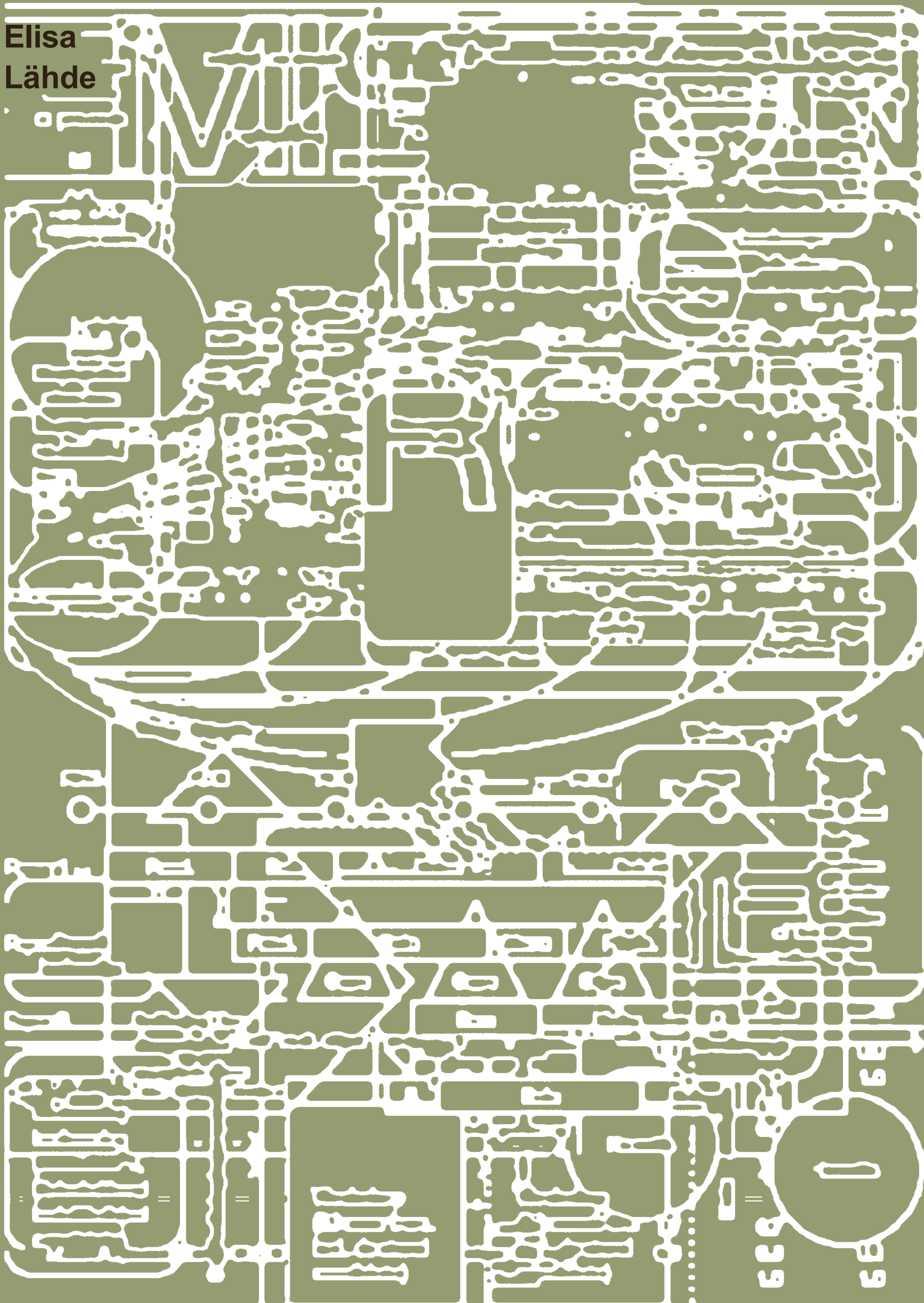
Elisa Lähde



MISSION BLUE-GREEN

The Significance of Co-Creation to Promote Multifunctional Green Infrastructure within Sustainable Landscape and Urban Planning and Design in Finland

Aalto University

BLUE-GREEN

ELISA LÄHDE is a practising landscape architect with a wide educational background extending from regional studies and environmental politics to landscape planning and urban design. She has a long working experience with landscape and urban architecture projects and is currently working in a leading position consulting sustainability of urban development and infrastructure projects. Elisa's skill for effortlessly combining abstract frameworks into practical solutions in an innovative way makes this book an enjoyable journey into transformative urban sustainability.

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Lähde

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Aalto University
School of Arts, Design and Architecture

CONTENTS

List of Abbreviations and Symbols

ES	Ecosystem Service
GI	Green Infrastructure
LID	Low-Impact Development
SUDS	Sustainable Urban Drainage Systems
WSUD	Water-Sensitive Urban Design

LIST OF PUBLICATIONS

This doctoral dissertation consists of a summary and the following publications that are referred to in the text by their numerals.

1. Lähde, Elisa; Di Marino, Mina. 2018. Multidisciplinary collaboration and understanding of green infrastructure: Results from the cities of Tampere, Vantaa and Jyväskylä (Finland). *Urban Forestry and Urban Greening*. Volume 40, April 2019, pp. 63-72.
2. Lähde, Elisa; Rosqvist, Kajsa. 2018. Barriers preventing development of integrated stormwater management in Helsinki, Finland. In: Rajaniemi, J. & Chudoba, M. (Eds.) *Re-City. (Im)possible Cities*. (DATUTOP). Tampere University of Technology, School of Architecture. pp. 29–48. ISBN 978-952-15-4144-5.
3. Tapaninaho, R.; Lähde, E. 2019. Multi-stakeholder cooperation for green infrastructure: Creating sustainable value. In Day, A.K. and Lehtimäki, Hanna. (Eds.) *Evolving Business Models in Ecosystem of Disruptive Technologies and Social Media*. New Delhi: Bloomsbury, pp. 169–181.
4. Lähde, Elisa; Khadka, Ambika; Kokkonen, Teemu; Tahvonen, Outi. 2019. Can we really have it all? Designing multifunctionality with sustainable urban drainage system elements. *Sustainability*. Volume 11, Issue 7, 1 April 2019, Article number 1854.

Author's Contribution

Publication 1. 'Multidisciplinary Collaboration and Understanding of Green Infrastructure: Results from the Cities of Tampere, Vantaa and Jyväskylä (Finland)'——The author was the main contributor to this publication. She led the collaborative efforts regarding the study design, data analysis, and results discussion. Mina di Marino participated in analysing and writing the paper and discussing the results.

Publication 2. 'Barriers Preventing Development of Integrated Stormwater Management in Helsinki, Finland'——The author was the main contributor to this publication. Kajsa Rosqvist participated in the practical implementation including collecting data and analysing and writing the paper.

Publication 3. 'Multi-Stakeholder Cooperation for Green Infrastructure: Creating Sustainable Value'——The author collaborated on the research design and practical implementation including collecting data and analysing and writing the paper. The author provided insight into co-framing the semi-structured interviews. Riikka Tapaninaho participated in the research design and practical implementation, including collecting and analysing data, writing the paper, and discussing the results.

Publication 4. 'Can We Really Have It All? Designing Multifunctionality with Sustainable Urban Drainage System Elements'——The author was the main contributor to this publication. She led the collaborative efforts regarding the study design, data analysis and results discussion. Ambika Khadka was responsible for designing, preparing and analysing quantity and quality results related to water. She also participated in writing the article. Teemu Kokkonen also participated in writing the article. Outi Tahvonen participated in designing and analysing the amenity- and biodiversity-related results and writing the article.

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ABSTRACT

We are undeniably living in an era of enormous environmental crisis, with climate change and species extinction as its most outstanding features. These issues challenge our societal systems and relationship with nature. In addition, more than half of the planet's population lives in urban areas, where environmental problems tend to culminate and where counter-active efforts should be concentrated.

