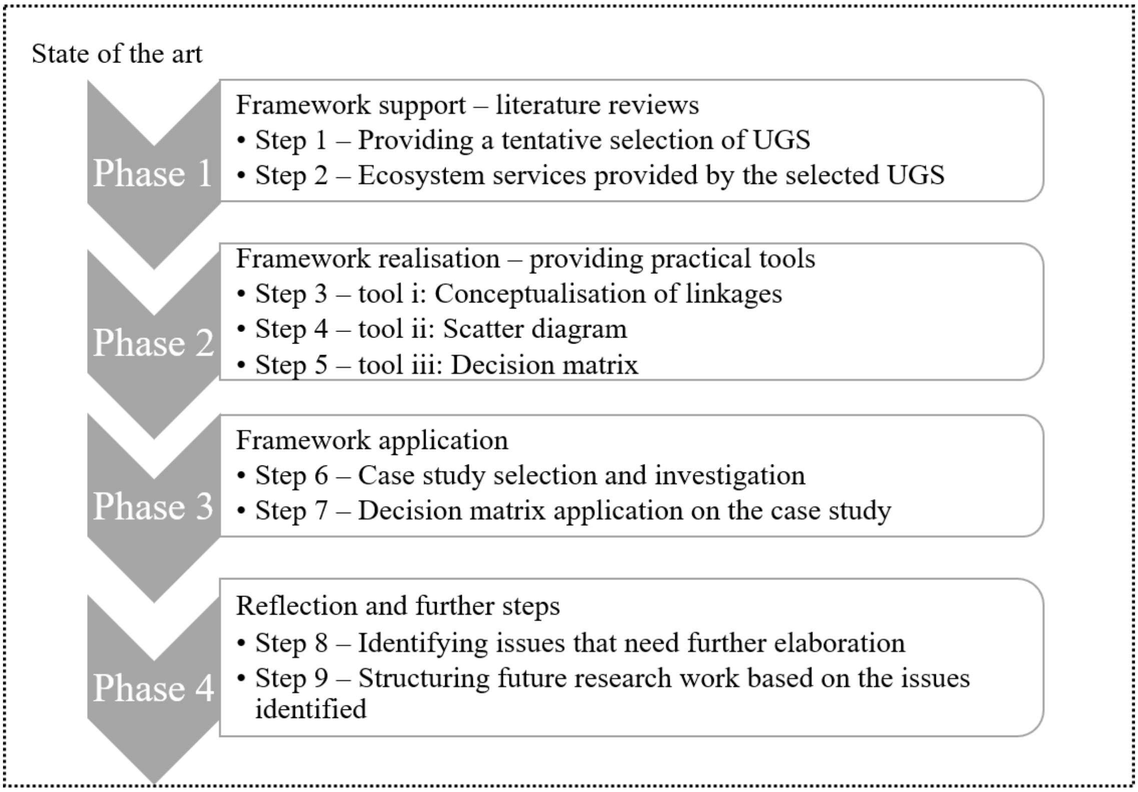


Figure 9. Methodology for developing, applying, and reflecting on the proposed bio-based land use framework.

3.1 Phase 1 – Framework support

The first phase of the methodology created the base for the framework building on the issues elaborated in the theoretical background (Chapter 2) by identifying relevant green land use elements as well as the benefits of these green land uses in terms of ES.

Step 1 - Providing a tentative selection of UGSs with potential for bio-based production on brownfields (Section 4.1.1). From the 44-item categorisation proposed by the Green Surge project (Haase et al., 2015) (Section 2.4.1), a tentative selection of 15 UGS elements has been identified to examine as potential future bio-based land uses on brownfields.

Step 2 - Linking the identified UGSs to the different types of ecosystem services they may provide (Section 4.1.2). The 15 UGSs selected from the Green Surge inventory was further investigated in terms of provision of ES. A literature survey was performed to present an inexhaustive list of ES that can be derived from the list of the UGSs potentially relevant for brownfields. The literature review was carried out using the Scopus database and was extensive but limited to the 15 specified UGSs, using the combination of search word "ecosystem services" AND the labels of the final set of 15 UGSs.

3.2 Phase 2 – Framework realisation

The second phase of the methodology aimed at conceptualising the bio-based land use framework by providing a set of practical tools consisting of a conceptualisation of linkages between different types of GROs, a scatter diagram over interventions and realisation times, and a decision matrix to assess UGS potential of a site. The basis of the framework is the literature explored in the previous steps and builds upon, but is not limited to, phytoremediation potential mapping (Kennen & Kirkwood, 2015; OVAM, 2019), the Greenland decision support framework (Cundy et al., 2015), the urban vacant land typology (Kim et al., 2018), models developed by Sustainable Brownfield Regeneration project (Ferber et al., 2006), the stages of brownfield redevelopment (Loures & Vaz, 2018), and the system of information categories for brownfield development (Rizzo et al., 2015).

Step 3 - Conceptualising the linkages between different types of GROs and prospective UGS uses, taking soil contaminants and time frames into account (Section 4.2.1). The resulting first tool of the framework is a conceptual diagram illustrating these linkages.

Step 4 – Synthesising required interventions, time frames and permanency of UGSs on brownfields (Section 4.2.2). The second tool of the framework is a scatter diagram that retains some features of the conceptual framework to provide a graphical representation of 15 UGS opportunities on brownfields taking into consideration the required intervention level, realisation time, and permanency.

Step 5 - Identifying the site-specific basic conditions affecting the viability of UGSs and assessing these conditions across different types of UGSs relevant for brownfields (Section 4.2.3). The third tool of the proposed framework is a decision matrix aimed to support an assessment of the potential for the different UGSs at a specific brownfield, by analysing whether the site fulfils a number of basic conditions.

3.3 Phase 3 – Framework application

The third phase of the methodology aimed to implement the tools developed in phase two in a case study to investigate the applicability of the framework.

Step 6 – Selecting and describing an appropriate case study for the application of the tools developed within the framework (Section 4.3.1). A case study was selected based on a set of criteria to secure the study to be relevant:

- To be a brownfield, i.e. have actual or potential contamination issue that poses a certain of risk; ecological, human health, or both.
- To have a certain type of survey performed (e.g. geographical, contamination) with access to the collected information.
- To be local so that data can be verified and recollected if necessary.
- To have a prospect of future development so that the framework application can generate relevant information.

Step 7 – Applying the decision matrix on the case study to determine the appropriate bio-based land use to be developed in future (Section 4.3.2). The decision matrix was applied using the relevant information gathered on the case study in the previous step.

3.4 Phase 4 – Reflections and further steps

The final phase of the methodology reflected on the previous phases to identify issues that need to be investigated further and to structure future work based on the findings.

Step 8 – Identifying issues that require further elaboration for the appropriate realisation of bio-based land uses on brownfields (Chapter 5). There may be issues that were loosely addressed or not covered at all in the framework, but still are essential for the UGS to be successful as a future land use on the brownfield. By reflecting on the framework development and application on a case study, such issues were recognised.

Step 9 – Structuring future research work based on the identified issues that are essential for a successful realisation of bio-based land uses on brownfields (Chapter 5). This is about elaboration on the essential but missing issues, how they can be addressed and incorporated for a successful transition from brownfields to bio-based land use. This essentially resulted in the outlining of the future scope of work that will be continued as the next part of the ongoing research work.

4 RESULTS

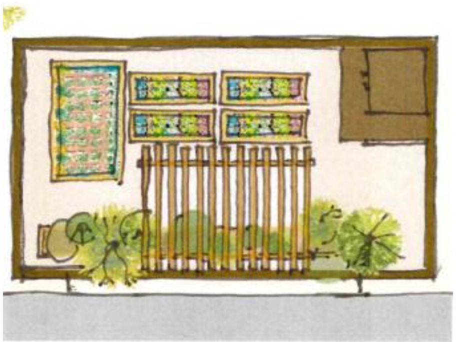
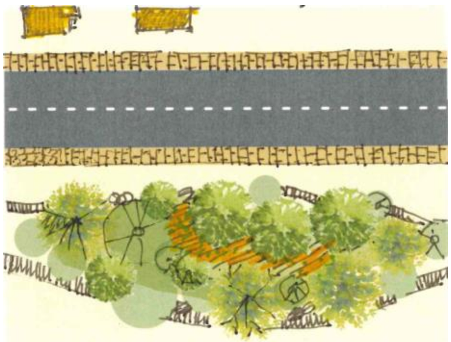
This chapter summarises the results of the first three phases of the research methodology. It starts with framework support, outlining the selected UGSs as potential bio-based land use options and the ES provided by the UGSs as bio-based products. Next, a bio-based framework is suggested consisting of three tools. Among these tools, the decision matrix is then applied to the case study, Polstjärnegatan in Gothenburg, Sweden.

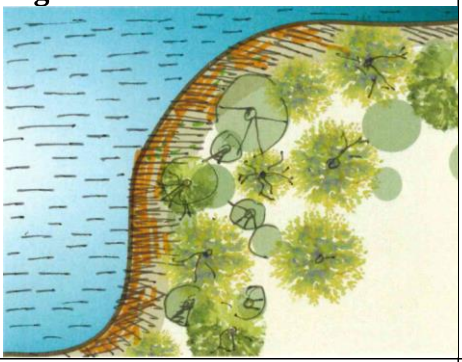
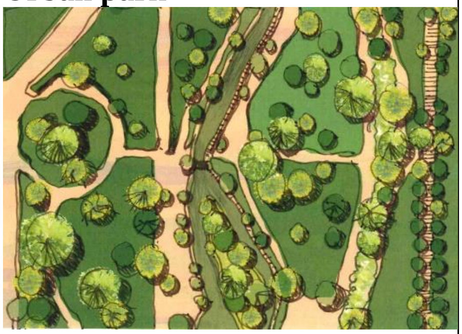
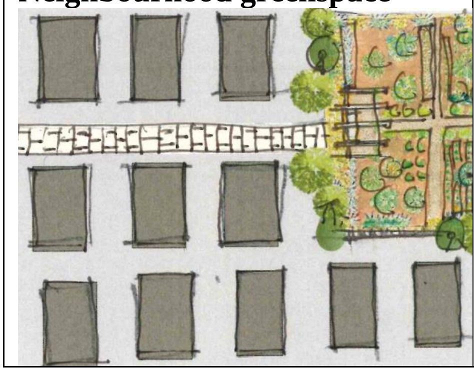
4.1 Framework support

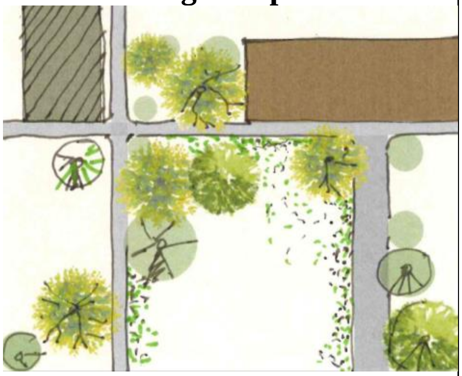
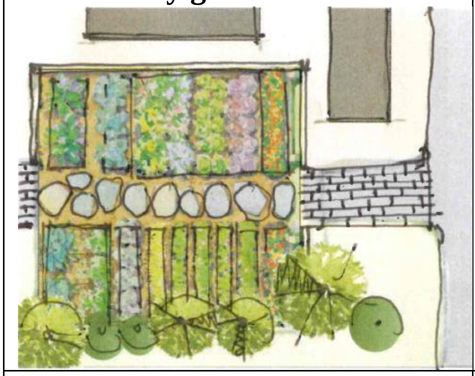
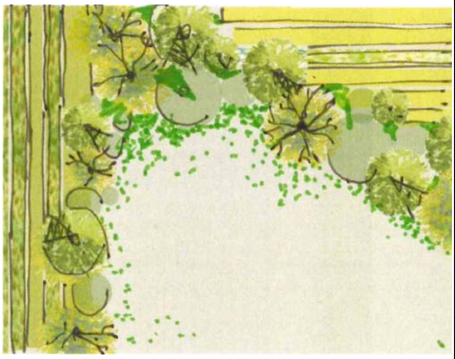
4.1.1 Selected UGSs as bio-based land use options

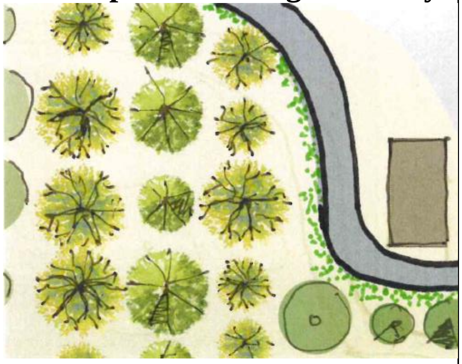
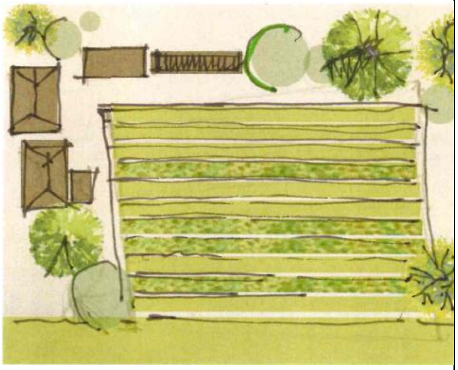
The UGS inventory created by Green Surge (Cvejić et al., 2017; Haase et al., 2015) has a total of 44 UGSs (in detail, Section 2.4.1) and among them, 15 has been selected to be investigated in this study as potential bio-based land use options at brownfields. The selected 15 UGSs are elaborated in Table 4 below.

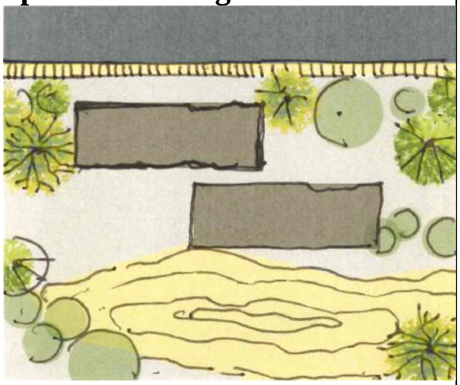
Table 4. The studied list of potential future green land use on urban brownfields derived from the Urban Greenspace (UGS) inventory by Green Surge (Haase et al., 2015). Illustrations are created by the author.

UGS name	Description
Building greens 	Building greens refer to plants on a balcony, roof, or any place within a building (Cvejić et al., 2017). They are mostly potted plants but the use of planter boxes are not uncommon, especially for rooftop gardening if the building is large enough (Cvejić et al., 2017; Livingroofs, 2020).
Bioswale 	Bioswales are defined as ‘vegetated, shallow, landscaped depressions designed to capture, treat, and infiltrate stormwater runoff as it moves downstream’ (NACTO, 2020). Bioswales are greater in length than width, often designed with engineered soils and vegetated mainly with both drought and flood withstanding plants (SSSA, 2020).

Riverbank green/Riparian vegetation 	Riparian vegetation or riverbank greens, also known as fringing vegetation, grows along banks of a waterway extending to the edge (WA Water, 2020). Wetland vegetation can include trees, shrubs or a ground layer consisting of herbs, grasses or their combination in shallow aquatic areas while submerged aquatic vegetation can be found in deeper wetlands (Wetland Info, 2020). For public use, these areas usually made accessible with foot or bike paths (Cvejić et al., 2017).
Urban park 	Urban parks are characterised as larger green areas within a city intended for recreational use by urban population and can include different features, such as trees, grassy areas, playgrounds, water bodies, ornamental beds, etc. (Cvejić et al., 2017).
Historical park/garden 	Historical parks are similar to urban parks, but with elements that are necessary to ensure the heritage status and thus requires distinct management (Cvejić et al., 2017). Examples of abandoned industrial sites turned into parks include the Seattle gasworks park, the Duisburg Nord park, and the Emscher Park.
Neighbourhood greenspace 	Neighbourhood greenspaces are characterised by Cvejić et al. (2015) as ‘semi-public green spaces, vegetated by grass, trees and shrubs in multi-story residential areas.’

Institutional greenspace 	Institutional greenspaces are green spaces in and around public and private institutions and corporation buildings (Cvejić et al., 2017).
Allotment 	Allotments are small parcels rented to people for mostly non-commercial production of fruits, vegetables, flowers, etc. (Cvejić et al., 2017; NSALG, 2020). Allotments were first conceptualised in the 19^{th} century to help the urban labouring poor to cultivate their food, but more recently the recreational purpose is also dominant (Boström, 2007; NSALG, 2020). As of 2007, there are about 42,000 allotment renters in Sweden alone (Boström, 2007).
Community garden 	Community gardens are defined as sections of land collectively gardened by a community for the specific purpose of growing fruits, vegetables and/or herbs for self-consumption (Egli et al., 2016; Ginn, 2012).
Grassland 	Grasslands are open and mostly flatlands with a grass cover that exists in every continent except Antarctica and relative to the definition, 20-40% of the land area of the world consists of grasslands (Nunez, 2019). Grazing land for cattle, as well as grass lawns, are also considered in this category.