Green infrastructure (GI) is a prominent approach to solving urban environmental issues. Generally, GI can be defined as an interconnected green space network that is planned and managed for its natural resources and values and for the associated benefits to the population. Within urban settings, GI can be defined as a strategic network of planned and unplanned urban green and blue spaces that help cities meet several urban challenges by delivering ecosystem services. This emerging concept has been considered a promising framework to connect natural and semi-natural systems using spatial planning policies and practices and, thus, to promote sustainability and climate resilience.

Solving complex sustainability-related problems requires inputs from various communities of knowledge. In this doctoral dissertation, the aim is to study the possibilities and potentials of co-creation to promote GI in different phases of urban and landscape planning and design. The methodological approach is action research, which has been implemented in four case studies in five Finnish cities. In all the cases, the adaptation of a scientific co-creation model has been the main approach to both 1) participating in the development process for a case site and 2) collecting data for the research.

The study of co-creation-led urban development processes, including the identification of existing barriers, reveals some of the critical factors and gaps in effectively adopting the GI approach in urban planning and design. The result of the study is an accelerating model that can be used as a concrete tool to boost co-creation in the planning and design of multifunctional green infrastructures. The GI-based approach challenges planning traditions and the conventional methods we have used to envision and construct our cities. Implementing the GI-based approach and supporting the planning and design of GI elements through co-creation helps us to reorganise our actions and processes related to biophysical structures and natural processes in urban areas and to better provide desired ecosystem services. Thus, co-creation can support the use of the GI-based approach as a game-changer that facilitates regime shift to adaptive governance, enabling systemic change from existing practices to a wider socio-ecological systems approach. The co-creative processes of planning and design of GI can be used as a platform to increase both the multifunctionality of GI solutions and the joint understanding of urban socio-ecological systems as a basis for sustainability.

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Helsinki, August 2020
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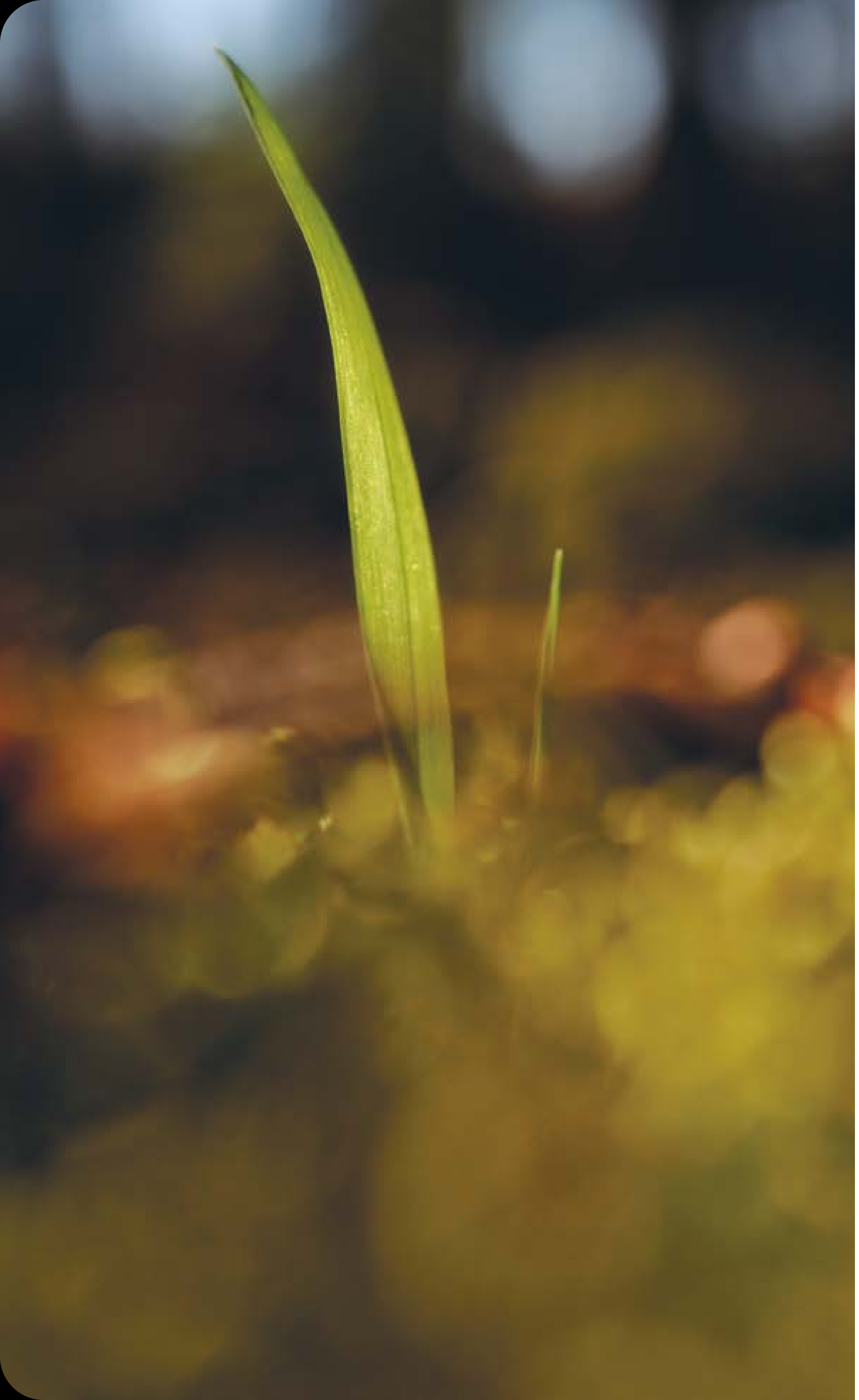


1 INTRODUCTION

Currently, we are living in an era of substantial environmental crisis, with the most outstanding features being climate change and species extinction. These issues challenge our societal systems and relationship with nature. Another megatrend is urbanisation, as more than half of the planet's population lives in urban areas, where environmental problems tend to concentrate. As an example, climate change can locally increase both the heat island effect and precipitation, leading to increased health and flood risks, especially in dense urban settings (Gill et al., 2007). Furthermore, new land-use development typically negatively affects natural environments, the related habitats, and local biodiversity, making urbanisation one of the most notable drivers of species extinction (Newbold et al., 2015).

Green infrastructure (GI) is a prominent approach to solving urban environmental issues and can be defined as 'an interconnected green space network (including natural areas and features, public and private conservation lands and other protected open spaces), that is planned and managed for its natural resources and values and for the associated benefits to the population' (Benedict and McMahon, 2012, p. 3). Within urban settings, GI is defined as a strategic network of planned and unplanned urban green and blue spaces that help address several urban challenges by delivering ecosystem services (ESs; Norton et al., 2015). Furthermore, the GI-based approach has been applied frequently to solve urban water issues (Flynn and Davidson, 2016). In some cases, the term *GI* has been used to address urban drainage solutions (Fletcher, 2015) or has been denoted as blue-green infrastructure. Despite its vagueness and multiple definitions, the emerging concept has been considered a promising framework to integrate natural processes within spatial planning policies and practices and, thus, to promote sustainability and climate resilience (Ahern, 2007; Lennon and Scott, 2014).

Solving complex sustainability-related problems requires input from various communities of knowledge (Mauser et al., 2013; Wyborn et al., 2019). More specifically, GI-related research often notes the collaboration between different stakeholders as one of the key factors for advancing GI-based approaches (i.e. Lennon et al., 2016; Faehnle et al., 2014; Ahern et al., 2014; Kopperoinen et al., 2014; Lafortezza et al., 2013; Mell, 2010). Interdisciplinarity and collaboration with stakeholders can enhance social, economic, and environmental benefits associated with the GI-based approach to urban planning and design by enabling a broader group of stakeholders to shape how the landscape is developed and managed. However, the potential composition of the stakeholder group, the scope of collaboration, and the urban development phases best suited to collaboration are not yet well established (Mell, 2017).

In this doctoral dissertation, the aim is to study the possibilities of collaboration to promote GI in different phases of landscape and urban planning and design processes through action research based on case studies. Following the growing body of literature promoting urban GI as a platform for knowledge, co-*creation* (Pauleit, 2019; Haase, 2017) was chosen as the specific manner of collaboration and was adapted to four Finnish case studies. Three of the four case studies included a strong emphasis on stormwater management, thus deepening the focus of the dissertation on sustainable urban drainage systems (SUDS).

This study of co-creation-led urban development processes, which includes the identification of existing barriers, enables the discussion of further conditions required for the effective adaptation of the GI-based approach in the context of landscape and urban planning and design and for realizing its subsequent benefits. The dissertation concerns the field of landscape architecture.

1.1 Aims and Research Questions

The overarching aim of this research is to understand how to co-create GI within landscape and urban planning and design in Finland and to determine what kind of further implementation is needed to strengthen the contribution of GI. The research is practice-oriented, as the overarching aim has been approached using four case studies dealing with the implementation of GI in different stages of urban development and the related working processes, knowledge needs, discussed barriers, and evaluation criteria. Within all the cases, the adaptation of a scientific co-creation model (Mauser et al., 2013) was the main approach to both participating in the planning or design process of a case site and collecting data for research purposes. The dissertation has two additional aims that are more concrete, that are related to each other, and that contribute to the overarching aim (Fig. 1).

The first part of the research concentrates on collaboration at the urban planning level. In this research, urban planning is understood as coordination of political and practical processes concerned with both strategic and statutory planning of land use in the urban context to create new qualities or assets (Van Assche et al., 2012). Accordingly, landscape planning is the component of urban planning processes concerned with physical, biological, cultural, and historical values and with the relationships and coordination between these values, other land uses, and the environment.

On the planning level, general outlines of the urban structure are formed, and GI and the hydrological cycle are combined with the technical and social structures of a city. Therefore, mistakes created in the planning phase are difficult to fix later in the GI solution design phase; thus, planning requires having a broad view. Accordingly, an additional aim of this work is to test the potential of co-creative processes to foster the adoption of a GI-based approach at the strategic planning level of urban development, with the goal of *understanding how co-creation can promote the development of more multifunctional GI*. The results allow further discussion, which is a required precondition for the effective use of the GI concept. This first portion of the research was conducted through two case studies, which are presented in the research papers 'Multidisciplinary Collaboration and Understanding of Green Infrastructure: Results

from the Cities of Tampere, Vantaa and Jyväskylä (Finland)' (Paper 1) and 'Barriers Preventing Development of Integrated Stormwater Management in Helsinki, Finland' (Paper 2). Both papers have specific research questions linked to the overall research aims in Fig. 1.

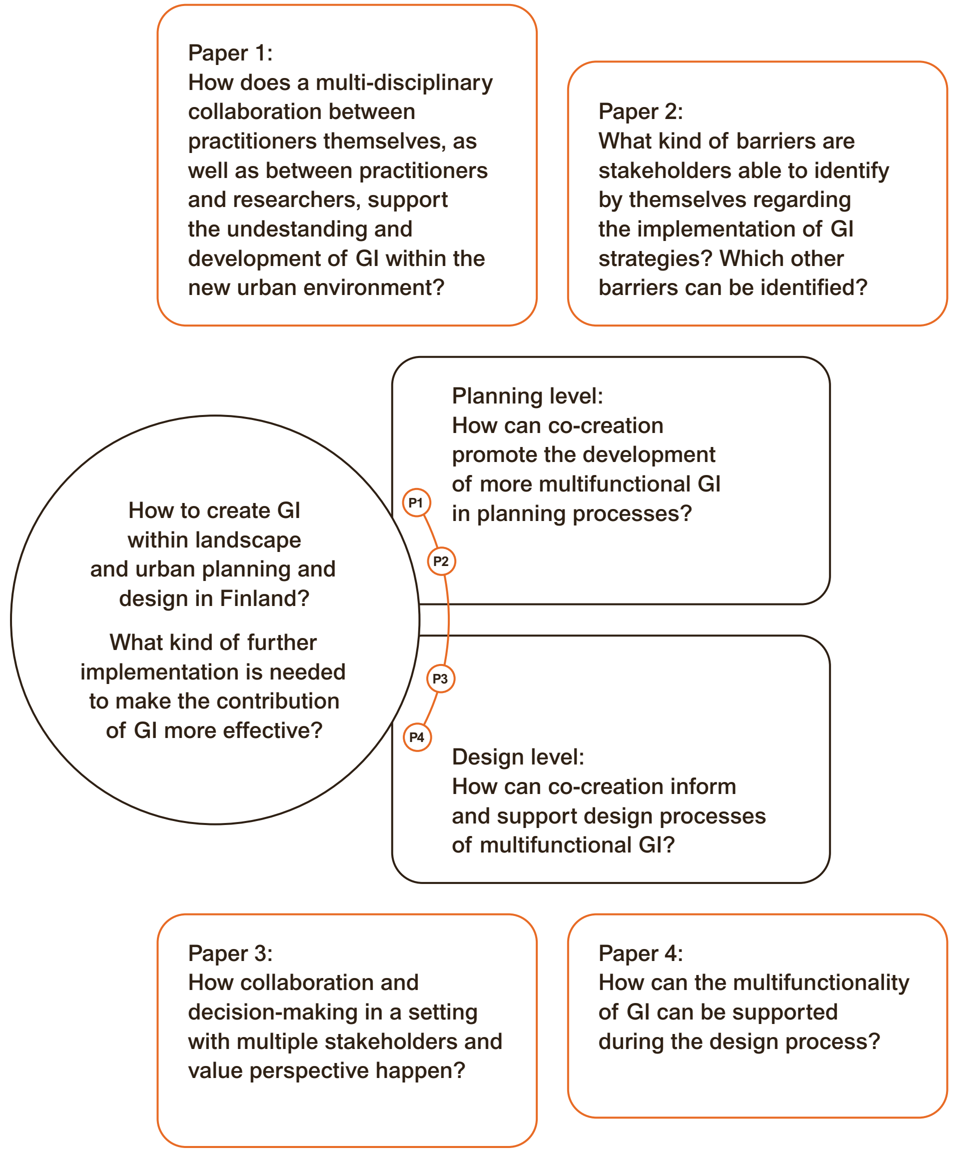


Fig 1. The main research question of the dissertation divided into two constituent aims, one concerning the planning level and the other concerning the design level; each includes two case studies. GI: green infrastructure. The additional aim and specific research questions of the papers related to the first part of the study on urban planning (papers 1 and 2), as well as to the second part of the study on urban design (papers 3 and 4).

In the second part of the research, the focus is on the GI solution design level. Design is understood as the process of designing and shaping the physical features of urban or landscape elements. It is creation and evaluation of the possible forms of something, including production (Van Assche et al., 2012).

The design of a GI solution is complex because the primary advantage of GI is multifunctionality (Hansen and Pauleit, 2014; Hansen et al., 2015). Multifunctionality is the capacity of a single solution to deliver multiple services. In the GI solution design process, water and vegetation are integrated with technical structures to deliver multifunctional benefits. The second part of this research addresses the design of GI solutions by defining the knowledge needs, design targets, and valuation criteria of GI solutions by asking *how can co-creation inform and support design processes of multifunctional GI?* This question is answered by conducting two more Finnish case studies (in the *Vauhtitie wetland* in Helsinki and the *Kirstinpuisto area* in Turku), whose outcomes were published in the research papers 'Multi-stakeholder Cooperation for Green Infrastructure: Creating Sustainable Value' (Paper 3) and 'Can We Really Have It All? Designing Multifunctionality with Sustainable Urban Drainage System Elements' (Paper 4), respectively. Both papers have specific research questions linked to the overall research aims displayed in Fig. 1.

1.2 Research Process and Dissertation Structure

This dissertation consists of three peer-reviewed journal papers and one peer-reviewed conference paper, which form the basis for the study. The list of publications with full bibliographical information is presented at the beginning of this dissertation.

The research was begun in 2014 by applying for funding and framing the overarching research questions, and it continued over five years until the beginning of 2020, as illustrated in Fig. 2. From the very beginning, GI and related stormwater solutions were the focus of the research, but during the process, the role of co-creation has become an essential component within the study of GI. In the end, the potential benefits of GI-related co-creation form the core theme of the dissertation.