Tree meadow/meadow orchard 	Tree meadows or orchard meadows are composed of scattered fruit trees within semi-natural grassland which in turn can be used for grazing (i.e. mixed agricultural use) (Cvejić et al., 2017; Plieninger et al., 2015; Rabenhorst, 2020). Scattered trees cover almost 55,000 km^2 of farmlands in Europe (Plieninger et al., 2015).
Biofuel production/agroforestry 	Biofuel production refers to land specifically devoted to energy crop production, such as short rotation coppice or poplar (Cvejić et al., 2017). Some food crops can essentially be used as biofuel feedstock and in Europe, most of the cultivation (80-85%) of rapeseed is for biodiesel production (Ericsson et al., 2009).
Horticulture/arable land 	Horticulture or arable land are defined as land devoted to commercial production of vegetables, flowers, berries, etc. (Cvejić et al., 2017).
Shrubland 	Shrublands are made of shrubs (i.e. short trees or hedges) with grass covers in between and thrive on areas where the climate is not favourable to support tall trees (NASA Earth Observatory, 2020).

Spontaneous vegetation	
	Spontaneous vegetation refers to spontaneously occurring pioneer or ruderal vegetation, more specifically those occurring on brownfield sites (Cvejić et al., 2017).

4.1.2 Products of Urban Green Spaces: Ecosystem Services

ES can be understood as 'the benefits human population derive, directly or indirectly, from ecosystem functions' (Costanza et al., 1997). The values and services provided by ecosystems can be categorised in many ways and the categorisation provided by The Economics of Ecosystems and Biodiversity (TEEB) is among the most widely used ones:

- Provisioning services – food, raw materials, freshwater, and medicinal resources;
- Regulating services – local climate and air quality, carbon sequestration and storage, moderation of extreme events, waste-water treatment, erosion prevention and maintenance of soil fertility, pollination, and biological control;
- Habitat or supporting services – habitats for species and maintenance of genetic diversity; and
- Cultural services – recreation, mental and physical health, tourism, aesthetic appreciation, an inspiration for culture, art and design, and spiritual experience and sense of place (TEEB, 2020).

UGS provides many essential non-material educational and recreational benefits to the urban dwellers and, most importantly, greenspaces in the cities can be directly associated with the overall wellbeing of the citizen (Chiesura, 2004; Maes et al., 2016). Still, only the provisioning services, such as food and biomass, has been part of the discussion so far as a biological resource in the bio-based CE (European Commission, 2019; TEEB, 2010). Limiting the discourse only to provisional services, especially in the cities, would be constraining in capturing many other vital services provided by greenspaces in cities. A literature review was carried out to better understand the extent of ES that can be provided by the 15 selected UGSs. The result is summarised below in Table 5.

Table 5. Ecosystem services of the studied list of potential future green land use.

Building greens	
Provisioning services	
Food	A study on the city of Bologna (Italy) shows rooftop gardens could provide more than 12,000 t/year of vegetables, satisfying 77 % of the inhabitants' requirements (Orsini et al., 2014).
Regulating services	
Local climate and air quality control	A literature review on urban green roofs finds their potential in cooling at street level to be 0.03–3 C° and in pollution control, such as small particle removal, 0.42–9.1 g/m^2 per year (Francis & Jensen, 2017).
Energy consumption control	Urban green roofs can potentially impact annual building energy consumption from a 7% increase to 90% decrease by contributing to indoor cooling, surface temperature differences and heat flux change (Francis & Jensen, 2017).
Rainwater retention	Extensive green roofs can retain almost 75% of rainwater (Scholz-Barth, 2001; Villarreal & Bengtsson, 2005).
Supporting services	
Biodiversity conservation	Green roofs can provide sites for bee conservation in urban areas if planted with native plants and foraging resources designed to accommodate bees (Tonietto et al., 2011).
Bioswale	
Regulating services	
Nutrient cycling and waste-water treatment	A study in residential areas in California (USA) finds bioswales to significantly reduce contaminants from stormwater, including suspended solids (81% reduction), metals (81% reduction), hydrocarbons (82% reduction), and pyrethroid pesticides (74% reduction) (Anderson et al., 2016).
Reduction in stormwater runoff	Another study on a bioswale on a parking lot in Davis (USA) reveals it to reduce runoff by 88.8% and total pollutant loading by 95.4% (Xiao & McPherson, 2011).
Riverbank green	
Provisioning services	
Food (indirect)	Riverbank greens provide habitat and support aquatic life (Ozawa & Yeakley, 2007) which in turns supports fishing activities (Ricaurte et al., 2017).
Raw materials	Riverbank greens can support production of vegetative biomass (Koopman et al., 2018).
Regulating services	
Carbon sequestration and storage	A study of a riverbank green in Mexico suggests that it can store 1.5 times more carbon than oak forests (Mendez-Estrella et al., 2017).

Nutrient cycling	Multiple studies show that riverbank greens act as a protective buffer between the waterbody and land-based activities both by filtering nutrients and by trapping nutrients for groundwater (de Sosa et al., 2018; Hill et al.. 2006; Kauffman et al., 1997; Meek et al., 2010; Mikkelsen & Vesho, 2000; Ozawa & Alan Yeakley, 2007; Pert et al., 2010; Tickner et al., 2001**)**.
Bank stability and flood attenuation	Riverbank greens help in trapping sediment during flooding events and form soil, slow down and spread flood water, increase bank stability and minimise soil loss in watercourses (de Sosa et al., 2018; Kauffman et al., 1997; McKergow et al., 2004; Meek et al., 2010; Mikkelsen & Vesho, 2000; Ozawa & Alan Yeakley, 2007; Pert et al., 2010; Tickner et al., 2001; Zaimes et al., 2007).
Water temperature regulation	Riverbank greens assist in regulating the watercourse temperature by providing shading (de Sosa et al., 2018; Naiman et al., 2010; Pert et al., 2010; Pusey & Arthington, 2003).
Supporting services	
Habitat and maintenance of species (aquatic and terrestrial)	Riverbank greens provide habitat and support for aquatic life, a refuge for wildlife in urban and rural areas, and contribute to species richness and biodiversity by maintaining wildlife movement corridors (de Sosa et al., 2018; Gray et al., 2014; Matos, Santos et al., 2009; Naiman et al., 2010; Ozawa & Alan Yeakley, 2007; Pert et al., 2010).
Cultural services	
Recreation and aesthetic appreciation	Riverbank greens help in increasing the aesthetic value of agricultural and urban landscapes as well as provide places for outdoor activity (C. S. Meek et al., 2010; Postel & Carpenter, 1997).
Culture and sense of place	For the locals of Central Benin, riverbank greens are a source of cultural importance and traditional knowledge and provide cultural identity and a source of belonging (Ceperley, Montagnini, & Natta, 2010; Ricaurte et al., 2017).
Urban park/Historical park/Institutional greenspace	
Regulating services	
Carbon sequestration and storage	The urban areas covered by parks, gardens, tree-lined avenues, sports fields, and hedges are important sinks for carbon dioxide (CO_2) by storing carbon through photosynthesis to form plant biomass (Gratani et al., 2016).
Air quality maintenance	A study in Pudong district, Shanghai (China) demonstrates the effect on air pollution by urban parks: 9.1% of total suspended solids (TSP) removal, 5.2% of SO_2 removal, and 6% of NO_2 removal (Yin et al., 2011).
Temperature regulation	A study conducted on 15 mid-size urban parks in Athens (Greece) shows that the cooling provided by the parks was varying between 3.3 and 3.8 K/h (Skoulika, Santamouris, Kolokotsa, & Boemi, 2014).
Supporting services	
Habitat and maintenance of species	A review covering 62 papers from 25 different countries shows that urban parks are consistently among the most species-rich types of urban green spaces and contain a large share of exotic species (Nielsen et al., 2014). Another study in Bangalore (India) shows that 77% of the vegetation in urban parks belongs to exotic species (Nagendra & Gopal, 2011).
Seed dispersion	A study conducted on the Stockholm National Urban Park (Sweden) that is home to one of the largest population of giant oaks shows that the

	replacement cost (RC) of the seed dispersion services provided by a pair of Eurasian Jay (living in the urban park) is between SEK 35,000 – 160,000 (Hougner et al., 2006).
Cultural services	
Healthy living	Urban park experience may reduce stress; provide a place to relax, enjoy peacefulness and tranquillity; and rejuvenate the city inhabitants (Chiesura, 2004; Gratani et al., 2016; Ulrich, 1981).
Overall wellbeing	A study covering 44 US cities shows that the quantity of parks (measured as the percentage of the city area covered by public parks) is among the strongest predictors of the overall wellbeing of the citizens, driven by parks' contribution to the physical and community wellbeing (Larson et al., 2016).
Neighbourhood greenspace/Allotment/Community garden	
Provisioning services	
Food products	Gross benefit from food products per allotment plot in Manchester (UK) can be up to £698 in a year. Apart from plant produce, live stocks such as chickens are also kept in the allotment garden (Speak et al., 2015). Community gardeners in New York City (USA) manage to supply a large share of their households' food product needs with the garden produce (Gregory et al., 2016).
Food security	Urban allotment gardens are a historically important source of urban resilience against food dependence, extreme weather events or even climate change contributing to long-term food security (Barthel & Isendahl, 2013; Lwasa et al., 2014; Speak et al., 2015).
Medicinal herb and tea	Several allotments in Manchester are found to be cultivating medicinal herbs both for medicine and culinary purpose (Speak et al., 2015).
Regulating services	
Soil health	A study in the UK shows that soils in allotment gardens have 32% higher soil organic carbon (SOC) concentrations and 36% higher Carbon: Nitrogen ratios than pastures and arable fields (Edmondson et al., 2014).
Stormwater retention	The community gardens of New York City, USA are expected to be retaining 45 million litres of stormwater due to their raised beds (Gittleman et al., 2017).
Supporting services	
Habitat and maintenance of species	A study found that the parks in Manchester (UK) to have about 65% of the species richness of Manchester allotment gardens (Speak et al., 2015). Allotment gardens in Poznan (Poland) also show to have more native varieties of flora (Borysiak et al., 2017). A study in Stockholm (Sweden) found the variability of bumblebee visits in urban allotment gardens to be higher than in peri-urban ones (Ahrné et al., 2009).
Cultural services	
Nature education	Allotment and community gardens are prime spots for education on nature and sustainable food production techniques among community groups in cities (Breuste & Artmann, 2015; Chan, DuBois, & Tidball, 2015; Middle et al., 2014; Speak et al., 2015).
Health benefits from	Allotment and community gardens provide alternative and more accessible physical activities, beneficiary especially for the elderly population (Middle et al., 2014; Speak et al., 2015).

physical activities	
Knowledge production	A study in Sub-Saharan Africa found community clinic gardens to be a place for co-production of knowledge on growing nutritious food by the involvement of multiple stakeholders (Cilliers et al., 2018).
Recreational benefits	The allotment gardens in Poznan (Poland) are treated like recreational retreats during the summer months (Speak et al., 2015). In Germany and Austria, allotment gardens are also considered as recreational areas in planning regulations (Breuste & Artmann, 2015).
Grassland/Shrubland	
Provisioning services	
Food, raw materials, medicinal plants	Grasslands are commonly used as grazing fields by many communities as well as providing games for hunting, thatching materials for roofs and walls, medicinal plants, and fruits (Dzerefos & Witkowski, 2001; Egoh et al., 2011; Friday et al., 1999; Miller, 2005; Sala & Paruelo, 1997; Wen et al., 2013).
Regulating services	
Carbon sequestration and storage	Grasslands in various regions act as soil carbon storage, at the same time providing sites for tree plantation to sequester aboveground carbon (Farley et al., 2013; Farley et al., 2004; Hofstede et al., 2002; Paul et al., 2002). A study across six European shrublands shows that the net carbon storage in these systems ranged from 1,163 g C/m^2 to 18,546 g C m^{-2} (Beier et al., 2009).
Water supply and storage	Grasslands play an important role in water supply by mitigating and storing runoff waters (Egoh et al., 2011; Farley et al., 2013; Kotze & Morris, 2001).
Supporting services	
Habitat and maintenance of species	Grassland restorations in China show improved biodiversity by 32.44% (Egoh et al., 2011; White et al., 2000).
Cultural services	
Maintenance of culture and tradition	Alpine grasslands play an important role in Tibetan culture and the maintenance of tradition (Dong et al., 2010; Wen et al., 2013).
Meadow orchard	
Provisioning services	
Food provision	In Berlin, fruit trees are abundantly used for an ornamental reason but can potentially be used for consumption as the fruits are found to pose no additional risk from pollution if washed thoroughly and stored properly (von Hoffen & Säumel, 2014).
Supporting services	
Habitat support	A study suggests that with proper maintenance of living ground cover in almond orchards, these could provide habitats for pollinators like native bees (Saunders et al., 2013). Orchards, abandoned and functioning, are found to provide habitat and refuge to birds (Myczko et al., 2013).

Biofuel agroforestry	
Provisioning services	
Raw materials (Biofuel and biomass)	Jatropha plantation in a study shows to produce 230 kg biodiesel replacement in fossil fuel per hectare as well as producing 4000 kg of plant biomass per year (Wani et al., 2012). Agroforestry intercropping of woody and perennial bioenergy crops increases combined biomass yield and reduce the cost of production (Haile et al., 2016).
Regulating services	
Carbon sequestration and storage	In 4 years, Jatropha cultivation is showed to have increased the carbon content by 19% resulting in 25000 kg carbon sequestrated per hectare (Wani et al., 2012).
Nutrient cycling and climate change support	Strategically planted willow buffers can improve the net global warming potential (GWP) and eutrophication potential (EP) of the soil, as well as cut back nutrient loading to waters (Styles et al., 2016).
Water supply and storage	The water holding capacity of the soil under Jatropha plantations showed to increase by 35% compared to adjacent soils (Wani et al., 2012).
Supporting services	
Habitat and maintenance of species	Agroforestry with combining grass cover and perennial biofuel plantings is expected to support a larger and more diverse bee community, as well as many other beneficial insects (Gardiner et al., 2010).
Horticulture	
Provisioning services	
Food and raw materials	Horticulture contributes directly to urban economics through the production and sales of horticulture products (Lohr & Relf, 2014).
Spontaneous vegetation	
Cultural services	
Recreational purpose	Based on expert and resident interviews conducted in Berlin (Germany), Hofmann et al. (2012) suggest that urban residents generally accept urban derelict land as recreational areas, if they are provided with minimum maintenance and accessibility.

4.2 A framework for assessing the bio-based land use potential of brownfields

4.2.1 A conceptualisation of linkages between land use, soil contaminants and time

As a first tool of the bio-based land use framework, the viabilities of future green land uses on urban brownfields can be conceptualised as a relationship between prospective bio-based land uses and their gentle remediation potential over time for different types of soil contaminants (Figure 10). A specific UGS will interplay with a set of GROs which will improve the soil condition, making room for new types of UGSs to take place. The new UGS, in turn, will facilitate the possibility of adopting new types of GROs that, subsequently, will make another UGS possible, and so on. For example, Land use 1 in Figure 8 can be building greens that can be practised on a sealed surface until a more intensive remediation process is scheduled (Whittinghill & Rowe, 2012). Bioswales and biofuel agroforestry are UGSs that potentially can be implemented on contaminated sites while assisting in the remediation of the soil (Andersson-Sköld et al., 2014; Xiao & McPherson, 2011), for example being Land use 2. Natural land uses, such as riverbank greens, have shown effectiveness in cycling, trapping, filtering or stabilising certain types of contaminants (de Sosa et al., 2018) and at the same time, they can be paired with GRO technologies amplifying and accelerating the remediation capabilities. Moreover, UGSs can be developed as a temporary measure bringing the abandoned land back in use immediately while a more extensive remediation project can be planned or funded. However, more extensive agricultural practices, such as horticulture and meadow orchards, need the soil to be sufficiently safe for food production (for example Land use n-1).