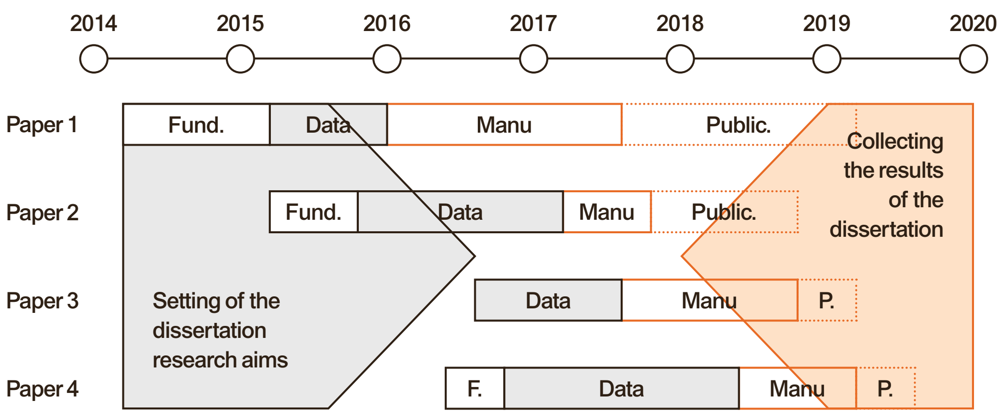
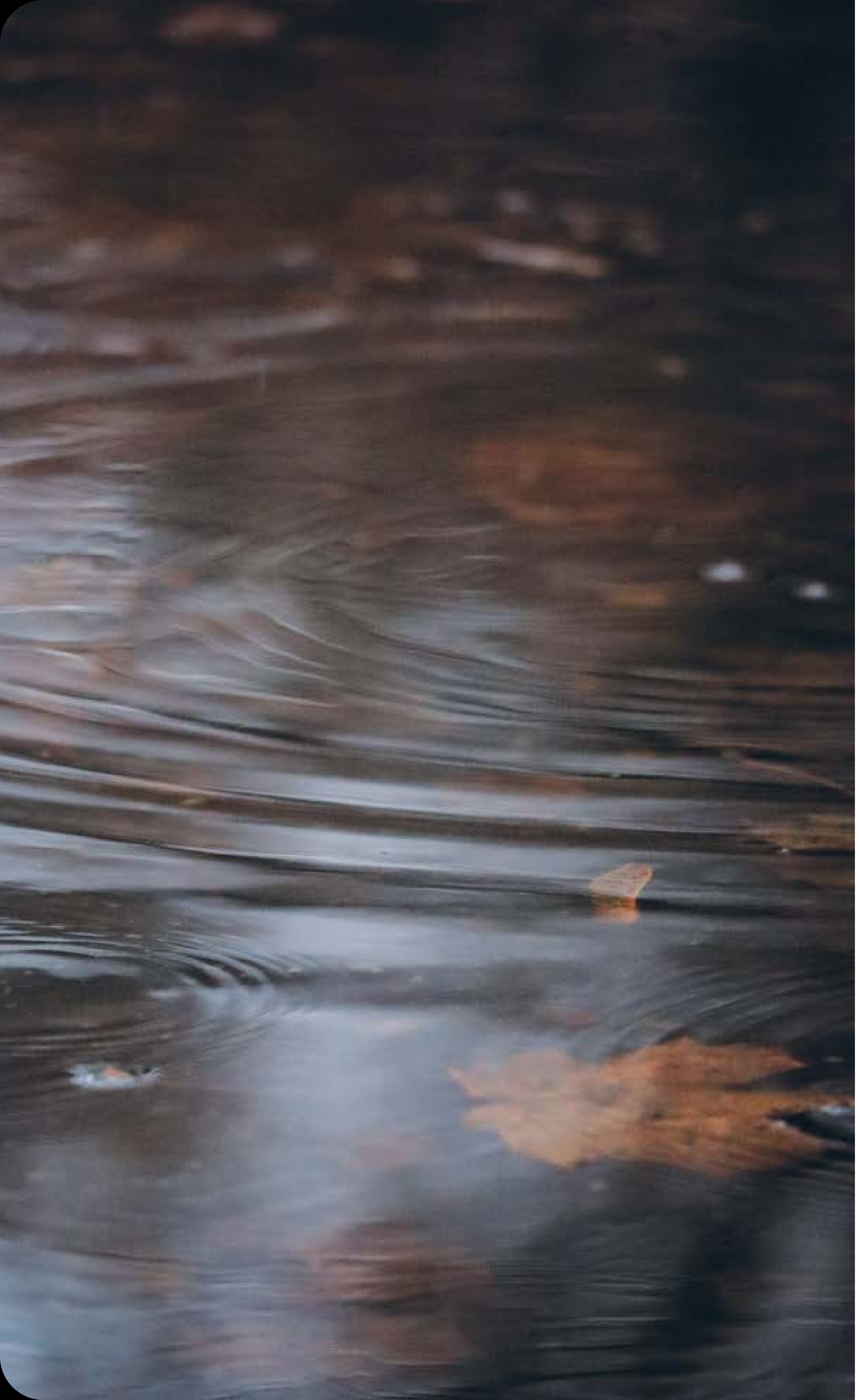


Fig 2. The timeline of the research process, consisting of four research papers (Fund: funding, Data: data production, Manu: preparation of the manuscript, Public: publication process).

The dissertation consists of five chapters. The introduction chapter describes the approach to the topic and the structure of the dissertation, and the research aims and questions are formulated. The second chapter presents the theoretical foundation of sustainable urban development, especially regarding the potential contributions of the urban green and water systems. Subsequently, the methodological approach of the research is introduced, after which the data produced with the help of the co-creation model and the analysis methods used in each paper are presented and justified. The reliability and validity of the research are then considered. The fourth chapter includes a summary of the research papers and the main results concerning the overarching research aims

of the dissertation. Finally, in Chapter 5, the scientific influence of the dissertation is discussed, and recommendations for further research are presented.

The significance of the research is that it reveals the importance of co-creation within landscape and urban planning and design as an essential approach to foster mutual capacity building and interdisciplinary learning, especially concerning socio-natural processes. In this context, co-creation accelerates a possible transition towards more adaptive governance models and a more sustainable future.



2 THEORETICAL BACKGROUND

This chapter positions the thesis within the context of the current relationships between humans and nature and the evolution of the concept of sustainability, where GI can play a pivotal and strategic role. In the first section of this chapter, the GI concept is defined more precisely as it relates to the dissertation aims and the model of co-creation. Thereafter, the relationship between humans and nature is presented as the background for the development of the GI-based approach. The relationship between humans and nature has been debated and defined throughout history in the areas of arts, philosophy, and politics. Given the emergence of local, and more recently global, environmental problems, a more sustainable approach towards nature and ecological processes is needed. The evolution of the concept of sustainability is briefly described in this chapter to promote the understanding of GI and its significance as a part of this process.

2.1 Green Infrastructure

In the European policy framework, GI has been defined as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' in both rural and urban settings (European Commission, 2013, p. 3). Moreover, 'GI is an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife' (Benedict and McMahon, 2006).

The theory and application of GI have increased substantially during the 21st century (Mell, 2019; Wright, 2011) and are 'advocated as a means to enhance ecosystem services [ESs] provision via spatial planning' (Lennon and Scott, 2014, p. 564). Despite its popularity, GI remains a broad concept in terms of appropriate scale (from the national level to local projects) and purpose (including multifunctionality, connectivity, and collaborative planning; Hansen and Pauleit, 2014), challenging exact definitions and solid implementation.

In this thesis, the term *GI-based approach* is used to refer to a strategic approach that addresses the understanding and development of an interconnected network of *GI elements* that maintain ecological processes and functions. A GI element can be a natural or human-made biological structure or component, such as an entire waterway, wetland, or woodland outside densely built urban areas or a park, meadow, green roof, rain garden, or single plant located within the urban fabric that provides ESs, a concept that is closely related to GI.

Moreover, ESs are benefits people obtain from nature (Millennium Ecosystem Assessment, 2005) that are delivered by well-functioning biological structures and processes according to the *cascade model* (Potschin and Haines-Young, 2011; Fig. 3). Complex social and ecological factors and their interactions create and alter ESs (Reyers et al., 2013). As we grow in our understanding of our influence on ES delivery and, indirectly, on our well-being, we can govern our effects by setting policy targets, developing indicators, and establishing monitoring programmes.

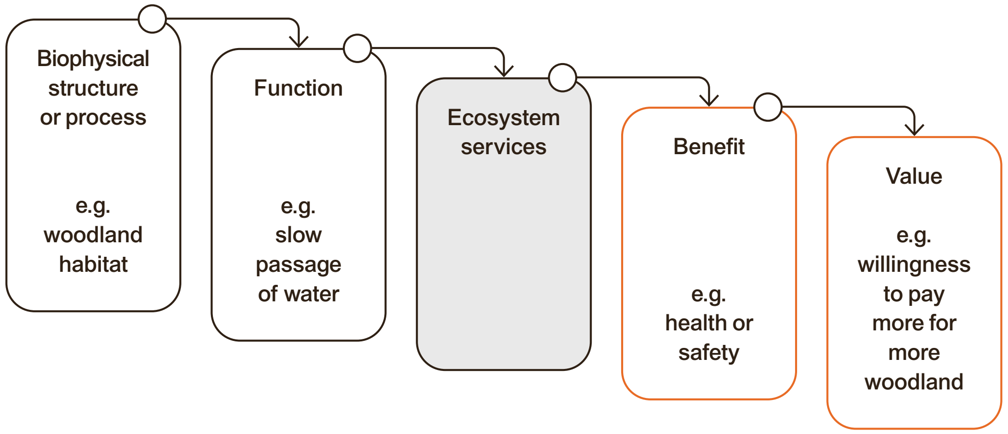


Fig. 3 The ecosystem service cascade model (adapted from Potschin and Haines-Young, 2011).

The 25 defined ESs are grouped into three main categories (Common International Classification of ESs, 2008; Fig. 4). Typically, cultural and provisioning services are well understood and, to some extent, are considered in urban planning, whereas regulating and maintenance services are less well known. However, they have an important role because they are associated with ecosystem processes that maintain environmental conditions that are favourable to life. Among the most important of these processes are cycling substances and ensuring the reproduction of organisms.

Today, the ES concept is resolutely situated within academic and practice debates on how to more accurately consider the value of environmental resources in decision-making (Apitz, 2013). The ES concept shifts the approach from conservation-oriented nature relationships to utility-oriented relationships.

> *Therefore, in defining what the 'significant' functions of an ecosystem are and what constitutes an 'ecosystem service', an understanding of spatial context (geographical location), societal choices and values (both monetary and non-monetary) is as important as knowledge about the structure and dynamics of ecological systems themselves. (Haines-Young and Potschin, 2010, p. 116)*

The comprehensiveness of the ES concept can help us shift away from managing natural resources one by one and treating the environment as an externality. Lennon and Scott (2014) suggested that, if we understand the complex interactions between space and society, we can restructure and realign purposes of spatial planning to facilitate mutually beneficial relations between humanity and the environment. Planning has the potential to contribute to the fluent provision of ESs and a transition to more resilient places that are able to cope with complex environmental disturbances. More precisely, GI has emerged

as a concept that may be employed to operationalise an ES-based approach within spatial planning policies and practices. Characterised by multifunctionality and connectivity, the GI-based approach emphasises enhancing and restoring natural assets and designing and creating new natural assets, in addition to the traditional protection of nature (European Environment Agency, 2011).

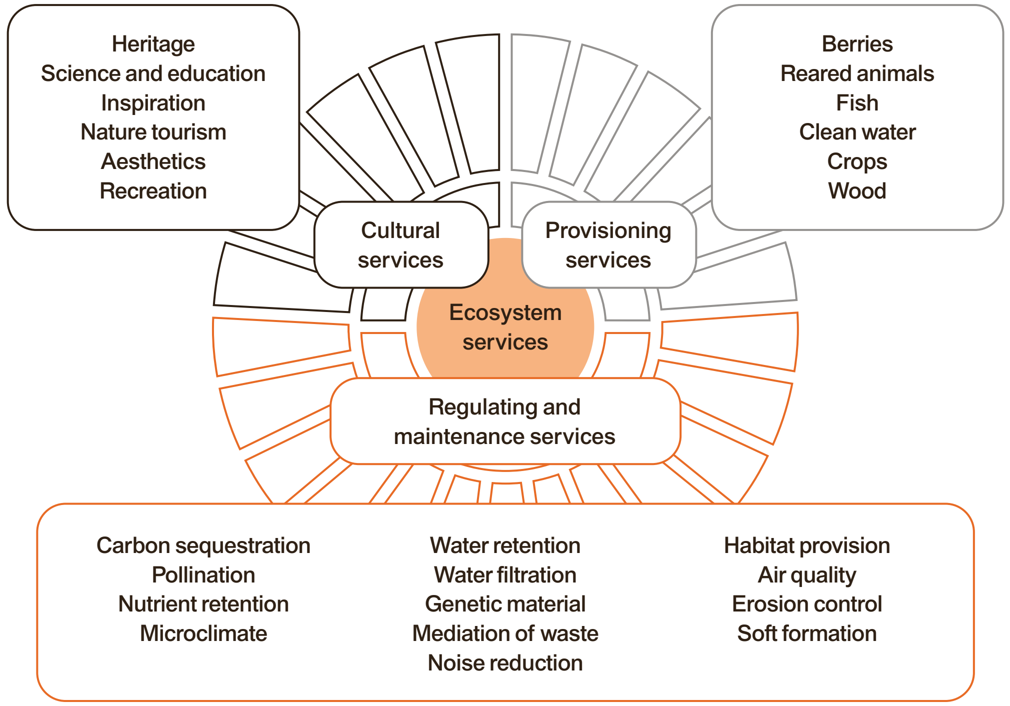


Fig. 4 Three main categories and 25 separate ecosystem services defined by Common International Classification of ESs (2008).

The maintenance and restoration of land-based ecosystems are key strategies to provide ESs and meet the local ES demand. This approach creates new requirements for urban areas, as each climate zone, each region, and each ecosystem requires a customised solution. Acknowledgement of the complex interactions between local circumstances and related societal demands challenges the existing means and purposes of spatial planning to facilitate an adequate GI network and mutually beneficial relations between humans and the environment (Davoudi, 2012; Wilkinson, 2012).

2.2 Green Infrastructure and Urban Water Systems

The GI-based approach can have clear synergies with sustainable urban water management, although urban water management has been traditionally disconnected from urban landscape planning. Brown et al. (2009) investigated the relationship between urban development and water management, showing that human needs (i.e. 'cumulative socio-political drivers') have promoted a shift in the development of water-related infrastructure from water supply systems to water sensitivity (Fig. 5).

This development has led to closer connections between water management and landscape planning. Over the last few decades, the decentralised, on-source approach has been a new paradigm in urban stormwater management (Marsalek and Chocat, 2002). Previously, urban drainage was considered only a problem, but related opportunities, such as increased biodiversity and climate adaptation, are now widely recognised (Ashley et al., 2013). This type of approach emphasises the use of multifunctional source controls, the transition from traditional drainage to a GI-based approach, and the consideration of additional environmental benefits (Mailhot and Duchence, 2010).