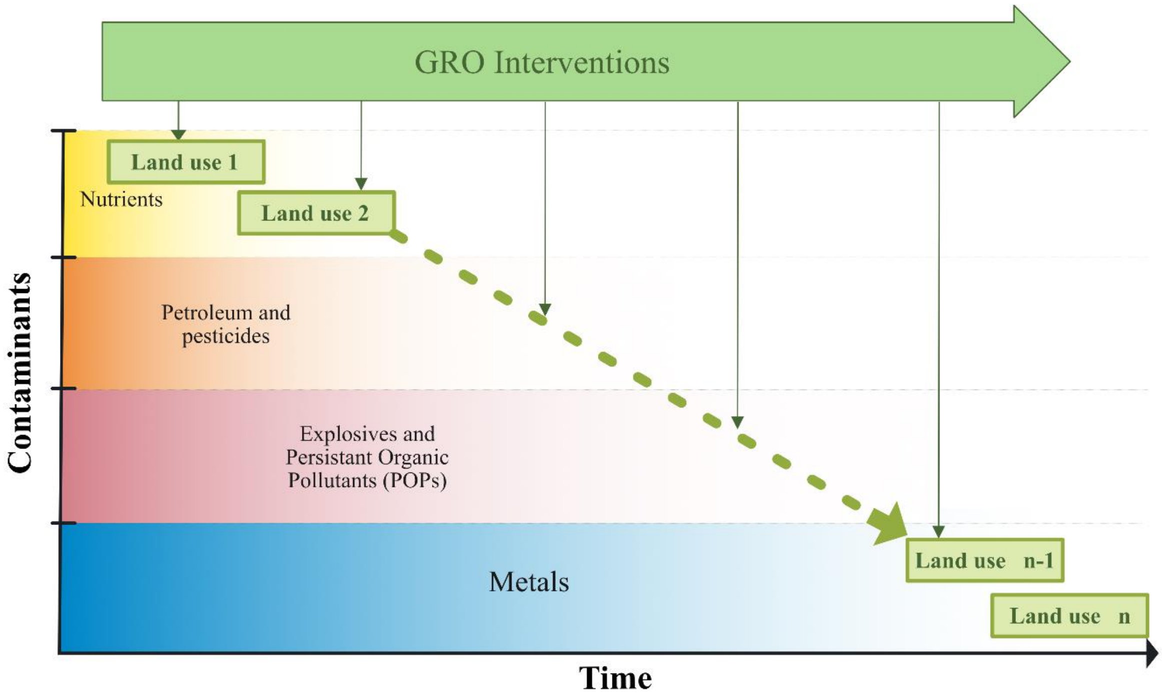


Figure 10. Conceptual framework showing how different types of gentle remediation options (GRO) relate to prospective UGS land uses, taking soil contaminants and time frames into account.

4.2.2 Bio-based land use across different timeframes and degrees of required interventions

The second tool of the bio-based land use framework puts different UGSs in the perspective of interventions and time frames required for UGS implementation. The scatter diagram in Figure 11 is developed as an intermediate step to provide a graphical representation of different bio-based land uses (the studied list of Table 3) on brownfields. The diagram is elaborated as follows:

- Potential future green land uses (the identified UGS elements in Table 3) are analysed in the context of two basic requirements: interventions and time needed to realise them.
- The Y-axis of the diagram represents the required intervention which can be understood as resource intensity requirements of e.g. information, stakeholder commitment and capital. This acts as a general understanding of the bulk of work entailed by the upcoming development The vertical position of each land-use in the figure depicts the relative scale of intervention required – low, medium or high – for a UGS to be realised.
- The X-axis of the diagram indicates the relative time frame in years (Y) estimated for realising the future green land use. This axis is scaled in three parts: immediate (<2 Y), intermediate (2-10 Y) and long term (>10Y). The land uses are positioned horizontally according to the expected time needed for implementation. Again, it needs to be stressed that the time frame provided here is for initial understanding as it is expected to be impacted heavily by site-specific criteria, such as site conditions, size, location, and not least concentrations and types of contaminants.
- The diagram finally incorporates the permanency of the green land uses based on their position in the diagram. The more time and resources required, the more likely it is for the green land use to be more permanent. Vice versa, land uses with low time and resource requirement can be considered as more temporary interventions.

The potential of UGSs depends on required intervention and the time needed to realise the land use. A provisional positioning of the selected types of UGSs (Figure 11) can be accomplished based on the literature but will ultimately be affected by local conditions.

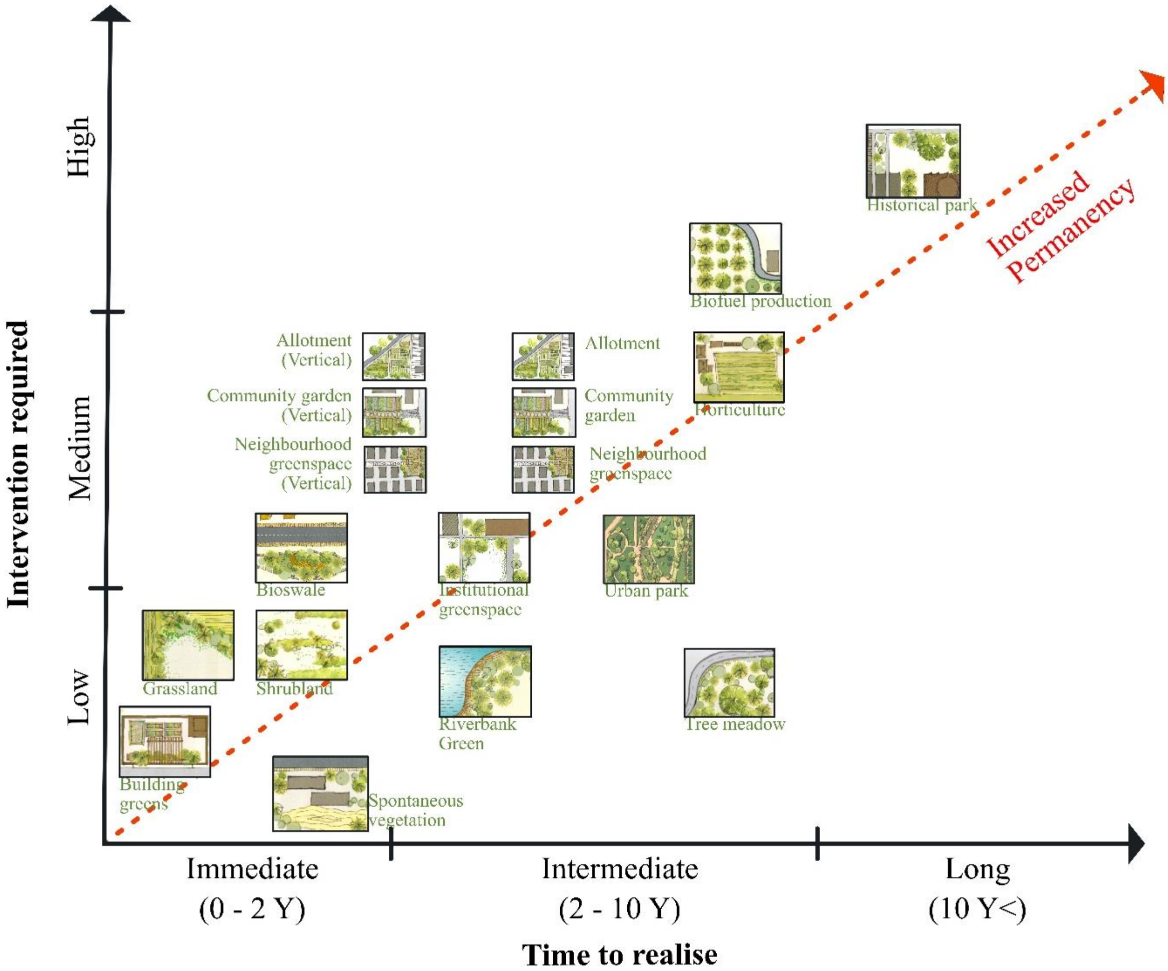


Figure 11. The scatter diagram of future bio-based land use on urban brownfields with provisional positioning of the icons.

Building greens can be immediately incorporated in the site with no or little modification, given that there are existing built structures on site (Castleton et al., 2010). Provided with enough structural integrity, roofs can also be fitted with gardens that can grow without the concern of contamination of the base soil (Whittinghill & Rowe, 2012). Permanency is not an issue considering the often temporary status of built structures on brownfields, but they can be kept if desired.

When brownfields remain abandoned for a significant period of time, a cover of spontaneous vegetation is often developed on-site (Mathey et al., 2018). If the site is too contaminated for spontaneous growth, carefully selected perennial species of grass can still be used to create a grass cover that can act as phytostabiliser (Vangronsveld et al., 1995). Similarly, shrubland can be achieved on contaminated sites with similar consideration but it is expected to take longer for the bush cover to develop (Velli et al., 2019). Again, permanency is not a primary concern, although spontaneously developed biodiversity resulting from ruderal vegetation might lead to calls for conservation (Planchuelo et al., 2019).

Riverbank greens with their riparian vegetation similarly might not require as intensive interventions but as the site areas are expected to be much larger, this would influence both capital requirement and time. Furthermore, the presence of rivers also brings the risk of increased exposure to contaminants due to flooding events (Pavlović et al., 2019) which potentially requires significant preventive interventions.

UGSs that require communal agricultural practices (e.g. neighbourhood greenspace, community gardens, allotments) are subjected to stricter regulations due to the added contamination exposure from consumption of food grown on-site, as well as active user exposure (Le Guern et al., 2018). Such practices taking place directly on the soil would need safety assurance for both users and the environment (SEPA, 1996). If the soil is sealed or covered, agricultural practices can take place vertically (e.g. in raised boxes) which is considered to be a safe practice by the United States Environmental Protection Agency (US EPA, 2011). Also, community-based interventions need to be scaled according to the multitude of users involved and the required and/or aspired levels of community engagement, especially since participating children may directly ingest soil (Ljung et al., 2007).

Tree meadows or orchards are UGSs that mainly consist of fruit trees which will take a long time to mature, have varied fruiting times, and require more intensive care, such as pruning (Karkee & Adhikari, 2015). Even if the fruit can potentially take up contaminants (Trapp, 2007), a study of fruit orchards in cities shows that by maintaining simple safety measures, such as thorough washing and safe storage, safety standards for the produce can be achieved (von Hoffen & Säumel, 2014). Horticulture targets crop production for commercial purposes which requires the soil to be safe and the food produce to meet set health standards to be marketable. If the soil is healthy, this does not necessarily need more interventions, but if not, it might require different types of detached cultivation technologies (e.g. vertical agriculture or hydro/aero/aquaponics)(Armanda, Guinée, & Tukker, 2019), or simply time for the brownfields to be safe enough to engage in such active use.

Biomass production can easily be practised on brownfields with less pressure from safety regulations as the produce is not for direct human consumption (Zhao et al., 2014). Also, biofuel production is less affected by soil contaminants and is suitable as the use of marginal lands (Andersson-Sköld et al., 2014). Still, although there is a potential market outlet for urban biomass, this potential will need significant interventions to be realised (Gondhalekar & Ramsauer, 2017).

Historical parks may contain soil contamination due to previous economic activities (Gąsiorek et al., 2017) posing significant risks to visitors (Hung et al., 2018). If used for recreational purposes, such parks do not only require facilities to accommodate a large number of users but may also need significant soil remediation (Biasioli & Ajmone-Marsan, 2007) if not designed in ways to protect visitors from exposure (Erdem & Nassauer, 2013).

Bioswales require a thorough understanding of the need of the site surroundings and type of contaminants as they primarily work as a filter for runoff water purification. The vegetation selection and landscaping interventions likely need to reflect this input of contaminants (Xiao & McPherson, 2011), e.g. by securing capture and treatment of the infiltrated runoff water (Papakos et al., 2010).

Institutional greenspace requires rigorous safety precautions due to more likely to be accessed by people, where a careful design of such spaces need to prompt people towards behaviour that avoid remnant contamination (Erdem & Nassauer, 2013). Urban parks can be realised similarly but might take longer time to realise needing to accommodate more diverse recreational needs.

4.2.3 A decision matrix for the potential future green land uses on urban brownfield

The final tool of the bio-based land use framework is a decision matrix that filters out appropriate bio-based land uses for a particular brownfield site based on the fulfilment of a set of basic conditions. Urban land use is a complex system that is constantly adapting to new necessities, more recently to accommodate the rising challenges of sustainable development (Wackernagel & Rees, 1998; Zhang et al., 2011). Increasing greenspace per capita is a standard strategy with often immediate but subtle impact. Integrating such space in the urban fabric is however a challenge (Doick et al., 2006). Retrofitting brownfields responds to the first step of this problem that requires finding a place for greenspace but, at the same time, it complicates the following steps with several inherent obstacles such as public stigma or possible contamination (Coffin, 2003; Erkilic & Ciravoglu, 2018).

As shown by previous studies, it is difficult to produce a definitive list of criteria for the evaluation of future land use on brownfields as there are many local and site-specific variables likely to be influential in decision making and which are hard to generalise. Each parcel of land is unique and so are the challenges associated with developing it (Kim et al., 2018; US EPA, 2011). An inexhaustive list of challenges is provided by US EPA (2011) in their interim guidelines to facilitate UA in brownfields: soil type, likely contaminants, crop type, garden size, climate, who enters the garden, individual gardener/farmer practice, how long they spend in the garden, growing for individual or family use, donation or market, state regulations, etc. A simpler set of hierarchical criteria is suggested by Kim et al. (2018) for development on urban vacant land: previous development, presence of contamination, historical importance, remediation feasibility, and existing vegetation quality. The European project CABERNET kept it even simpler by using only land value and reclamation cost to categorise brownfields (Bardos et al., 2016b; Ferber et al., 2006; Tang & Nathanail, 2012). Based on these previous studies, a suggested shortlist of basic conditions including the pre-conditions required for bio-based land uses is presented in Table 6. This shortlist is not intended as a complete set but rather as a starting point to trigger the process of greening by indicating the potential of a brownfield.

Table 6. The suggested list of basic conditions affecting the potential of bio-based land use on brownfields.

Basic conditions	**Description**
Pre-conditions	Building greens – Presence of built infrastructures Institutional greenspace – Institutional ownership or interest Riverbank greens – Presence of a waterway Historical park – Historical relevance Neighbourhood greenspace – Adjacent neighbourhood Spontaneous vegetation – Derelict site conditions
Density	The density in the urban context, having an either dense or sparse character of building stock within the site or positioned either in a dense or sparse neighbourhood.
Sealing	The presence of sealing on soil that e.g. may function as an exposure barrier on contaminated soil and provide a surface for vertical planting
Size	The size of the land parcel available for development further categorised as large (>1 ha), medium (0.1-1 ha), small (<0.1 ha). For some land uses, the available size is affected by the share of sealed and non-sealed areas on the site.
Access	The degree of (future) public access to the site.
Management	The type of management involved in or required for bio-based production in the future bio-based land use.
Profit	The need for profit generation linked to the biological resources to be produced on the site.
GROs potential	The possibility of green land use to facilitate soil remediation through GROs. This always implies that a risk assessment is needed to ensure that the risks are not too high (for humans or ecosystems) to be handled with GRO.
Regulations	The regulations and policies by authorities (local, national or global), that need to be adhered to when realising a new land use.

The next step is to connect the different types of UGS to the basic conditions affecting green land use on brownfields, by a screening matrix (Table 7) pairing the potential future UGS options (Table 4) with the selected set of basic conditions (Table 6). The degree of fulfilment of basic conditions for a particular brownfield site can be marked using green (fulfilled), brown (not fulfilled), grey (unsure), yellow (can be changed if needed) or blue (not applicable). At this point, this decision matrix is exploratory and needs to be applied and assessed through future empirical work.

Future green land use on urban brownfields depends on the *density* of the urban area. For example, in compactly developed parts of a city, both vertical building greens and bioswales on roadsides could still be manageable within a tightly weaved urban fabric while building greens make less sense in more sparsely built areas. Also, UA practices that traditionally take place in sparse parts of cities can be done vertically in dense neighbourhoods. Though there is high pressure on land in many cities, legislative or financial issues can hinder the pace of brownfield development. In such cases, spontaneous vegetation can bring abandoned land back into delivering ecosystem functions also in dense areas.

Sealing becomes important since most greenspaces require open soil but again, vertical greens, as well as allotments and community gardens, can take place on sealed surfaces, e.g. overriding the safety precautions needed for contaminated soil exposure. Obviously, UGSs such as grassland, shrubland, meadow orchards and horticulture cannot take place on sealed surfaces.

Though the *size* of the brownfield is somewhat subjective, natural UGSs, such as riverbank green, grassland and shrubland require rather large parcels of land, as do commercial agriculture practices, such as horticulture and biofuel. Meadow orchards and historical parks may take place on both large and medium-sized sites. In contrast, communal green space practices, such as neighbourhood greenspaces, community gardens and allotments, can be managed on medium to small land plots. Building greens are not dependent on the size of the soil surface but the floor or wall area of the built infrastructure. Spontaneous vegetation will grow on any brownfield irrespective of its size.

Access to a site will also have an impact on the viability of the future bio-based land uses. UGSs such as riverbank greens and shrubland, and possibly also grassland and meadow orchards, are expected to have public *access*. Bioswales are usually also public, typically being part of other public spaces such as roadsides or parking lots. Access to agricultural uses ranges from semi-public to private, depending on the flexibility and interests of the responsible authority, owner or active users.

The number and type of involved stakeholders in developing and maintaining a UGS also depend on how the *management* is carried out for the type of activity. Commercial agriculture is commonly practised as a private business, while neighbourhood greenspaces, community gardens and allotments, typically are for communal usage. Meadow orchards can be managed during harvesting seasons both privately and communally.

For the products of agricultural activities in urban greenspaces, *profit* requirements may play a critical role. The products from horticulture and biofuel production are for commercial purposes and require buyers, refineries, and a functional niche market. Environmental improvements through e.g. building greens can also bring commercial benefits. In contrast, food produced from communal agricultural practices are for personal or shared use and typically does not require a commercial outlet.

Two criteria need to be checked to assess the *GRO potential* in parallel to the green land use. Firstly, for GROs such as phytoremediation to be effective, it needs to take place in the soil itself, thus the soil cannot be sealed. Secondly, as GROs would take place on contaminated sites, any edible produce grown directly in the soil is potentially unsafe for consumption. Grassland and meadow orchard can also be considered unsafe as they can be used for cattle grazing and could affect the cattle, and consequently humans by biomagnification. There may be specific types of crops in combination with specific types of contaminants that still makes it possible to grow edible crops, but such a scenario would need an in-depth risk assessment to be accepted. If the produce is not for human consumption and the site is unsealed, GRO intervention can in principle take place parallel to green land use. However, human activities at contaminated sites always imply some human exposure to contaminants via soil intake, dermal contact, inhalation of dust and vapours, and a risk assessment should always be carried out.

Different types of local, national and transnational *regulations* strongly affect what can and cannot be done on brownfields and site specifics such as contaminant condition can have an impact on what sort of regulations would apply on a specific site.

Table 7. Decision matrix for potential future green land uses on urban brownfields. If the condition in the box is fulfilled for a specific site: mark green . If not fulfilled: mark brown . If unsure: mark grey . If it needs to (or can) be changed: mark yellow . If not applicable: mark blue .

Basic Conditions \ UGS		Building green	Bioswale	Riverbank green	Urban park	Historical park	Neighbour-hood greenspace	Institutional greenspace	Allotment	Community garden	Grassland	Meadow orchard	Biofuel production	Horticulture	Shrubland	Spontaneous vegetation
Pre-condition		Buildings	-	River	-	History	Adjacent housing	Institution	-	Community	-	-	-	-	-	Derelict
Density	**Site**	Preferably dense	Dense or sparse	Sparse	Sparse	Sparse	Dense or sparse	Dense or sparse;	Dense or sparse	Dense or sparse	Sparse	Sparse	Sparse	Sparse	Sparse	Dense or Sparse
	Surroundings	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense	Dense or sparse	Preferably dense	Preferably dense	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse
Sealing		Sealed, but unsealed is possible	Unsealed, but sealed is possible	Unsealed	Unsealed	Unsealed	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed	Unsealed	Unsealed	Unsealed	Unsealed	Unsealed, but sealed is possible
Size		Preferably small	Preferably small or medium	Large, but medium possible	Medium or large	Medium or large	Preferably small or medium	Medium or large	All sizes	Preferably small or medium	Large	Large, but medium is possible	Large, but medium is possible	Medium or large	Large	All sizes
Access		Private, semi-public or public	Preferably public	Preferably public	Public	Public	Semi-public or public	Semi-public or public	Semi-public or public	Semi-public or public	Preferably public	Private, semi-public or public	Private	Private or semi-public	Preferably public	Private, semi-public or public
Management		Individual, communal, private or public	Private or public	Private or public	Private or public	Private or public	Communal, private or public	Private or public	Communal, private or public	Communal, private or public	Private or public	Communal, private or public	Private or public	Communal, private or public	Public	Individual, communal, private or public
Profit		Needed, there is a market	Not needed	Not needed	Not needed	Not needed	Not needed or needed, there is a market	Not needed or needed, there is a market	Not needed or needed, there is a market	Not needed or needed, there is a market	Needed, there is a market	Needed, there is a market	Needed, there is a market	Needed, there is a market	Not needed	Not needed
GRO potential		Yes, if unsealed	Yes, if unsealed	Yes	Yes	Yes	Yes, if unsealed	Yes, if unsealed	Yes, if unsealed and the produce is not for consumption	Yes, if unsealed and the produce is not for consumption	Yes, if not used for cattle grazing	Yes, if the produce is for consumption	Yes	Yes, if the produce is not for consumption	Yes	Yes, if unsealed
Regulation		Depends on site specifics and local regulatory systems														

4.3 Framework application

4.3.1 Case study – Polstjärnegatan in Gothenburg, Sweden

The case study is a brownfield in Gothenburg (Sweden) with confirmed contamination issues. A tire 1 environmental risk assessment or human health and ecological risk assessment is carried out by the consultant company SWECO in 2016 for Gothenburg municipality (Kaltin & Almqvist, 2016). The risk assessment report has been used as the primary source of information for the site investigation. An additional in-person survey of the physical conditions of the site was done by the author on January 11, 2020, and the photographs used in this section are taken then as part of the survey.

Geographical context

The study site is located within the Lindholmen district and is part of an urban landscape that is undergoing rapid transformation. The area is surrounded by roads and railways on all sides; Polstjärnegatan to the south (the street that is being used to refer to the site), Karlavagnsgatan to the east, a petrol pump and fast food restaurant (Sybilla) to the west, and a rail line (Hamnbanan) to the north. For the geographic location of the site, refer to Figure 12b. The site is part of the concept plan of Karlastaden, a large scale housing and commercial facility (Figure 12b, highlighted, see legends, and for more information the project's link), where the construction is ongoing for some parts. The planned future use of the site is as a park area, specially designed to help with the surface water runoff (Figure 12c) with new roads constructed on the sides.

The study area comprises about 14,800 m^2, which mostly consists of sparsely vegetated spaces at present (Figures 12a and 12c). Part of the site is currently being used to store construction materials (e.g. sands, gravels; Figures 12d and 12e) and onsite construction sheds for the workers involved in building Karlastaden is soon to be placed on the site. The site is rented by the construction company Serneke for seven years which is the expected length of the construction period of the premises in the surroundings.

Historical use and contamination

The contamination risk assessment by Sweco shows that, historically, most of the site has previously been used as a yard with loading and unloading operations for coal products, forming part of Sannegårdshamnen and its shipyard. The shipyard was in operation from the early 1900s to 1980-90s. After the shipyard was closed, the site was turned into a golf course, demolishing the yard structures and the rail cross-ties and replacing them with sludge brought in from Ryaverket (sewage treatment plant) to model the surface. The golf course was closed in the early 2000s and since then the site has remained unused for a large part, although several illegal cable burning spots for metal reclamation have been found upon closer physical investigations which are also contamination hotspots.

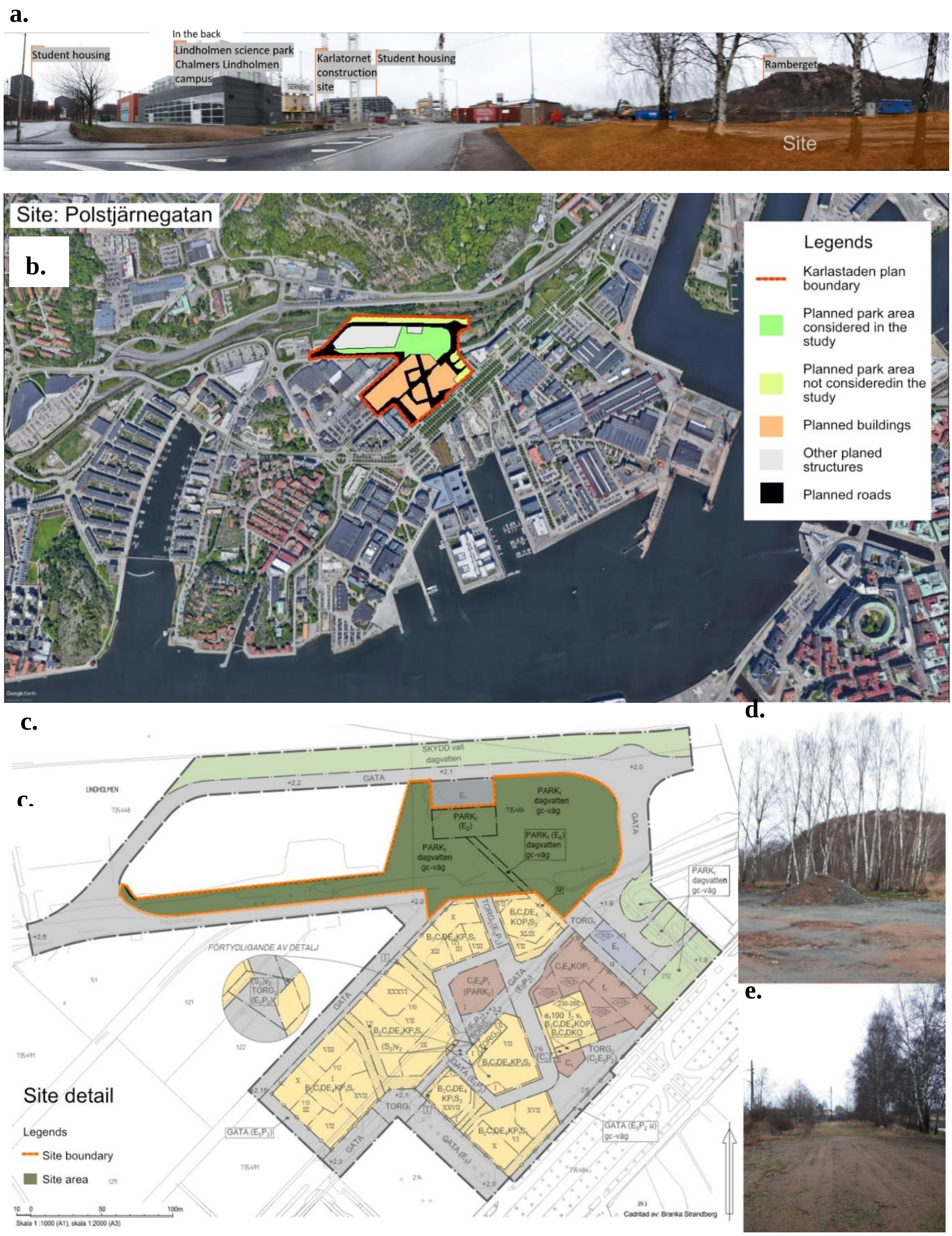


Figure 12: a. Panoramic view of the case study site, Polstjärnegatan, and the surroundings (source: author); b. Location map of the case study with the planned future intervention (source: background is sourced from Google earth with the interpolation done by the author); c. Concept plan of the Karlastaden development with the site area highlighted (source: Kaltin & Almqvist (2016) further edited by author); d. and e. Physical conditions of the site as of January 11, 2020 (source: author).

The analysis results indicate that the pollution levels in the surface soil (0-0.7 m) within a relatively large part of the area are higher than the quantitative remediation targets for the land use, 'park area'. The remediation targets have been sourced from another risk assessment study that developed site-specific guideline values for 'park area' in a different case study site. Within limited areas where the cable burning has been observed, the most superficial soil exhibits high levels (usually higher than FA) of lead, copper and zinc.

4.3.2 Decision matrix application

The first step of applying the decision matrix (Section 4.2.3) is to check how the case study site at Polstjärnegatan performs concerning the basic conditions detailed in Table 6. The results from this first step are detailed below in Table 8.

Checking through the *pre-conditions* required for six of the UGSs, the site fulfils the pre-conditions for two of these. The site is in derelict condition with some vegetation cover, i.e. spontaneous vegetation is possible. It has an adjacent residential neighbourhood so the pre-condition for neighbourhood greenspaces is also fulfilled. Pre-conditions for two more UGSs can potentially be met through future interventions: building greens that would need physical structures currently missing and institutional greenspace if an institution grows an interest for the site. The site is not near any waterway, so riverbank green is not possible. The site also doesn't retain any feature of historical significance that would be of preservation interest, so a historical park is also not a likely land use.

For *density*, the site is located in a rapidly developing urban area but the site in itself is large in *size* (~ 1.48 ha) and empty, apart from the scattered vegetation. It is also *unsealed.* The *access* to the future land use developed on the site is difficult to assume beforehand but as the designated future land use in the current development plan of the site is as a park area, public or at least, semi-public access can be expected. Both *management* and *profit*, on the other hand, cannot be clearly defined at present. The requirement for the last two basic conditions, *GRO potential* and *regulation,* are still to be investigated in future studies (see Chapter 5).

Table 8. The fulfilment of the list of basic conditions for the case study Polstjärnegatan.

Basic conditions	**Description**	**Polstjärnegatan**
Pre-conditions	Building greens - Presence of built infrastructures	Not present but can be changed if needed
	Institutional greenspace- Institutional ownership or interest	Not present but can be changed if needed
	Riverbank greens - Presence of a waterway	Not present
	Historical park- Historical relevance	Not present
	Neighbourhood greenspace-Adjacent neighbourhood	Present, adjacent housing facilities
	Spontaneous vegetation- Derelict site conditions	Present
Density	Site (Dense or sparse)	Sparse
	Surroundings (Dense or sparse)	Dense
Sealing	Sealed or unsealed	Unsealed
Size	Large (>1 ha), medium (0.1-1 ha), small (<0.1 ha)	Large (14,800 m^2 ~1.48 ha)
Access	Public, semi-public, or private	Semi-public or public
Management	Individual, communal, private or public	Undecided, possibly public
Profit	Needed or not needed	Undecided, but can be both
GRO potential	The possibility of green land use to facilitate soil remediation with GROs. This always implies that a risk assessment is needed to ensure that the risks are not too high (for humans or ecosystems) to be handled with GRO.	Not investigated yet
Regulations	The regulations and policies by authorities (local, national or global), that need to be adhered to when realising a new land use.	Not investigated yet

After analysing the basic conditions, the decision matrix is applied to the case study, Polstjärnegatan, see Table 9.

As pre-conditions for two of the UGSs are not fulfilled, *riverbank green* and *historical park*, this makes them unviable future land use options for the site. Pre-conditions for two other UGSs, *building green* and *institutional greenspace*, are not yet fulfilled but can be changed in future, but this still makes them impractical to consider in the present condition of the site.

As a result of applying the decision matrix, the basic conditions are fulfilled at the case study site for six out of fifteen UGSs: There is already some *spontaneous vegetation* on the site at present so this can clearly be continued in future. Similarly, other types of natural vegetation cover, such as *grassland* and *shrubland,* are also possible on site, although this would require proper planning and consideration for the contamination condition.

Table 9. Decision matrix application on the case study site, Polstjärnegatan. If the condition in the box is fulfilled for a specific site: mark green . If not fulfilled: mark brown If unsure: mark grey If it needs to (or can) be changed: mark yellow . If not applicable: mark blue

Basic Conditions / UGS		Building green	Bioswale	Riverbank green	Urban park	Historical park	Neighbour-hood greenspace	Institutional greenspace	Allotment	Community garden	Grassland	Meadow orchard	Biofuel production	Horticulture	Shrubland	Spontaneous vegetation
Pre-condition		Buildings	-	River	-	History	Adjacent housing	Institution	-	Community	-	-	-	-	-	Derelict
Density	Site	Preferably dense	Dense or sparse	Sparse	Sparse	Sparse	Dense or sparse	Dense or sparse;	Dense or sparse	Dense or sparse	Sparse	Sparse	Sparse	Sparse	Sparse	Dense or Sparse
	Surroundings	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense	Dense or sparse	Preferably dense	Preferably dense	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse	Dense or sparse
Sealing		Sealed, but unsealed is possible	Unsealed, but sealed is possible	Unsealed	Unsealed	Unsealed	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed, but sealed is possible	Unsealed	Unsealed	Unsealed	Unsealed	Unsealed	Unsealed, but sealed is possible
Size		Preferably small	Preferably small or medium	Large, but medium possible	Medium or large	Medium or large	Preferably small or medium	Medium or large	All sizes	Preferably small or medium	Large	Large, but medium is possible	Large, but medium is possible	Medium or large	Large	All sizes
Access		Private, semi-public or public	Preferably public	Preferably public	Public	Public	Semi-public or public	Semi-public or public	Semi-public or public	Semi-public or public	Preferably public	Private, semi-public or public	Private	Private or semi-public	Preferably public	Private, semi-public or public
Management		Individual, communal, private or public	Private or public	Private or public	Private or public	Private or public	Communal, private or public	Private or public	Communal, private or public	Communal, private or public	Private or public	Communal, private or public	Private or public	Communal, private or public	Public	Individual, communal, private or public
Profit		Needed, there is a market	Not needed	Not needed	Not needed	Not needed	Not needed or needed, there is a market	Not needed or needed, there is a market	Not needed or needed, there is a market	Not needed or needed, there is a market	Needed, there is a market	Needed, there is a market	Needed, there is a market	Needed, there is a market	Not needed	Not needed
GRO potential		Yes, if unsealed	Yes, if unsealed	Yes	Yes	Yes	Yes, if unsealed	Yes, if unsealed	Yes, if unsealed and the produce is not for consumption	Yes, if unsealed and the produce is not for consumption	Yes, if not used for cattle grazing	Yes, if the produce is for consumption	Yes	Yes, if the produce is not for consumption	Yes	Yes, if unsealed
Regulation		Depends on site specifics and local regulatory systems														

Urban park is both a possible and likely UGS as the future planned land use is in fact a park area.