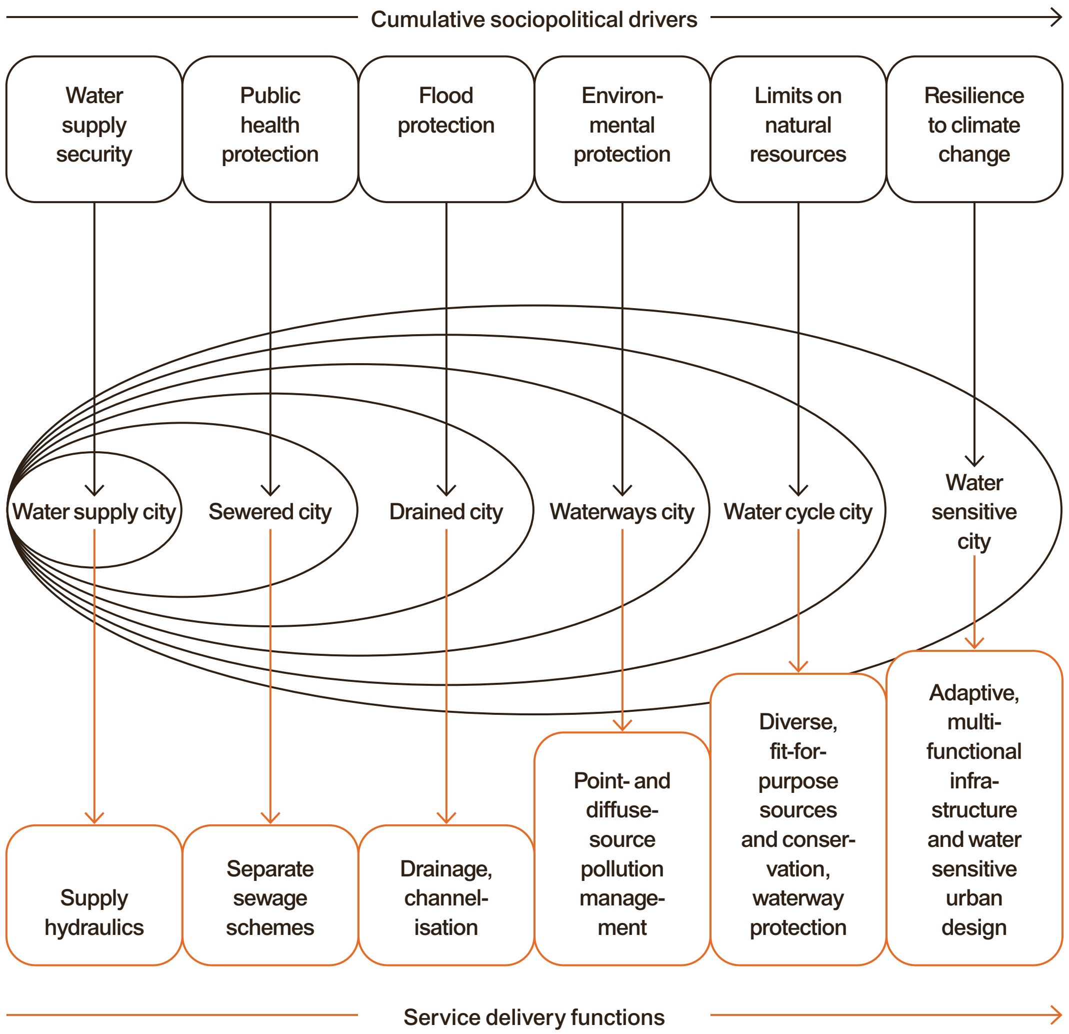


Fig. 5 The evolution of an urban water management paradigm (adapted from Brown et al., 2009).

SUDS are practical applications of the GI-based approach. They use natural processes (infiltration, evapotranspiration, filtration, retention, and reuse) to mimic the natural water cycle of a site. In different contexts, these practices can be referred to by other similar terms (Fletcher et al., 2015), such as low-impact development (LID), best management practices, and water-sensitive urban design (WSUD). Some of the approaches are more strategic (e.g. WSUD), some heavily emphasise water quality and quantity management (i.e. LID), and others emphasise the provision of ESs. In this thesis, the term SUDS is used to describe all kinds of sustainable urban drainage applications to sustain the existing local hydrology that harvest, infiltrate, slow, store, convey, and treat surface water in ways that differ from mainstream, conventional drainage practices.

If the functionality and potential benefits of SUDS are correctly understood, it is possible to create comprehensive treatment trains, a combination of multiple complementary SUDS elements

designed to meet the needs of a local environment to achieve better overall quality and quantity management (Revitt et al., 2014). In addition, SUDS can create substantial amenity, recreational, and identity benefits, among other ESs (Haase, 2015; Demuzere et al., 2014; Scholz, 2014), thus connecting water management to the urban green network as an essential part of the urban GI.

Nature-based solutions (NBSs) are also embedded in the SUDS concept, but the term generally refers to a larger set of applications that are comparable to GI elements (Dushkova and Haase, 2020). The NBSs are interventions based on nature that are envisaged to address sustainability challenges, such as resource shortages, floods, health risks, and ecosystem degradation caused by the processes of urbanisation and climate change (Dorst et al., 2019). Moreover, an NBS 'includes the main ideas of green and blue infrastructure, ecosystem services, and biomimicry concepts' and enhances urban regeneration, especially highlighting climate change adaptation and mitigation (Dushkova and Haase, 2020, p. 1).

In general, NBSs and SUDS with urban water management reveal one of the main advantages of the GI-based approach, multifunctionality, which is defined as the ability of GI to 'perform several functions and provide several benefits on the same spatial area' (European Environment Agency, 2012). Additionally, it has been described as the capacity of GI to provide multiple ESs (Liquete et al., 2015). Multifunctionality has subsequently crystallised as a key criterion in determining the quality of an urban landscape (Hansen and Pauleit, 2014; Hansen et al., 2015) and is considered a basic attribute of urban environments that allows them to respond to different challenges and maintain the quality of life (Wang and Banzhaf, 2018). Therefore, multifunctionality is a quality or characteristic that should be incorporated in urban planning and design processes, but operationalisation and practical examples are still lacking (Hansen et al., 2019).

2.3 Sustainable Development

From a broader perspective, the emergence of the GI-based approach can be considered a consequence of the redefinition of the relationship between humans and nature, similar to the way that SUDS, as a part of the water management infrastructure, reflects the development of a new urban and water relationship (Fig. 5). The evolution of the relationship between humans and nature is briefly described in the next two paragraphs and frames the GI-based approach as an essential part of sustainable urban development.

The conventional dichotomist approach claims that nature exists independently of society (White et al., 2016; Carolan, 2005), and this worldview has dominated Western history (Descola and Palsson, 1996). This worldview has been supported by religious assumptions that perceive humans as the crowning glory of God's creation with the development of capitalism, the industrial revolution, and modern science (Hopwood et al., 2005). For example, the *Oxford English Dictionary* (2019) defines *nature* as 'the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations'.

Currently, natural and human societies are understood as being intertwined and interacting (White et al., 2016). Our actions affect the natural world, and biophysical and ecological processes can simultaneously play an important role in shaping social conditions. However, it has taken some time to reach this understanding (Carolan, 2005), as clarified in the following paragraphs.

Nature consists of ecosystems that are the result of interacting organisms and their physical environments. Ecological processes sustain all ecosystems, keeping them alive and functioning, and they are connected, according to Alexander Von Humboldt (Wulf, 2015). Von Humboldt was an 18th-century scientist and explorer who claimed that the world is a single interconnected system in which ecological processes have produced diverse ecosystems and related biological communities over millions of years. Thus, he understood that nature is a huge, complex system.

It took 100 years more to fully and scientifically understand that humans are part of that system. In the mid-19th century, George Perkins Marsh was the first to declare that the actions of humankind disturb and threaten existing ecosystems (MacKinnon, 2013). Marsh showed that ancient human civilisations left their mark on the landscape and that their rise and fall were both related to natural resources and the overconsumption of them.

During the 20th century, the effects of industrialisation, consumerism, and the growing population have become more evident. Roots of the environmental and sustainability movements have their origin in the 1960s when the first environmental science books, such as Rachel Carson's *Silent Spring* (1962), were published, and the adverse environmental effects caused by human actions were questioned for the first time. Environmental threat analysis started the development of both environmental policy strategies and environmental legislation, and the United Nations (UN) held its first environmental conference in 1972. During the same year, the concept of *sustainability* was introduced in the publication *The Limits of Growth* (Meadows et al., 1972).

However, the real breakthrough for the concept *sustainable development* was the 1987 book *Our Common Future* by the Brundtland Commission (World Commission on Environment and Development, 1987). This book was also 'the first overview of the globe, which considered the environmental aspects of development from an economic, social and political perspective', thus entwining social and ecological aspects more tightly together (Redclift, 2015, p. 212). Although the book warned of international environmental problems and criticised industrialised countries, it saw economic development as still desirable; thus, the concept of sustainable development moved from the margins to the mainstream (Wheeler, 1998).