Meadow orchard is another UGS whose basic conditions are completely fulfilled. Still, as it is a UGS that can potentially produce edible products (i.e. fruits from the fruit trees) and given the contamination conditions of the site, producing edible products can be a reason of concern without proper risk management. *Allotment* is also a plausible UGS on the site but will need even more careful attention on the safety guidelines and risk management considering the site contamination conditions as it is a user intensive UA.

Neighbourhood greenspace and *community garden* are examples of other UA land use that fulfils all the basic conditions apart from the size which might be possible to change in future through subdivision of urban functions at the site. But the concerns over contamination similar to that of allotment will be an issue for these practices as well.

Horticulture is the final UA practices that undoubtedly will need careful guidance and consideration to be implemented on the site. However, the main issue will be that this land use would most likely require exclusively private access while the planned future land use on the site is public or at least semi-public. Even though *biofuel production* on the site can be undertaken with little to no concern over the contamination condition, this land use will also lead to privatised or limited access to the site.

In relation to *Bioswale*, the site does not fulfil the basic condition for size as small to medium sizes are preferable. Still, this UGS can be especially applicable on the site given the site context. Bioswales work to treat and capture stormwater runoff and as the site is surrounded by heavily trafficked roads, this could be an appropriate land use to implement. A subdivision of urban functions at the site could facilitate such land use and this is corroborated by the planned future land use for the site which is ‘park area specially designed to help with the surface water runoff’ (Section 4.3.1, p. 41).

5 ONGOING WORK – REFLECTIONS AND FURTHER STEPS

This chapter identifies issues that require further investigation for a successful assessment of the potential for bio-based land use on urban brownfields and outlines the ongoing work addressing these issues.

Urban brownfields face a multitude of issues but, at the same time, provide a unique opportunity for incorporating bio-based land uses in the cities. The bio-based land use framework introduced in this thesis tackles a number of the relevant aspects, but it was apparent from the framework realisation and application that some aspects need further elaboration for completing an assessment of the potential for bio-based land use on brownfields. The three issues that have been identified and presently are being investigated further are discussed in the following sections.

5.1 Stakeholder planning and governance for realising bio-based land uses

Section 2.7 elaborates on how realising bio-based land uses on urban brownfields would contribute to the much-needed greenspaces in the cities providing many ES that impacts the health and well-being of the citizens as well as urban environments. The competition for urban land among stakeholders is, however, very high and retrofitting brownfields as urban greenspaces will inevitably involve a range of stakeholders who may have conflicting interest in the issue. Any initiative to realise bio-based land use needs considerate and consistent planning for facilitating multi-stakeholder engagement.

The purpose of the ongoing work regarding the stakeholder engagement is to develop a method that may support the facilitation of a feasible and democratic process of brownfield regeneration for a more effective and realistic realisation of bio-based land uses (Amirtahmasebi et al., 2016; Bunyan, 2015). The ongoing work is focused on the case study site, Polstjärnegatan, Gothenburg (SE). The objectives of the study are to:

- identify and analyse the relevant stakeholders to realise a bio-based land use in urban brownfields
- suggest a generic method for stakeholder analysis and engagement that can be adapted according to different cases and different land uses

The bio-based land use matrix filters out certain UGSs that are appropriate for the site and the further analysis co-produced with the stakeholders will help shorten the list. Stakeholder groups relevant for realising bio-based land uses on urban brownfields will be identified from the literature and will then be localised for the case study to create a list of stakeholders that can be used for creating a reference group whose members will be further engaged via workshops or questionnaire surveys. The Crosby method (1991) is selected to develop a matrix in which information for each stakeholder group is arranged according to the group's interests, the level of resources it possesses, its capacity for mobilisation of resources, and the group's position on the issue in question. The strategy decided at present is to develop questionnaires according to the Crosby queries and to use the data to analyse stakeholders' power and interest in realising specific UGS on site.

5.2 Selection of GRO strategies corresponding to different bio-based land uses

One of the key arguments for assessing the potential for bio-based land use on brownfields is to explore the gentle remediation potential of the vegetation to manage risks posed by the contamination present on site. Complementing a bio-based reuse of brownfields, the remediation process can potentially be carried out by means of GRO strategies which are based on low-cost and long-term methods, without negative secondary impacts and with potential to manage risks and improve soil ecology (Bardos et al., 2008; Onwubuya et al., 2009). GROs are elaborated (Section 2.5) and also included as a basic condition in the decision matrix (Table 5) but assessing GRO potential for contamination risk mitigation and strategy selection is dependent on a multitude of issues (e.g. type of contaminants, exposure pathways, land use) that cannot simply be generalised and will require decision support in itself (Cundy et al., 2015; Kennen & Kirkwood, 2015).

The ongoing study regarding this issue focuses on developing decision support strategies to assess GRO potential and select GRO strategies along different timeframes to reach the maximum benefits of a brownfield within the circular land-use regime. The scope of work within this study includes:

- Reviewing existing decision support strategies for assessing GRO potential and selecting GRO strategies to analyse different criteria and identify the ones that can support land use and contaminant specific selection;
- Characterising the critical risks associated with different green land uses and contaminants and identifying relevant risk mitigation mechanisms for GRO strategies,
- Modelling a Decision Support Tool (DST) that supports a site-specific selection of GRO strategies along different land uses; and
- Applying the new DST on a case study.

5.3 Evaluating contamination risks in different Urban Agriculture practices

One issue that has been identified since the framework development is that certain UGSs are more sensitive to the potential contamination of urban brownfields than others. Specifically, UGSs that are also UA practices are more susceptible as the consumption of fresh produce grown on contaminated soil can be an added exposure pathway for the urban population (Säumel et al., 2012). These concerns have led many countries to follow strict regulations for gardening in urban areas, considering the use as sensitive to contamination exposure as residential use (US EPA, 2011). But there are many different types of UA practices with varying degrees of user involvement and management. Although there are some studies published on human health risks associated with UA (Entwistle et al., 2019; Margenat et al., 2019; Sharma et al., 2015; Weber et al., 2019), there exist neither a definitive soil screening guideline used by city authorities that refers to different UA practices nor studies on UA scenarios that would help modify the exposure parameters to facilitate creating of such models

Further work planned on this issue is to identify different UA scenarios and to compare the contamination exposure in these scenarios to highlight the difference in associated risks. The scope of work includes creating an exposure risk model combined with UA scenario sensitive parameters to test on different UA practices. The scenario exposure data is planned to be collected from surveying different UA user groups in Gothenburg, Sweden. Data collected via a questionnaire survey will be used for more accurate input data which better represent real-life scenarios. More knowledge on the exposure from soil contamination from different UA practices would provide more options to bring back obsolete land in use.

6 DISCUSSION AND CONCLUSIONS

The final chapter of the thesis presents a summary discussion on the thesis output and limitations. It further outlines possible future works in support of the future realisation of bio-based land use on urban brownfields.

The suggested framework for assessing bio-based land use potentials on urban brownfields is presented in Section 4.2. The framework is the result of initial attempts to incorporate CE values with marginal urban land renewal by exploring their potential to be redeveloped as urban greenspaces. The framework consists of three tools; a) a general conceptualisation of how the potential for bio-based production on brownfields is linked to soil contaminants, gentle soil remediation options and time; b) a graphical representation of required interventions and time spans to realise bio-based land uses on brownfields, and c) a decision matrix showing how site-specific conditions affect the potential for different types of bio-based land uses.

The framework application at the case study site, Polstjärnegatan in Gothenburg, shows the potential of the developed tool. The decision matrix applied to the case helps to filter out urban greenspaces that are preferable considering the basic conditions of the study site. The potential for future land uses on brownfields can be attributed to many site-specific conditions (Kim et al., 2018; US EPA, 2011) and the decision matrix consists of a limited set of conditions. Thus, it was also apparent that even with just elementary insights on a brownfield's contextual properties, the list of potential bio-based land uses can be shortened even further. Applying the decision matrix can also help to support the present choice of future land use as park area specially designed to help with the surface water runoff' (Kaltin & Almqvist, 2016) at Polstjärnegatan as both 'urban park' and 'bioswales' are filtered out as appropriate future green land use on the site.

The case study application also highlighted the limitations of the framework in addressing issues that are vital for realising certain bio-based land uses. Several issues have been identified that needs in-depth consideration for the bio-based land use to be realised and are presently being investigated. Involvement of stakeholders is essential in effective realisation of urban greenspaces, as discussed by Azadi et al. (2011) who goes on to identify groups of stakeholder that are of particular importance. Bio-based land uses and GRO technologies can potentially be combined for management of the site. GRO as the sustainable alternatives of resource-intensive 'dig and dump' remediation (Carlon et al., 2009; Cundy et al., 2015; EEA, 2014) has the large potential to be implemented at low-level contaminated sites (Cundy et al., 2016). This potential has been addressed in the decision matrix. But to understand the GRO potential, analysis of several site-specific elements, such as type of contaminants (Kennen & Kirkwood, 2015), climate conditions, site topography (Andersson-Sköld et al, 2014) and soil quality aspects other than contaminant concentrations, needs to be assessed. This will essentially lead to the next step which would be selecting appropriate GRO technology regarding the site-specific conditions.

One of the biggest challenges in retrofitting brownfields is the risk of exposure from the potential contamination and the risk is even heightened for some bio-based land uses, i.e. UA (US EPA, 2011). The bio-based land use framework leaves room for further development on risk management on contaminated sites, especially regarding UA practices that would benefit from more insights on the risk associated with the land uses.

It is important to keep in mind that the case study for the framework in this thesis has been a local brownfield site in Gothenburg and that the outputs from the framework application, its benefits and limitations, thus are contextual. Applying the framework in different cases would help to bring forward different benefits and limitations which would in return, help to improve the framework. The application of the framework in the Swedish context is none the less an important exercise that will help to increase the applicability of the framework also for other contexts. However, the framework in itself is not an endpoint in the quest for realising bio-based land uses on brownfields, but rather something useful at the beginning of a redevelopment process. The bio-based land use framework is designed to be used at the initial stage of an urban land redevelopment process but needs to be supported with flexible policies promoting bio-based solutions. Policy guidelines need to be developed to support not only bio-based land uses at brownfields, but also provide guidance on assessing GRO potential and implementation as a bio-based remediation solution for these uses. But for GROs to be incorporated in policymaking, knowledge on the effectiveness of GROs to manage risks and the conditions under which GRO are possible to implement need to be developed and communicated. A better understanding of UGSs as bio-based land use options, coupled with the decision matrix for the assessment of their potential as future land uses on brownfields can, in the meantime, assist the relevant stakeholders and support decision-makers in redeveloping brownfields for green land use.

The main conclusions of this study are:

- Urban brownfields provide a unique opportunity to incorporate Circular Economy (CE) values in cities and can be identified as valuable land wastes of a linear land use system, in this way providing new options for bio-based land uses. In the circular land use system, brownfields are not considered as a waste but as a valuable resource in the transition from abandonment to redevelopment and reuse.
- Bio-based land uses can be appropriated as urban greenspaces (UGS) which are fundamental for urban wellbeing by providing the citizens with numerous ecosystem services (ES) that can be considered as bio-based products in the urban context.
- Bio-based land uses in combination with gentle remediation options (GROs) can potentially be used to manage risks to humans and ecosystems posed by contamination present on the brownfields.

- The presented bio-based land use framework can help to assess the potential for bio-based land use on urban brownfields utilising the three practical tools:
    - A diagram indicating the linkages between various bio-based land uses on brownfields and GRO interventions over time;
    - A scatter diagram with a set of 15 bio-based land uses to conceptualise the potential of these linkages; and
    - A decision matrix to analyse the requirements and assessing the potential for UGSs and GROs on brownfields.
- The application of the decision matrix on a case study site helped to filter the potential bio-based land uses on the site as well as to highlight the issues that need further investigation for a successful transformation from brownfield to urban greenspace.

The following areas for further research have been also identified:

- Ongoing works to broaden the scope of application of bio-based land use framework are presented below:
    - Stakeholder planning and governance for realising bio-based land uses,
    - Selection of GRO strategies corresponding to different bio-based land uses,
    - Evaluating contamination risks in different Urban Agriculture (UA) practices.
- Continuing the work on the case study by applying the other two tools developed as part of the framework (the conceptualisation of linkages (Figure 10) and bio-based land uses across different timeframes and degrees of required intervention (Figure 11)) to understand the applicability and analyse the output.
- Exploring the potential of the bio-based land use framework at the city scale and producing GIS-based visualisations of:
    - bio-based land use alternatives and their impact on bio-based production over time; and
    - stakeholder preferences/expectations linked to bio-based production in particular locations in the city.
- Exploring the regulatory landscape involving brownfield revitalisation and greenspace realisation to support policy formation on:
    - guidelines for short term and intermediate term bio-based land use on brownfields; and
    - the institutional innovation needed for implementing a circular economy in promoting circular bio-based land use on cities.

The research work in this thesis has led to a better understanding of the benefits and the potential of bio-based land uses on urban brownfields. The tools developed as part of the bio-based land use framework offer different ways of assessing the bio-based land use potential. The research output can help to strengthen the sustainable redevelopment of urban brownfields by incorporating CE values to the agenda.

REFERENCES

Ahrné, K., Bengtsson, J., & Elmqvist, T. (2009). Bumble Bees (Bombus spp) along a Gradient of Increasing Urbanization. *PLoS ONE*, *4*(5), e5574. https://doi.org/10.1371/journal.pone.0005574

Amirtahmasebi, R., Orloff, M., Wahba, S., & Altman, A. (2016). *Regenerating Urban Land: A Practitioner's Guide to Leveraging Private Investment*. Washington, DC. Retrieved from https://openknowledge.worldbank.org/handle/10986/24377

Anderson, B. S., Phillips, B. M., Voorhees, J. P., Siegler, K., & Tjeerdema, R. (2016). Bioswales reduce contaminants associated with toxicity in urban storm water. *Environmental Toxicology and Chemistry*, *35*(12), 3124–3134. https://doi.org/10.1002/etc.3472

Andersson-Sköld, Y., Bardos, P., Chalot, M., Bert, V., Crutu, G., Phanthavongsa, P., … Cundy, A. B. (2014). Developing and validating a practical decision support tool (DST) for biomass selection on marginal land. *Journal of Environmental Management*, *145*, 113–121. https://doi.org/10.1016/j.jenvman.2014.06.012

Angel, S., Parent, J., Civco, D. L., Blei, A., & Potere, D. (2011). The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Progress in Planning*, *75*(2), 53–107. https://doi.org/10.1016/j.progress.2011.04.001

Armanda, D. T., Guinée, J. B., & Tukker, A. (2019). The second green revolution: Innovative urban agriculture's contribution to food security and sustainability – A review. *Global Food Security*, *22*, 13–24. https://doi.org/10.1016/J.GFS.2019.08.002

Azadi, H., Ho, P., Hafni, E., Zarafshani, K., & Witlox, F. (2011). Multi-stakeholder involvement and urban green space performance. *Journal of Environmental Planning and Management*, *54*(6), 785–811. https://doi.org/10.1080/09640568.2010.530513

Bardos, P., Andersson-Skold, Y., Blom, S., Keuning, S., Pachon, C., & Track, T. (2008). Brownfields, bioenergy and biofeedstocks, and green remediation. In *Proceedings of the 10th International UFZ-deltares/TNO Conference on Soil:Water Systems (CONSOIL), Special Sessions* (pp. 3–10). Milan, Italy. Retrieved from https://www.scopus.com/record/display.uri?eid=2-s2.0-70350546476&origin=inward&txGid=0221dfc12975964a704e9170728783a8#

Bardos, R. P., Jones, S., Stephenson, I., Menger, P., Beumer, V., Neonato, F., … Wendler, K. (2016). Optimising value from the soft re-use of brownfield sites. *Science of the Total Environment*, *563–564*, 769–782. https://doi.org/10.1016/j.scitotenv.2015.12.002

Barthel, S., & Isendahl, C. (2013). Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, *86*(2013), 215–225. Retrieved from https://www.sciencedirect.com/science/article/pii/S0921800912002431

Beier, C., Emmett, B. A., Tietema, A., Schmidt, I. K., Peñuelas, J., Láng, E. K., … Spano, D. (2009). Carbon and nitrogen balances for six shrublands across Europe. *Global Biogeochemical Cycles*, *23*(4), n/a-n/a. https://doi.org/10.1029/2008GB003381

Biasioli, M., & Ajmone-Marsan, F. (2007). Organic and inorganic diffuse contamination in urban soils: the case of Torino (Italy). *Journal of Environmental Monitoring*, *9*(8), 862. https://doi.org/10.1039/b705285e

Borysiak, J., Mizgajski, A., & Speak, A. (2017). Floral biodiversity of allotment gardens and its contribution to urban green infrastructure. *Urban Ecosystems*, *20*(2), 323–335. https://doi.org/10.1007/s11252-016-0595-4

Boström, L. (2007). *Koloniträdgården: odling eller rekreation?* SLU, Horticulture.

Braungart EPEA. (2018). C2C Design Concept | braungart.com. Retrieved January 3, 2019, from http://braungart.epea-hamburg.org/en/content/c2c-design-concept

Breure, A. M., Lijzen, J. P. A., & Maring, L. (2018). Soil and land management in a circular economy, *624*, 1025–1030. https://doi.org/10.1016/j.scitotenv.2017.12.137

Breuste, J. H., & Artmann, M. (2015). Allotment Gardens Contribute to Urban Ecosystem Service: Case Study Salzburg, Austria. *Journal of Urban Planning and Development*, *141*(3), A5014005. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000264

Bučienė, A. (2003). The Shrinking rate of utilized Agricultural Land And its components in Baltic Sea region Countries. *Regional Formation and Development Studies, no. 1 (6)*, 6–14.

Bunyan, P. (2015). Regenerating the City: People, Politics, Power and the Public Sphere. *Local Government Studies*, *41*(3), 362–378. https://doi.org/10.1080/03003930.2014.982109

Carlon, C., Hope, B., & Quercia, F. (2009). Contaminated Land: A Multi-Dimensional Problem. In *Decision Support Systems for Risk-Based Management of Contaminated Sites* (pp. 1–23). Boston, MA: Springer US. https://doi.org/10.1007/978-0-387-09722-0_6

Castleton, H. F., Stovin, V., Beck, S. B. M., & Davison, J. B. (2010). Green roofs; building energy savings and the potential for retrofit. *Energy and Buildings*, *42*(10), 1582–1591. https://doi.org/10.1016/J.ENBUILD.2010.05.004

Ceperley, N., Montagnini, F., & Natta, A. K. (2010). *Significance of sacred sites for riparian forest conservation in Central Benin*. *BOIS & FORETS DES TROPIQUES* (Vol. 303). Soc. Retrieved from http://revues.cirad.fr/index.php/BFT/article/view/20450/20209

Chan, J., DuBois, B., & Tidball, K. G. (2015). Refuges of local resilience: Community gardens in post-Sandy New York City. *Urban Forestry & Urban Greening*, *14*(3), 625–635. https://doi.org/10.1016/j.ufug.2015.06.005

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, *68*(1), 129–138. Retrieved from https://www.sciencedirect.com/science/article/pii/S0169204603001865?via%3Dihub

Chowdhury, S. (2020). *Urban potential in Bio-based Circular Economy Literature review report*. Gothenburg, Sweden.

Cilliers, S. S., Siebert, S. J., Du Toit, M. J., Barthel, S., Mishra, S., Cornelius, S. F., & Davoren, E. (2018). Garden ecosystem services of Sub-Saharan Africa and the role of health clinic gardens as social-ecological systems. *Landscape and Urban Planning*, *180*, 294–307. https://doi.org/10.1016/j.landurbplan.2017.01.011

Coffin, S. L. (2003). Closing the brownfield information gap: Some practical methods for identifying brownfields. *Environmental Practice*, *5*(1), 34–39. https://doi.org/10.1017/S1466046603030126

COM/2011/0571. Road Map to a Resource Efficient Europe (2011). European Commission: EUR-Lex. Retrieved from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0571

Copernicus EU. (2020a). CORINE Land Cover — Copernicus Land Monitoring Service. Retrieved January 21, 2020, from https://land.copernicus.eu/pan-european/corine-land-cover

Copernicus EU. (2020b). Urban Atlas — Copernicus Land Monitoring Service. Retrieved January 21, 2020, from https://land.copernicus.eu/local/urban-atlas

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., … van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260. https://doi.org/10.1038/387253a0

Crosby, B. (1991). Stakeholder Analysis : A Vital Tool for Strategic Managers. *U.S Agency for International Development*, (2), 1–6. https://doi.org/10.1155/2011/953047

Cundy, A. B., Bardos, R. P., Church, A., Puschenreiter, M., Friesl-Hanl, W., Müller, I., … Vangronsveld, J. (2013). Developing principles of sustainability and stakeholder engagement for "gentle" remediation approaches: The European context. *Journal of Environmental Management*, *129*, 283–291. https://doi.org/10.1016/j.jenvman.2013.07.032

Cundy, A. B., Bardos, R. P., Puschenreiter, M., Mench, M., Bert, V., Friesl-Hanl, W., … Vangronsveld, J. (2016). Brownfields to green fields: Realising wider benefits from practical contaminant phytomanagement strategies. *Journal of Environmental Management*, *184*, 67–77. https://doi.org/10.1016/j.jenvman.2016.03.028

Cundy, A., Bardos, P., Puschenreiter, M., Witters, N., Mench, M., Bert, V., … Vangronsveld, J. (2015). Developing Effective Decision Support for the Application of "Gentle" Remediation Options: The GREENLAND Project. *Remediation Journal*, *25*(3), 101–114. https://doi.org/10.1002/rem.21435

Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., & Strohbach, M. (2015). *A typology of urban green spaces , ecosyestem provisioning Services and Demands* (Vol. Report D3.). Copenhagen.

Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., & Strohbach, M. (2017). A typology of urban green spaces, ecosystem services provisioning services and demands, *7*, 68.

D'Amato, D., Korhonen, J., & Toppinen, A. (2019). Circular, Green, and Bio Economy: How Do Companies in Land-Use Intensive Sectors Align with Sustainability Concepts? *Ecological Economics*, *158*, 116–133. https://doi.org/10.1016/j.ecolecon.2018.12.026

de Sosa, L. L., Glanville, H. C., Marshall, M. R., Prysor Williams, A., & Jones, D. L. (2018). Quantifying the contribution of riparian soils to the provision of ecosystem services. *Science of The Total Environment*, *624*, 807–819. https://doi.org/10.1016/j.scitotenv.2017.12.179

De Sousa, C. A. (2003). Turning brownfields into green space in the City of Toronto. *Landscape and Urban Planning*, *62*(4), 181–198. https://doi.org/10.1016/S0169-2046(02)00149-4

De Sousa, C. A. (2006). Unearthing the benefits of brownfield to green space projects: An examination of project use and quality of life impacts. *Local Environment*, *11*(5), 577–600. https://doi.org/10.1080/13549830600853510

Debolini, M., Valette, E., François, M., & Chéry, J.-P. (2015). Mapping land use competition in the rural–urban fringe and future perspectives on land policies: A case study of Meknès (Morocco). *Land Use Policy*, *47*, 373–381. https://doi.org/10.1016/j.landusepol.2015.01.035

Dickinson, N M, Mackay, J. M., Goodman, A., & Putwain, P. (2000). Planting trees on contaminated soils: Issues and guidelines. *Land Contamination and Reclamation*, *8*(2), 87–101. https://doi.org/10.2462/09670513.561

Dickinson, Nicholas M., Baker, A. J. M., Doronila, A., Laidlaw, S., & Reeves, R. D. (2009). Phytoremediation of inorganics: Realism and synergies. *International Journal of Phytoremediation*, *11*(2), 97–114. https://doi.org/10.1080/15226510802378368

Diplock, E. E., Mardlin, D. P., Killham, K. S., & Paton, G. I. (2010). The Role of Decision Support for Bioremediation Strategies, Exemplified by Hydrocarbons for In Site and Ex Situ Procedures. In S. Cummings (Ed.), *Bioremediation. Methods in Molecular Biology (Methods and Protocols)* (Vol. 599, pp. 201–215). Humana Press. https://doi.org/10.1007/978-1-60761-439-5

Dixon, T., Raco, M., Catney, P., & Lerner, D. N. (2007). *Sustainable Brownfield Regeneration: Liveable Places from Problem Spaces*. (T. Dixon, M. Raco, P. Catney, & D. N. Lerner, Eds.), *Sustainable Brownfield Regeneration: Liveable Places from Problem Spaces*. Wiley-Blackwell. https://doi.org/10.1002/9780470692110

Doick, K. J., Sellers, G., Hutchings, T. R., & Moffat, A. J. (2006). Brownfield sites turned green: Realising sustainability in urban revival. *WIT Transactions on Ecology and the Environment*, *94*, 131–140. https://doi.org/10.2495/BF060131

Domenech, T., & Bahn-Walkowiak, B. (2019). Transition Towards a Resource Efficient Circular Economy in Europe: Policy Lessons From the EU and the Member States. *Ecological Economics*, *155*(August 2017), 7–19. https://doi.org/10.1016/j.ecolecon.2017.11.001

Dong, S., Wen, L., Zhu, L., & Li, X. (2010). Implication of coupled natural and human systems in sustainable rangeland ecosystem management in HKH region. *Frontiers of Earth Science in China*, *4*(1), 42–50. https://doi.org/10.1007/s11707-010-0010-z

Dzerefos, C., & Witkowski, E. (2001). Density and potential utilisation of medicinal grassland plants from Abe Bailey Nature Reserve, South Africa. *Springer*, (Biodiversity & Conservation). Retrieved from https://link.springer.com/article/10.1023/A:1013177628331

Edmondson, J. L., Davies, Z. G., Gaston, K. J., & Leake, J. R. (2014). Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. *Journal of Applied Ecology*, *51*(4), 880–889. https://doi.org/10.1111/1365-2664.12254

EEA. (2014). *Progress in management of contaminated sites in Europe*. Copenhagen. https://doi.org/10.2788/4658

EEA. (2018). Urban land take — European Environment Agency. Retrieved April 8, 2019, from https://www.eea.europa.eu/airs/2018/natural-capital/urban-land-expansion

Egli, V., Oliver, M., & Tautolo, E. S. (2016, June 1). The development of a model of community garden benefits to wellbeing. *Preventive Medicine Reports*. Elsevier Inc. https://doi.org/10.1016/j.pmedr.2016.04.005

Egoh, B. N., Reyers, B., Rouget, M., & Richardson, D. M. (2011). Identifying priority areas for ecosystem service management in South African grasslands. *Journal of Environmental Management*, *92*(6), 1642–1650. https://doi.org/10.1016/J.JENVMAN.2011.01.019

Ellen MacArthur Foundation. (2013). *Towards a Circular Economy*. Cowes, United Kingdom. https://doi.org/10.1162/108819806775545321

Ellen MacArthur Foundation. (2019). The Circular Economy systems diagram. Retrieved July 22, 2020, from https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail

Ellen MacArthur Foundation. (2020). Biological and technical material flows. Retrieved July 22, 2020,

from https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail
Enell, A., Andersson-Sköld, Y., Vestin, J., & Wagelmans, M. (2016). Risk management and regeneration of brownfields using bioenergy crops. *Journal of Soils and Sediments*, *16*(3), 987–1000. https://doi.org/10.1007/s11368-015-1264-6
Entwistle, J. A., Amaibi, P. M., Dean, J. R., Deary, M. E., Medock, D., Morton, J., … Bramwell, L. (2019). An apple a day? Assessing gardeners' lead exposure in urban agriculture sites to improve the derivation of soil assessment criteria. *Environment International*, *122*, 130–141. https://doi.org/10.1016/j.envint.2018.10.054
Erdem, M., & Nassauer, J. I. (2013). Design of Brownfield Landscapes Under Different Contaminant Remediation Policies in Europe and the United States. *Landscape Journal*, *32*(2), 277–292. https://doi.org/10.3368/lj.32.2.277
Erickson, D. L. (2006). *MetroGreen : connecting open space in North American cities*. Island Press.
Ericsson, K., Rosenqvist, H., & Nilsson, L. J. (2009). Energy crop production costs in the EU. *Biomass and Bioenergy*, *33*(11), 1577–1586. https://doi.org/10.1016/j.biombioe.2009.08.002
Erkilic, N. H., & Ciravoglu, A. (2018). Revitalizing Undefined Urban Saces by Temporary Urban Strategies. In S. G. Akdag, S. Soygenis, & M. Vatan (Eds.), *Borders in Architecture*, *CAUMME 2018 International Symposium* (pp. 145–152). Istanbul.
European Commission. Closing the loop - An EU action plan for the Circular Economy, Pub. L. No. COM/2015/0614 final (2015). Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
European Commission. (2017). *EU agricultural outlook*. Retrieved from https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/agricultural-outlook-2017-30_en.pdf
European Commission. (2019). Bio-based products | Internal Market, Industry, Entrepreneurship and SMEs. Retrieved June 13, 2019, from http://ec.europa.eu/growth/sectors/biotechnology/bio-based-products_en
European Compost Network. (2017). ECN - Bio-waste in Circular Economy. Brussels, Belgium. Retrieved from https://www.compostnetwork.info/download/ecn-biowaste-circular-economy/
European Compost Network. (2019). Biowaste in the Circular Economy - European Compost Network. Retrieved July 15, 2019, from https://www.compostnetwork.info/policy/circular-economy/
Evangelou, M. W. H., Conesa, H. M., Robinson, B. H., & Schulin, R. (2012). Biomass Production on Trace Element–Contaminated Land: A Review. *Environmental Engineering Science*, *29*(9), 823–839. https://doi.org/10.1089/ees.2011.0428
Evangelou, M. W. H., Papazoglou, E. G., Robinson, B. H., & Schulin, R. (2015). Phytomanagement: Phytoremediation and the Production of Biomass for Economic Revenue on Contaminated Land. In *Phytoremediation* (pp. 115–132). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-10395-2_9
FAO. (2019). FAO's role in Urban Agriculture | FAO | Food and Agriculture Organization of the United Nations. Retrieved June 7, 2019, from http://www.fao.org/urban-agriculture/en/
Farley, K. A., Bremer, L. L., Harden, C. P., & Hartsig, J. (2013). Changes in carbon storage under alternative land uses in biodiverse Andean grasslands: implications for payment for ecosystem services. *Conservation Letters*, *6*(1), 21–27. https://doi.org/10.1111/j.1755-263X.2012.00267.x
Farley, K. A., Kelly, E. F., & Hofstede, R. G. M. (2004). Soil Organic Carbon and Water Retention after Conversion of Grasslands to Pine Plantations in the Ecuadorian Andes. *Ecosystems*, *7*(7), 729–739. https://doi.org/10.1007/s10021-004-0047-5
Fässler, E., Robinson, B. H., Stauffer, W., Gupta, S. K., Papritz, A., & Schulin, R. (2010). Phytomanagement of metal-contaminated agricultural land using sunflower, maize and tobacco. *Agriculture, Ecosystems & Environment*, *136*(1–2), 49–58. https://doi.org/10.1016/J.AGEE.2009.11.007
Ferber, U., Grimski, D., Millar, K., & Nathanail, P. (2006). *Sustainable Brownfield Regeneration: CABERNET Network Report*. Nottingham. https://doi.org/10.1007/978-90-481-9757-6
Francis, L. F. M., & Jensen, M. B. (2017). Benefits of green roofs: A systematic review of the evidence for three ecosystem services. *Urban Forestry & Urban Greening*, *28*, 167–176. https://doi.org/10.1016/J.UFUG.2017.10.015

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production*, *168*, 833–845. https://doi.org/10.1016/J.JCLEPRO.2017.09.056

Frantál, B., Klusáček, P., Kunc, J., Martinát, S., Osman, R., Bartke, S., … Sileam, T. (2012). *Report on results of survey on brownfield regeneration and statistical analysis : TIMBRE Deliverable D3.1*. Copenhagen. https://doi.org/10.13140/2.1.1546.7202

Freeman, R. E. E., & McVea, J. (2005). A Stakeholder Approach to Strategic Management. *SSRN Electronic Journal*, (January). https://doi.org/10.2139/ssrn.263511

French, C. J., Dickinson, N. M., & Putwain, P. D. (2006). Woody biomass phytoremediation of contaminated brownfield land. *Environmental Pollution*, *141*(3), 387–395. https://doi.org/10.1016/j.envpol.2005.08.065

Friday, K. S., Drilling, M. E., & Garrity, D. P. (1999). Imperata grassland rehabilitation using agroforestry and assisted natural regeneration. *International Centre for Research in Agroforestry, Southeast Asian Regional Research Programme, Bogor, Indonesia.* Retrieved from https://www.fs.usda.gov/treesearch/pubs/6773

Gardiner, M. A., Tuell, J. K., Isaacs, R., Gibbs, J., Ascher, J. S., & Landis, D. A. (2010). Implications of Three Biofuel Crops for Beneficial Arthropods in Agricultural Landscapes. *BioEnergy Research*, *3*(1), 6–19. https://doi.org/10.1007/s12155-009-9065-7

Gąsiorek, M., Kowalska, J., Mazurek, R., & Pająk, M. (2017). Comprehensive assessment of heavy metal pollution in topsoil of historical urban park on an example of the Planty Park in Krakow (Poland). *Chemosphere*, *179*, 148–158. https://doi.org/10.1016/j.chemosphere.2017.03.106

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Ginn, F. (2012). Dig for Victory! New histories of wartime gardening in Britain. *Journal of Historical Geography*, *38*(3), 294–305. https://doi.org/10.1016/j.jhg.2012.02.001

Gittleman, M., Farmer, C. J. Q., Kremer, P., & McPhearson, T. (2017). Estimating stormwater runoff for community gardens in New York City. *Urban Ecosystems*, *20*(1), 129–139. https://doi.org/10.1007/s11252-016-0575-8

Goh, C. S. (2020). Transforming exploitative land-based economy: The case of Borneo. *Environmental Development*, *33*, 100487. https://doi.org/10.1016/j.envdev.2019.100487

Gondhalekar, D., & Ramsauer, T. (2017). Nexus City: Operationalizing the urban Water-Energy-Food Nexus for climate change adaptation in Munich, Germany. *Urban Climate*, *19*, 28–40. https://doi.org/10.1016/j.uclim.2016.11.004

Gratani, L., Catoni, R., Puglielli, G., Varone, L., Crescente, M. F., Sangiorgio, S., & Lucchetta, F. (2016). Carbon Dioxide (CO2) Sequestration and Air Temperature Amelioration Provided by Urban Parks in Rome. *Energy Procedia*, *101*, 408–415. https://doi.org/10.1016/J.EGYPRO.2016.11.052

Gray, C. L., Slade, E. M., Mann, D. J., & Lewis, O. T. (2014). Do riparian reserves support dung beetle biodiversity and ecosystem services in oil palm-dominated tropical landscapes? *Ecology and Evolution*, *4*(7), 1049–1060. https://doi.org/10.1002/ece3.1003

Gregory, M. M., Leslie, T. W., & Drinkwater, L. E. (2016). Agroecological and social characteristics of New York city community gardens: contributions to urban food security, ecosystem services, and environmental education. *Urban Ecosystems*, *19*(2), 763–794. https://doi.org/10.1007/s11252-015-0505-1

Haase, D., Kabisch, N., Strohbach, M., Eler, K., & Pintar, M. (2015). *Urban GI Components Inventory Milestone 23* (Vol. 7).