Numerous definitions exist for *sustainability* and *sustainable development* that depend on the changing cultural constructions placed on the environment (Redclift, 2005). Accordingly, no single unified philosophy of sustainable development exists (Hopwood et al., 2005). The more recent awareness of large, persistent changes (Rocha et al., 2015), such as species extinction, increased pollution, and lack of resources, has prompted the development of various policies that attempt to guide us towards sustainable development (e.g. World Summit on Sustainable Development, 2002; Transforming our World: The 2030 Agenda for Sustainable Development, 2015; Steffen et al., 2015).

Furthermore, escalating climate change and biodiversity loss both indicate that complex social and ecological interactions have resulted in increased exposure to new types of risk (Helbing, 2013), generating new demands for sustainable development. Inherent in the concept of sustainable development is the idea that society needs to change, although our conceptions of the scale, tools, and actors associated with the change vary from moderate status quo views to radical transformative views (Hopwood et al., 2005). However, the demands for a more comprehensive transformation and a systemic approach have recently increased as people gain new comprehension of the magnitude, frequency, and consequences of environmental changes caused by humans (Reyers et al., 2018).

2.4 Sustainability and Systems Thinking

Increased understanding of our effects on the planet and of what kind of ecological feedback loops are generated by our social and economic actions has resulted in the definition of the *Anthropocene*, a new geological era. The Anthropocene has been defined as the age of humans (Reyers et al., 2018), and various views exist on its precise starting point, but 'there is no doubt that, since the middle of the 20th century, human beings have exerted enormous pressure on some of the most crucial bio-geo-chemical cycles' (da Veiga, 2017, p. 235) at such a large scale that it is now threatening our well-being. Escalating environmental changes interact and connect across scales with great social and economic consequences and turbulence, triggering feedback loops (Steffen et al., 2011).

With the increasing understanding that the biosphere is in a constant state of change and that those changes and the associated processes can play key roles in shaping human societies, the interest in resilience has grown. *Resilience* is a concept that comes from natural science, referring to the ability of a system to absorb disturbances and retain its basic function and structure (Walker and Salt, 2006). The response of any system to shocks and disturbances depends on its context, connections across scales, and current state. Resiliency is the capacity of a system to undergo change and retain essentially the same function, structure, and feedback.

In the context of sustainable development, resilience is linked to adaptive strategies to cope with and adapt to changes and the *socio-ecological system* (SES) approach (Reyers et al., 2018; Folke, 2016). According to the SES approach, all individuals, communities, and societies operate in social systems that are embedded in the biosphere and ecological systems; thus, humans all exist within SESs. Moreover, SESs are complex adaptive systems, where sustainable development requires 'finding ways for people and institutions to govern social-ecological dynamics for improved human well-being, at the local, across levels and scales, to the global' (Folke, 2016, p. 1). Sustainable development requires *systems thinking*, which must be based on the appreciation of the intertwined nature of the environment and society with feedback loops operating in both directions.

2.5 Urban Development and Sustainability

Urban development has followed the changing needs of human societies, and sustainability is no exception to this trend. As over half of the human population is currently living in urban areas that shape external ecosystems and depend on them for water, food, and other ESs, urbanisation is a major driver of the Anthropocene (Barau and Ludin, 2012). Furthermore, urban areas can be considered interlinked SESs that are complex and adaptive (Sellberg et al., 2015). Thus, *sustainable urban development* is necessary and can support our attempts to live in a more balanced way with ecological processes.

Sustainable urban development can encompass various efforts: attempts to build a smart information society, to establish friendly and liveable communities, to reduce carbon footprints, and to promote balanced ecological development through GI (Jong et al., 2015). In discussions and political initiatives, these efforts are often linked together, and related concepts overlap and even mix. The term *sustainable city* is an umbrella category that gathers ideas about how 'comprehensive human-supported technological interventions benefit social well-being, economic growth and ecological regeneration in the city' (Jong et al., 2015, p. 26).

In contrast, the concept of a *resilient city* is related to safety science, environmental science, and governance. In this research, *resilient city* refers to *adaptive governance*, a regime that increases positive interactions between a city and its natural environment, especially regarding ES provision. In doing so, the adaptive governance involves a transformation in the ways urban planning systems are approached and how practitioners conceive of their influence on urban SESs.

Consequently, adaptive governance is the practical embodiment of the resiliency approach. Both social and ecological systems are complex systems, and SES governance requires insight into their coevolution. According to Assche et al. (2019), critical requirements for adaptive governance include constant learning and allowing both experts and local knowledge to influence decision-making to manage the couplings between systems. The management of these couplings makes the social and ecological systems more, less, or differently responsive to each other and modifies their effects on each other. New governance configurations are necessary, both enabling and embodying veried couplings between social systems or between social and ecological systems (Assche et al., 2019). Regime shifts to policy interventions, targets, and adaptive management that acknowledge and are based on the system's irreducible complex structure are proposed for sustaining desirable system outcomes.

Following this need to reassess linkages between social, ecological, and planning systems, Lennon and Scott (2014, p. 569) identified an ecological fix, a transition in landscape and urban planning processes and practices to 'fully integrate the ecological dimension alongside traditional planning concerns'. GI is perceived as a concept that can deliver socio-ecological integration and allow humans to work towards alignment with nature. Similarly, Ahern (2007) stated that the implementation of urban GI is essential to achieving a regime shift, placing ES provisions and environmental risks as central concerns of urban planning.

From the SES perspective, resilience also includes the capacity of the system to transform with change. Transformability is the capacity of an SES to learn, combine experience and knowledge, and adjust its responses to changing external drivers and internal processes (Folke, 2006). The resilience approach allows the new identity of an SES to emerge through interactions of individuals, communities, and societies through their interplay with the biosphere within and across scales (Folke et al., 2010). Living with such complexity and change is facilitated by co-creation and adaptive approaches. Therefore, it seems essential to further test the potential of co-creation to promote the GI-based approach and study what kind of additional implementation is needed to strengthen the contribution of GI.

2.6 The Need for Co-creation

The implementation of the GI-based approach is complex, beleaguered by uncertainties (Lennon et al., 2017), and often hindered by social, organisational, or political barriers, including a silo mentality (Kambites and Owen, 2006). Earlier studies have shown that the interaction of research and practice improves the use of scientific knowledge (Arnott et al., 2020) and the involvement of multiple participants in producing new ways to integrate knowledge into decision-making and action (Wyborn et al., 2019).

The need for multidisciplinary co-creative processes has been brought to the attention of the landscape and urban planning community as a means of sharing learning and the understanding of GI (Lennon et al., 2016; Faehnle et al., 2014; Ahern et al., 2014;

Kopperoinen et al., 2014; Lafortezza et al., 2013). To solve complex environmental problems, we need new types of collaboration (O'Brien, 2012; Mauser et al., 2013; Wyborn et al., 2019). In addition, professional silos and the lack of a collaborative approach have been identified as two of the main barriers that limit the adoption of GI (Lennon et al., 2016; Ahern et al., 2014; Mell, 2010). Moreover, knowledge-related barriers could be lowered by promoting collaboration with different stakeholders (O'Donnell et al., 2017).

In this context, researchers serve as facilitators when collaborating with planners and local governments in outlining policies and programmes for the development of GI (Hostetler et al., 2011). Co-creation should involve a wider range of stakeholders in landscape and urban planning, landscape architecture, ecology, architecture, and urban design (Ahern et al., 2014).

It is also important to understand that the introduction of GI to several disciplines, such as landscape architecture, landscape planning, urban planning, engineering, and urban design, does not occur straightforwardly. Professional, cultural, planning, and political contexts exist in which new GI knowledge is challenged by the status quo of expertise (Di Marino and Lapintie, 2018).

Our understanding of ESs delivered by urban green structures is still limited because nature is valued primarily for recreation or limited-use habitat conservation (Lennon and Scott, 2014). Additionally, practitioners do not yet possess a clear understanding of what constitutes GI, or they are confused by the complexity and ambiguity of the concept (Wright, 2011). Thus, GI cannot be implemented as a top-down strategic planning approach, but new forms of interaction must be explored between stakeholders and inside professional collaborations. To achieve GI's potential, practitioners need to comprehend how the approach is implemented in practice (Wright, 2011).