Hahn, K. (2013). Soil contamination can be a deterrent to urban agriculture - MSU Extension. Retrieved December 7, 2018, from https://www.canr.msu.edu/news/soil_contamination_can_be_a_deterrent_to_urban_agriculture

Haile, S., Palmer, M., & Otey, A. (2016). Potential of loblolly pine: switchgrass alley cropping for provision of biofuel feedstock. *Agroforestry Systems*, *90*(5), 763–771. https://doi.org/10.1007/s10457-016-9921-3

Hansen, A. C., Zhang, Q., & Lyne, P. W. L. (2005). Ethanol–diesel fuel blends — a review. *Bioresource*

Technology, *96*(3), 277–285. https://doi.org/10.1016/J.BIORTECH.2004.04.007
Hill, A. R. (1996). Nitrate Removal in Stream Riparian Zones. *Journal of Environment Quality*, *25*(4), 743. https://doi.org/10.2134/jeq1996.00472425002500040014x
Hofmann, M., Westermann, J. R., Kowarik, I., & Van der Meer, E. (2012). Perceptions of parks and urban derelict land by landscape planners and residents. *Urban Forestry and Urban Greening*, *11*(3), 303–312. https://doi.org/10.1016/j.ufug.2012.04.001
Hofstede, R. G. M., Groenendijk, J. P., Coppus, R., Fehse, J. C., & Sevink, J. (2002). Impact of Pine Plantations on Soils and Vegetation in the Ecuadorian High Andes. *Https://Doi.Org/10.1659/0276-4741(2002)022[0159:IOPPOS]2.0.CO;2*, *22*(2), 159–167. https://doi.org/10.1659/0276-4741(2002)022[0159:IOPPOS]2.0.CO;2
HOMBRE. (2014). *Holistic Management of Brownfield Regeneration HOMBRE ' s Role in Brownfields Management and Avoidance*.
Hougner, C., Colding, J., & Söderqvist, T. (2006). Economic valuation of a seed dispersal service in the Stockholm National Urban Park, Sweden. *Ecological Economics*, *59*(3), 364–374. https://doi.org/10.1016/j.ecolecon.2005.11.007
Huang, H., Yu, N., Wang, L., Gupta, D. K., He, Z., Wang, K., … Yang, X. (2011). The phytoremediation potential of bioenergy crop Ricinus communis for DDTs and cadmium co-contaminated soil. *Bioresource Technology*, *102*(23), 11034–11038. https://doi.org/10.1016/J.BIORTECH.2011.09.067
Hung, W.-C., Hernandez-Cira, M., Jimenez, K., Elston, I., & Jay, J. A. (2018). Preliminary assessment of lead concentrations in topsoil of 100 parks in Los Angeles, California. *Applied Geochemistry*, *99*, 13–21. https://doi.org/10.1016/J.APGEOCHEM.2018.10.003
Hunter, H., Fellows, C., Rassam, D., … R. D.-… R. C. for, & 2006, undefined. (n.d.). Managing riparian lands to improve water quality: optimising nitrate removal via denitrification. *Citeseer*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.502.5639&rep=rep1&type=pdf
Jónsson, J. Ö. G., & Davídsdóttir, B. (2016, June 1). Classification and valuation of soil ecosystem services. *Agricultural Systems*. Elsevier Ltd. https://doi.org/10.1016/j.agsy.2016.02.010
Juwarkar, A. A., Singh, S. K., & Mudhoo, A. (2010). A comprehensive overview of elements in bioremediation. *Reviews in Environmental Science and Bio/Technology*, *9*(3), 215–288. https://doi.org/10.1007/s11157-010-9215-6
Kaltin, S., & Almqvist, P. (2016). *Polstjärnegatan (Uppdragsnummer 1312233000) Kompletterande miljöteknisk markundersökning inom del av lindholmen 735:448 M FL, inklusive riskbedömning och åtgärdsutredning*. Gothenburg, Sweden.
Karkee, M., & Adhikari, B. (2015). A Method for Three-Dimensional Reconstruction of Apple Trees for Automated Pruning. *Transactions of the ASABE*, *58*(3), 565–574. https://doi.org/10.13031/trans.58.10799
Kennen, K., & Kirkwood, N. (2015). Site Contaminants. In *Phyto : principles and resources for site remediation and landscape design* (p. 63). Routledge.
Kim, G., Miller, P. A., & Nowak, D. J. (2018). Urban vacant land typology: A tool for managing urban vacant land. *Sustainable Cities and Society*, *36*, 144–156. https://doi.org/10.1016/J.SCS.2017.09.014
Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*(April), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005
Koopman, K. R., Straatsma, M. W., Augustijn, D. C. M., Breure, A. M., Lenders, H. J. R., Stax, S. J., & Leuven, R. S. E. W. (2018). Quantifying biomass production for assessing ecosystem services of riverine landscapes. *Science of The Total Environment*, *624*, 1577–1585. https://doi.org/10.1016/J.SCITOTENV.2017.12.044
Kotze, D., & Morris, C. (2001). Grasslands: A Threatened Life-Support System. Retrieved from https://scholar.google.com/scholar_lookup?title=Grasslands – A Threatened Life-Support System&publication_year=2001&author=D. Kotze&author=C. Morris
Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K. H., Haberl, H., & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological Economics*, *68*(10), 2696–2705. https://doi.org/10.1016/j.ecolecon.2009.05.007

Larson, L. R., Jennings, V., & Cloutier, S. A. (2016). Public Parks and Wellbeing in Urban Areas of the United States. *PLOS ONE*, *11*(4), e0153211. https://doi.org/10.1371/journal.pone.0153211

Le Guern, C., Jean-Soro, L., Béchet, B., Lebeau, T., & Bouquet, D. (2018). Management initiatives in support of the soil quality of urban allotment gardens: Examples from Nantes (France). *Land Degradation & Development*, *29*(10), 3681–3692. https://doi.org/10.1002/ldr.3123

Lee, R. A., & Lavoie, J.-M. (2013). From first- to third-generation biofuels: Challenges of producing a commodity from a biomass of increasing complexity. *Animal Frontiers*, *3*(2), 6–11. https://doi.org/10.2527/af.2013-0010

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042

Lin, B. B., Philpott, S. M., & Jha, S. (2015). The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. *Basic and Applied Ecology*, *16*(3), 189–201. https://doi.org/10.1016/J.BAAE.2015.01.005

Livingroofs. (2020). Green Roofs and Urban Green Space. Retrieved January 10, 2020, from https://livingroofs.org/health-and-wellbeing/

Ljung, K., Oomen, A., Duits, M., Selinus, O., & Berglund, M. (2007). Bioaccessibility of metals in urban playground soils. *Journal of Environmental Science and Health, Part A*, *42*(9), 1241–1250. https://doi.org/10.1080/10934520701435684

Lohr, V. I., & Relf, P. D. (2014). Horticultural science's role in meeting the need of urban populations. In *Horticulture: Plants for people and places, volume 3: Social horticulture* (pp. 1047–1086). https://doi.org/10.1007/978-94-017-8560-0_31

Loures, L., & Panagopoulos, T. (2007). Sustainable reclamation of industrial areas in urban landscapes. *WIT Transactions on Ecology and the Environment*, *102*, 791–800. https://doi.org/10.2495/SDP070752

Loures, Luis. (2015). Post-industrial landscapes as drivers for urban redevelopment: Public versus expert perspectives towards the benefits and barriers of the reuse of post-industrial sites in urban areas. *Habitat International*, *45*(P2), 72–81. https://doi.org/10.1016/j.habitatint.2014.06.028

Loures, Luís, & Panagopoulos, T. (2007). From derelict industrial areas towards multifunctional landscapes and urban renaissance. *WSEAS Transactions on Environment and Development*, *3*(10), 181–188.

Loures, Luis, & Vaz, E. (2018). Exploring expert perception towards brownfield redevelopment benefits according to their typology. *Habitat International*, *72*, 66–76. https://doi.org/10.1016/j.habitatint.2016.11.003

Luo, X. S., Yu, S., Zhu, Y. G., & Li, X. D. (2012). Trace metal contamination in urban soils of China. *Science of the Total Environment*, *421–422*, 17–30. https://doi.org/10.1016/j.scitotenv.2011.04.020

Lwasa, S., Mugagga, F., Wahab, B., Simon, D., Connors, J., & Griffith, C. (2014). Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation. *Urban Climate*, *7*, 92–106. https://doi.org/10.1016/j.uclim.2013.10.007

Maes, J., Zulian, G., Thijssen, M., Castell, C., Baro, F., Ferreira, A., … Alves, F. (2016). *Mapping and assessment of ecosystems and their services in the EU - Urban ecosystems*. https://doi.org/10.2779/75203

Margenat, A., Matamoros, V., Díez, S., Cañameras, N., Comas, J., & Bayona, J. M. (2019). Occurrence and human health implications of chemical contaminants in vegetables grown in peri-urban agriculture. *Environment International*, *124*, 49–57. https://doi.org/10.1016/j.envint.2018.12.013

Marlair, G., Rotureau, P., Breulet, H., & Brohez, S. (2009). Booming development of biofuels for transport: Is fire safety of concern? *Fire and Materials*, *33*(1), 1–19. https://doi.org/10.1002/fam.976

Masi, F., Rizzo, A., & Regelsberger, M. (2018). The role of constructed wetlands in a new circular economy, resource oriented, and ecosystem services paradigm. *Journal of Environmental Management*, *216*, 275–284. https://doi.org/10.1016/j.jenvman.2017.11.086

Mathey, J., Arndt, T., Banse, J., & Rink, D. (2018). Public perception of spontaneous vegetation on brownfields in urban areas—Results from surveys in Dresden and Leipzig (Germany). *Urban*

Forestry & Urban Greening, *29*, 384–392. https://doi.org/10.1016/J.UFUG.2016.10.007
Matos, H. M., Santos, M. J., Palomares, F., & Santos-Reis, M. (2009). Does riparian habitat condition influence mammalian carnivore abundance in Mediterranean ecosystems? *Biodiversity and Conservation*, *18*(2), 373–386. https://doi.org/10.1007/s10531-008-9493-2
McKergow, L. A., Prosser, I. P., Grayson, R. B., & Heiner, D. (2004). Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland. 2. Water quality. *Soil Research*, *42*(4), 485. https://doi.org/10.1071/SR02156
Meek, C. S., Richardson, D. M., & Mucina, L. (2010). A river runs through it: Land-use and the composition of vegetation along a riparian corridor in the Cape Floristic Region, South Africa. *Biological Conservation*, *143*(1), 156–164. https://doi.org/10.1016/J.BIOCON.2009.09.021
Meek, M. E. B., Boobis, A. R., Crofton, K. M., Heinemeyer, G., Raaij, M. Van, & Vickers, C. (2011). Risk assessment of combined exposure to multiple chemicals: A WHO/IPCS framework. *Regulatory Toxicology and Pharmacology*, *60*(2), S1–S14. https://doi.org/10.1016/j.yrtph.2011.03.010
Mendez-Estrella, R., Romo-Leon, J., & Castellanos, A. (2017). Mapping Changes in Carbon Storage and Productivity Services Provided by Riparian Ecosystems of Semi-Arid Environments in Northwestern Mexico. *ISPRS International Journal of Geo-Information*, *6*(10), 298. https://doi.org/10.3390/ijgi6100298
Middle, I., Dzidic, P., Buckley, A., Bennett, D., Tye, M., & Jones, R. (2014). Integrating community gardens into public parks: An innovative approach for providing ecosystem services in urban areas. *Urban Forestry & Urban Greening*, *13*(4), 638–645. https://doi.org/10.1016/J.UFUG.2014.09.001
Mikkelsen, K., & Vesho, I. (2000). Riparian soils: A literature review. Retrieved from https://digital.lib.washington.edu/researchworks/handle/1773/17038
Miller, D. (2005). The Tibetan steppe. In J. Suttie, S. Reynolds, & C. Batello (Eds.), *Grasslands of the world, Plant production and protection* (pp. 305–342). Rome: Food and Agriculture Organization of the United Nations.
Mont, O., Plepys, A., Whalen, K., & Nussholz, J. (2018). *Business Model Innovation for a Circular: Drivers and barriers for the Swedish industry – the voice of REES companies*. Lund, Sweden.
Mougeot, L. J. A. (1999). Urban Agriculture: Definition, Presence, Potentials and Risks, and Policy Challenges. *International Workshop on Growing Cities Growing Food: Urban Agriculture on the Policy Agenda*, *31*(2), 58.
Myczko, Ł., Rosin, Z. M., Skórka, P., Wylegała, P., Tobolka, M., Fliszkiewicz, M., … Tryjanowski, P. (2013). Effects of management intensity and orchard features on bird communities in winter. *Ecological Research*, *28*(3), 503–512. https://doi.org/10.1007/s11284-013-1039-8
NACTO. (2020). Bioswales | National Association of City Transportation Officials. Retrieved January 10, 2020, from https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/bioswales/
Nagendra, H., & Gopal, D. (2011). Tree diversity, distribution, history and change in urban parks: Studies in Bangalore, India. *Urban Ecosystems*, *14*(2), 211–223. https://doi.org/10.1007/s11252-010-0148-1
Naiman, R., Decamps, H., & McClain, M. (2010). *Riparia: ecology, conservation, and management of streamside communities*. Retrieved from https://books.google.com/books?hl=en&lr=&id=n6i_2G2f2KAC&oi=fnd&pg=PR11&ots=PiP26QCnvn&sig=odEaqaiZycol_5XgqBdO_leVKcc
NASA Earth Observatory. (2020, January 20). Shrubland: Mission: Biomes.
Nielsen, A. B., van den Bosch, M., Maruthaveeran, S., & van den Bosch, C. K. (2014). Species richness in urban parks and its drivers: A review of empirical evidence. *Urban Ecosystems*, *17*(1), 305–327. https://doi.org/10.1007/s11252-013-0316-1
NSALG. (2020). Brief history of allotments – The National Allotment Society – National Society of Allotment and Leisure Gardeners Ltd. Retrieved January 17, 2020, from https://www.nsalg.org.uk/allotment-info/brief-history-of-allotments/
Nunez, C. (2019). National Geographic| Grasslands, explained. Retrieved January 20, 2020, from https://www.nationalgeographic.com/environment/habitats/grasslands/
Öberg, T., & Bergbäck, B. (2005). A review of probabilistic risk assessment of contaminated land.

Journal of Soils and Sediments, *5*(4), 213–224. https://doi.org/10.1065/jss2005.08.143
Onwubuya, K., Cundy, A., Puschenreiter, M., Kumpiene, J., Bone, B., Greaves, J., … Müller, I. (2009). Developing decision support tools for the selection of “gentle” remediation approaches. *Science of The Total Environment*, *407*(24), 6132–6142. https://doi.org/10.1016/J.SCITOTENV.2009.08.017
Orsini, F., Gasperi, D., Marchetti, L., Piovene, C., Draghetti, S., Ramazzotti, S., … Gianquinto, G. (2014). Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: the potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. *Food Security*, *6*(6), 781–792. https://doi.org/10.1007/s12571-014-0389-6
OVAM. (2019). *Phytoremediation - Code of Good Practice*. Mechelen. Retrieved from www.ovam.be
Ozawa, C. P., & Yeakley, J. A. (2007). Performance of management strategies in the protection of riparian vegetation in three oregon cities. *Journal of Environmental Planning and Management*, *50*(6), 803–822. https://doi.org/10.1080/09640560701610552
Papakos, T. H., Gould, M., & Brunner, J. (2010). Redeveloping Brownfields with LID Design. In *Low Impact Development 2010* (pp. 1684–1697). Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/41099(367)145
Paul, K. I., Polglase, P. J., Nyakuengama, J. G., & Khanna, P. K. (2002). Change in soil carbon following afforestation. *Forest Ecology and Management*, *168*(1–3), 241–257. https://doi.org/10.1016/S0378-1127(01)00740-X
Pavlović, P., Marković, M., Kostić, O., Sakan, S., Đorđević, D., Perović, V., … Mitrović, M. (2019). Evaluation of potentially toxic element contamination in the riparian zone of the River Sava. *CATENA*, *174*, 399–412. https://doi.org/10.1016/j.catena.2018.11.034
Pengra, B. (2012). *One Planet, How Many People? A Review of Earth’s Carrying Capacity*.
Perino, G., Andrews, B., Kontoleon, A., & Bateman, I. (2011). *Urban Greenspace Amenety - Economic Assessment of Ecosystem Services provided by UK Urban Habitats*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.692.5982
Pert, P. L., Butler, J. R. A., Brodie, J. E., Bruce, C., Honzák, M., Kroon, F. J., … Wong, G. (2010). A catchment-based approach to mapping hydrological ecosystem services using riparian habitat: A case study from the Wet Tropics, Australia. *Ecological Complexity*, *7*(3), 378–388. https://doi.org/10.1016/J.ECOCOM.2010.05.002
Pimentel, D., & Patzek, T. (2006). Green Plants, Fossil Fuels, and Now Biofuels. *BioScience*, *56*(11), 875–875. https://doi.org/10.1641/0006-3568(2006)56[875:gpffan]2.0.co;2
Pitt, J., & Heinemeyer, C. (2015). Introducing ideas of a circular economy. In *Environment, Ethics and Cultures: Design and Technology Education’s Contribution to Sustainable Global Futures* (pp. 245–260). Sense Publishers. https://doi.org/10.1007/978-94-6209-938-8_16
Planchuelo, G., von Der Lippe, M., & Kowarik, I. (2019). Untangling the role of urban ecosystems as habitats for endangered plant species. *Landscape and Urban Planning*, *189*, 320–334. https://doi.org/10.1016/j.landurbplan.2019.05.007
Plieninger, T., Levers, C., Mantel, M., Costa, A., Schaich, H., & Kuemmerle, T. (2015). Patterns and Drivers of Scattered Tree Loss in Agricultural Landscapes: Orchard Meadows in Germany (1968-2009). *PLOS ONE*, *10*(5), e0126178. https://doi.org/10.1371/journal.pone.0126178
Postel, S., & Carpenter, S. (1997). Freshwater ecosystem services. In *Nature’s Services: Societal Dependence on Natural Ecosystems* (pp. 195–214). Washington, DC: Island Press. Retrieved from https://books.google.com/books?hl=en&lr=&id=QYJSziDfTjEC&oi=fnd&pg=PA195&ots=YgyQJVEXAg&sig=yfTx90GYkhyvyJVW3akRl9spUQU
Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular Cities: Mapping Six Cities in Transition. *Environmental Innovation and Societal Transitions*, *26*, 171–194. https://doi.org/10.1016/j.eist.2017.03.002
Priyadarshini, P., & Abhilash, P. C. (2020). Fostering sustainable land restoration through circular economy-governed transitions. *Restoration Ecology*, *28*(4), 719–723. https://doi.org/10.1111/rec.13181
Pusey, B. J., & Arthington, A. H. (2003). Importance of the riparian zone to the conservation and management of freshwater fish: a review. *Marine and Freshwater Research*, *54*(1), 1. https://doi.org/10.1071/MF02041
Rabenhorst. (2020). Meadow Orchards - Rabenhorst Saft. Retrieved January 20, 2020, from

https://m.rabenhorst.de/en/science-of-juice/meadow-orchards/

Reddy, K. R., Adams, J. A., & Richardson, C. (1999). Potential Technologies for Remediation of Brownfields, *3*(April), 61–68. Retrieved from http://ascelibrary.org/doi/pdf/10.1061/(ASCE)1090-025X(1999)3:2(61)

Ricaurte, L. F., Olaya-Rodríguez, M. H., Cepeda-Valencia, J., Lara, D., Arroyave-Suárez, J., Max Finlayson, C., & Palomo, I. (2017). Future impacts of drivers of change on wetland ecosystem services in Colombia. *Global Environmental Change*, *44*, 158–169. https://doi.org/10.1016/J.GLOENVCHA.2017.04.001

Rizzo, E., Pesce, M., Pizzol, L., Alexandrescu., F. M., Giubilato, E., Critto, A., … Bartke, S. (2015). Brownfield regeneration in Europe: Identifying stakeholder perceptions, concerns, attitudes and information needs. *Land Use Policy*, *48*, 437–453. https://doi.org/10.1016/j.landusepol.2015.06.012

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Rosén, L., Back, P. E., Söderqvist, T., Norrman, J., Brinkhoff, P., Norberg, T., … Döberl, G. (2015). SCORE: A novel multi-criteria decision analysis approach to assessing the sustainability of contaminated land remediation. *Science of the Total Environment*, *511*, 621–638. https://doi.org/10.1016/j.scitotenv.2014.12.058

Sala, O., & Paruelo, J. (1997). Ecosystem services in grasslands. In G. . Daily (Ed.), *Nature's Services: Societal Dependence on Natural Ecosystems* (pp. 237–252). Washington, DC: Island Press. Retrieved from https://books.google.com/books?hl=en&lr=&id=Mwy8BwAAQBAJ&oi=fnd&pg=PA237&ots=0-9e6tKEFN&sig=pu1EbF9eiJX9ky0fvxiarBfPKJE

Säumel, I., Kotsyuk, I., Hölscher, M., Lenkereit, C., Weber, F., & Kowarik, I. (2012). How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany. *Environmental Pollution*, *165*, 124–132. https://doi.org/10.1016/J.ENVPOL.2012.02.019

Saunders, M. E., Luck, G. W., & Mayfield, M. M. (2013). Almond orchards with living ground cover host more wild insect pollinators. *Journal of Insect Conservation*, *17*(5), 1011–1025. https://doi.org/10.1007/s10841-013-9584-6

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, 48–56. https://doi.org/10.1016/j.envdev.2015.09.002

Scholz-Barth, K. (2001). Green on top. *Urban Land*, 83–97. Retrieved from http://www.roofmeadow.com/wp-content/uploads/Green_on_Top.pdf

Scullion, J. (2006). Remediating polluted soils. *Naturwissenschaften*, *93*(2), 51–65. https://doi.org/10.1007/s00114-005-0079-5

SEPA. (1996). *Development of generic guideline values*. Stockholm. Retrieved from http://www.naturvardsverket.se/Documents/publikationer/620-4639-X.pdf?pid=2721

SEPA. (2016). *Riktvärden för förorenad mark. Generella riktvärden för förorenad mark*. Retrieved from https://www.naturvardsverket.se/Om-Naturvardsverket/Publikationer/ISBN/5900/978-91-620-5976-7/

Sharma, K., Cheng, Z., & Grewal, P. S. (2015). Relationship between soil heavy metal contamination and soil food web health in vacant lots slated for urban agriculture in two post-industrial cities. *Urban Ecosystems*, *18*(3), 835–855. https://doi.org/10.1007/s11252-014-0432-6

Silins, I., Berglund, M., Hanberg, A., Boman, A., Fadeel, B., Gustavsson, P., … Stenius, U. (2011). *Human Health Risk Assessment of Combined Exposures to Chemicals*. Stockholm.

Skoulika, F., Santamouris, M., Kolokotsa, D., & Boemi, N. (2014). On the thermal characteristics and the mitigation potential of a medium size urban park in Athens, Greece. *Landscape and Urban Planning*, *123*, 73–86. https://doi.org/10.1016/j.landurbplan.2013.11.002

Speak, A. F., Mizgajski, A., & Borysiak, J. (2015). Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity. *Urban Forestry & Urban Greening*, *14*(4), 772–781. https://doi.org/10.1016/J.UFUG.2015.07.007

SSSA. (2020). Rain Gardens and Bioswales | Soil Science Society of America. Retrieved January 10, 2020, from https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/rain-gardens-bioswales

Ståhle, A. (2010). More green space in a denser city: Critical relations between user experience and urban form. *URBAN DESIGN International*, *15*(1), 47–67. https://doi.org/10.1057/udi.2009.27

Styles, D., Börjesson, P., D'Hertefeldt, T., Birkhofer, K., Dauber, J., Adams, P., … Rosenqvist, H. (2016). Climate regulation, energy provisioning and water purification: Quantifying ecosystem service delivery of bioenergy willow grown on riparian buffer zones using life cycle assessment. *Ambio*, *45*(8), 872–884. https://doi.org/10.1007/s13280-016-0790-9

Swanwick, C., Dunnett, N., & Woolley, H. (2003). Nature, role and value of green space in towns and cities: An overview. *Built Environment*, *29*(2), 94–106. https://doi.org/10.2148/benv.29.2.94.54467

Tang, Y. T., & Nathanail, P. C. (2012). Sticks and Stones: The impact of the definitions of brownfield in policies on socio-economic sustainability. *Sustainability*, *4*(5), 840–862. https://doi.org/10.3390/su4050840

TEEB. (2010). *The economics of ecosystems and biodiversity : ecological and economic foundations*. (P. Kumar, Ed.). Earthscan. Retrieved from https://www.routledge.com/The-Economics-of-Ecosystems-and-Biodiversity-Ecological-and-Economic-Foundations/Kumar/p/book/9780415501088

TEEB. (2020). Ecosystem Services - TEEB. Retrieved January 22, 2020, from http://www.teebweb.org/resources/ecosystem-services/

The World Bank. (2020). Urban population (% of total population) | Data. Retrieved September 29, 2020, from https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

Tonietto, R., Fant, J., Ascher, J., Ellis, K., & Larkin, D. (2011). A comparison of bee communities of Chicago green roofs, parks and prairies. *Landscape and Urban Planning*, *103*(1), 102–108. https://doi.org/10.1016/j.landurbplan.2011.07.004

Trapp, S. (2007). Fruit Tree model for uptake of organic compounds from soil and air†. *SAR and QSAR in Environmental Research*, *18*(3–4), 367–387. https://doi.org/10.1080/10629360701303693

Tripathi, V., Edrisi, S. A., & Abhilash, P. C. (2016). Towards the coupling of phytoremediation with bioenergy production. *Renewable and Sustainable Energy Reviews*, *57*, 1386–1389. https://doi.org/10.1016/J.RSER.2015.12.116

U.S. EPA. (2011). *Reusing Potential Contaminant Landscapes: Growing Gradens in Urban Soils (Fact Sheet)*. Retrieved from www.cluin.org/ecotools/soil.cfm.

Ulrich, R. S. (1981). Natural Versus Urban Scenes. *Environment and Behavior*, *13*(5), 523–556. https://doi.org/10.1177/0013916581135001

UNEP-DTIE. (2012). *Cities and Buildings UNEP initiatives and projects*.

UNEP. (2011). Towards a Green Economy.

United Nations. (2014). *World urbanization prospects: The 2014 Revision, Highlights* (Vol. 12). New York. https://doi.org/10.4054/DemRes.2005.12.9

United Nations. (2020). THE 17 GOALS | Department of Economic and Social Affairs. Retrieved August 5, 2020, from https://sdgs.un.org/goals

US EPA. (2011). *Brownfields and Urban Agriculture: Interim Guidelinrs for safe Gardening Practices*.

Vangronsveld, J., Van Assche, F., & Clijsters, H. (1995). Reclamation of a bare industrial area contaminated by non-ferrous metals: In situ metal immobilization and revegetation. *Environmental Pollution*, *87*(1), 51–59. https://doi.org/10.1016/S0269-7491(99)80007-4

Velli, A., Pirola, A., & Ferrari, C. (2019). Evaluating landscape changes using vegetation and land-use maps: an integrated approach. *Landscape Research*, *44*(6), 768–781. https://doi.org/10.1080/01426397.2018.1513128

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate Change and Food Systems. *Annual Review of Environment and Resources*, *37*(1), 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Villarreal, E. L., & Bengtsson, L. (2005). Response of a Sedum green-roof to individual rain events. *Ecological Engineering*, *25*(1), 1–7. https://doi.org/10.1016/J.ECOLENG.2004.11.008

von Hoffen, L. P., & Säumel, I. (2014). Orchards for edible cities: Cadmium and lead content in nuts, berries, pome and stone fruits harvested within the inner city neighbourhoods in Berlin, Germany. *Ecotoxicology and Environmental Safety*, *101*, 233–239. https://doi.org/10.1016/J.ECOENV.2013.11.023

WA Water. (2020). Government of Western Australia, Department of Water and Environmental Regulation- Aquatic and riparian vegetation. Retrieved January 10, 2020, from http://www.water.wa.gov.au/water-topics/waterways/values-of-our-waterways/aquatic-and-riparian-vegetation

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: reducing human impact on the earth*. Retrieved from https://books.google.com/books?hl=en&lr=&id=WVNEAQAAQBAJ&oi=fnd&pg=PR9&ots=VlXM6NxQOl&sig=HTqYRKb_H6IkForEgdqDRpeIPJU

Wani, S. P., Chander, G., Sahrawat, K. L., Srinivasa Rao, C., Raghvendra, G., Susanna, P., & Pavani, M. (2012). Carbon sequestration and land rehabilitation through Jatropha curcas (L.) plantation in degraded lands. *Agriculture, Ecosystems & Environment*, *161*, 112–120. https://doi.org/10.1016/j.agee.2012.07.028

Weber, A. M., Mawodza, T., Sarkar, B., & Menon, M. (2019). Assessment of potentially toxic trace element contamination in urban allotment soils and their uptake by onions: A preliminary case study from Sheffield, England. *Ecotoxicology and Environmental Safety*, *170,* 156–165. https://doi.org/10.1016/j.ecoenv.2018.11.090

Wen, L., Dong, S., Li, Y., Li, X., Shi, J., Wang, Y., … Ma, Y. (2013). Effect of Degradation Intensity on Grassland Ecosystem Services in the Alpine Region of Qinghai-Tibetan Plateau, China. *PLoS ONE*, *8*(3), e58432. https://doi.org/10.1371/journal.pone.0058432

Wetland Info. (2020). Riparian vegetation (Department of Environment and Science, Queensland Governmant, Australia). Retrieved January 10, 2020, from https://wetlandinfo.des.qld.gov.au/wetlands/ecology/components/flora/riparian-vegetation.html

White, R. P., Murray, S., & Rohweder, M. (2000). *Pilot analysis of global ecosystems : grassland ecosystems*. (M. Edeburn, Ed.). World Resources Institute. Retrieved from https://www.wri.org/publication/pilot-analysis-global-ecosystems-grassland-ecosystems

Whittinghill, L. J., & Rowe, D. B. (2012). The role of green roof technology in urban agriculture. *Renewable Agriculture and Food Systems*, *27*(4), 314–322. https://doi.org/10.1017/S174217051100038X

Winans, K., Kendall, A., & Deng, H. (2017). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews*, *68*(October 2015), 825–833. https://doi.org/10.1016/j.rser.2016.09.123

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2014.01.017

Wu, J. (2014). Urban ecology and sustainability: The state-of-the-science and future directions. *Landscape and Urban Planning*, *125*, 209–221. https://doi.org/10.1016/J.LANDURBPLAN.2014.01.018

Xiao, Q., & McPherson, E. G. (2011). Performance of engineered soil and trees in a parking lot bioswale. *Urban Water Journal*, *8*(4), 241–253. https://doi.org/10.1080/1573062X.2011.596213

Yin, S., Shen, Z., Zhou, P., Zou, X., Che, S., & Wang, W. (2011). Quantifying air pollution attenuation within urban parks: An experimental approach in Shanghai, China. *Environmental Pollution*, *159*(8–9), 2155–2163. https://doi.org/10.1016/j.envpol.2011.03.009

Yousaf, B., Liu, G., Abbas, Q., Wang, R., Imtiaz, M., & Zia-ur-Rehman, M. (2017). Investigating the uptake and acquisition of potentially toxic elements in plants and health risks associated with the addition of fresh biowaste amendments to industrially contaminated soil. *Land Degradation & Development*. https://doi.org/10.1002/ldr.2821

Zaimes, G., Nichols, M., Green, D., & Crimmins, M. (2007). *Understanding Arizona's riparian areas*. Retrieved from https://repository.arizona.edu/handle/10150/146921

Zhang, X., Wu, Y., & Shen, L. (2011). An evaluation framework for the sustainability of urban land use: A study of capital cities and municipalities in China. *Habitat International*, *35*(1), 141–149. https://doi.org/10.1016/J.HABITATINT.2010.06.006

Zhao, X., Monnell, J. D., Niblick, B., Rovensky, C. D., & Landis, A. E. (2014). The viability of biofuel production on urban marginal land: An analysis of metal contaminants and energy balance for pittsburgh’s sunflower gardens. *Landscape and Urban Planning, 124,* 22–33. https://doi.org/10.1016/j.landurbplan.2013.12.015

7 PUBLICATION