Collaborative processes have become a cornerstone of research to achieve new sustainability-related knowledge and implement its findings: collaboration brings scientific and practical knowledge together with a wide range of relevant stakeholders and can lead to societal change (Wyborn et al., 2019). Collaboration among diverse actors can help to develop common ground and mutual understanding. Furthermore, it can create new capacities to integrate science with enhanced engagement of stakeholders (van Kerkhoff and Lebel, 2015).

In this research, capacity is regarded as a relevant outcome of the co-creation process. Capacity can be defined as '… the ability to perform functions, solve problems, and set and achieve objectives' (Fukuda-Parr et al., 2003, p. 8) on three levels: the systems level, the institutional level and the individual level (UNDP, 1998). Furthermore, van Kerkhoff and Lebel (2015) emphasize capacities to create, access, interpret, and apply scientific and research-based knowledge along with capacities to combine science with existing, localized knowledge, practices, and governance as responses to global environmental change.

However, from the researcher's perspective, difficulties still exist in providing notions and tools that are adequate for the implementation of GI through co-creation. While collaborative processes have been identified as effective strategies to implement new knowledge about planning (Opdam, 2010; Lennon et al., 2016), they have also been criticised for offering little clarity on process objectives and outcomes (van der Jagt et al., 2019), for lacking evidence supporting claims of impact (Lemos et al., 2018), for involving overly local orientation (Sutherland et al., 2017), or for reinforcing the power of policy elites or those who have the time and capacity to engage, thereby marginalizing those with alternative perspectives (Lövbrand 2011; Turnhout et al., 2020).

In this research, the model of co-creation (Fig. 6) proposed by Mauser et al. (2013) is used to frame collaborative actions between stakeholders. The model is a tool to introduce ‘new research strategies, with a strong focus on joint efforts by researchers from the natural, social and human sciences and engineering to contribute’ to a globally sustainable future (Mauser et al., 2013, p. 421).

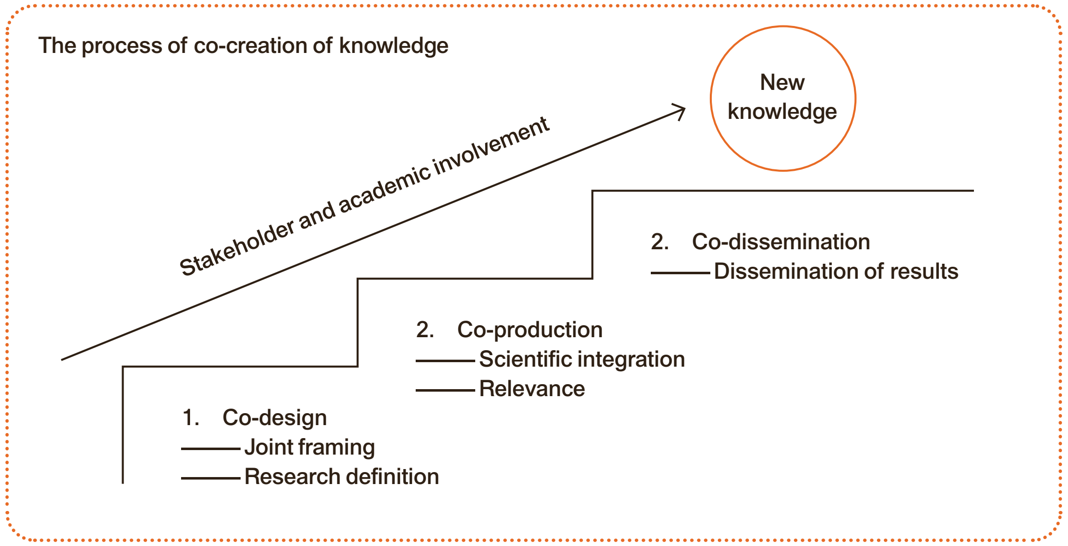
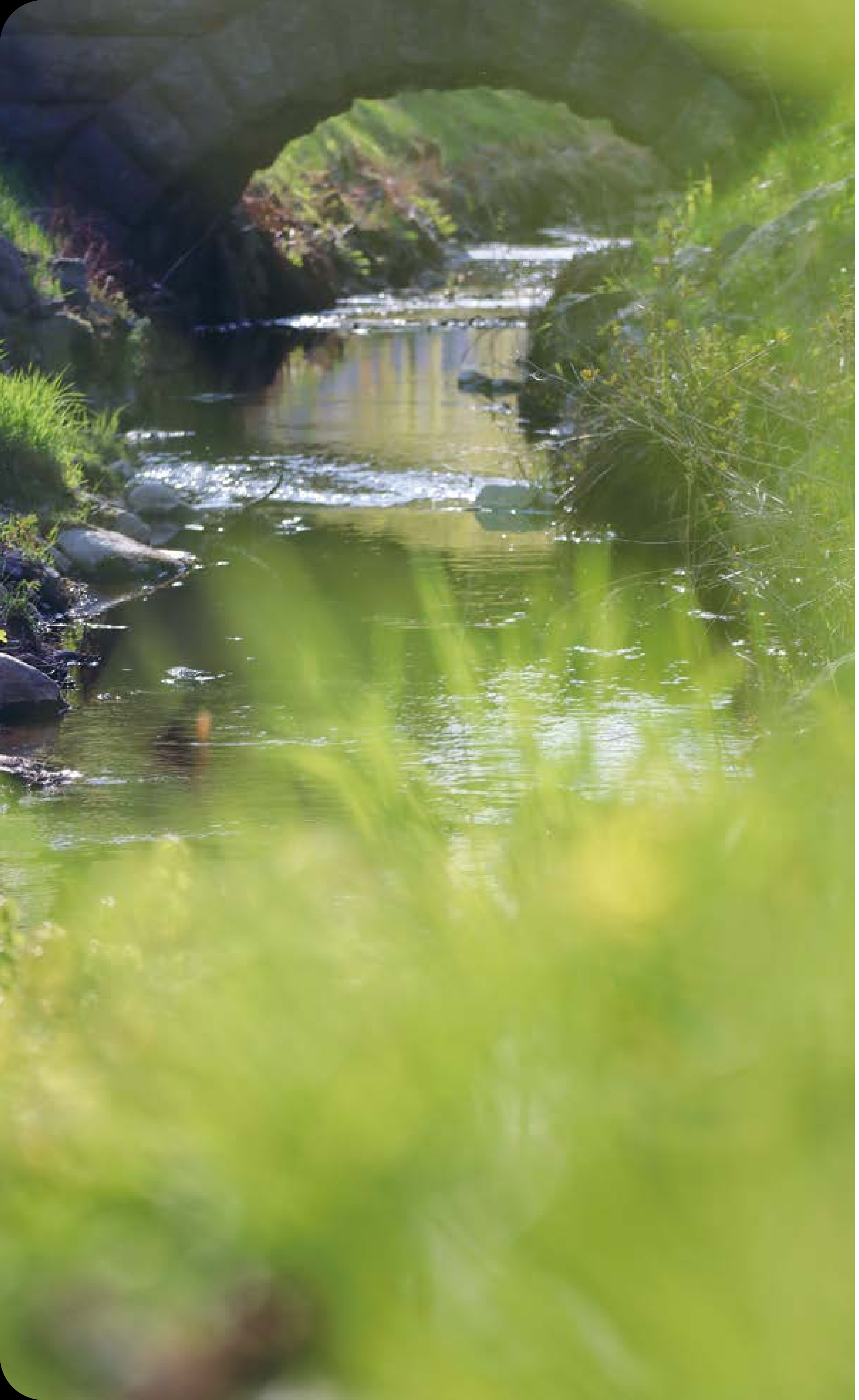


Fig. 6 The steps of knowledge co-creation (adapted from Mauser et al., 2013).

The model introduces three steps of the research process, identified as follows:

1) *co-framing* (originally *co-design*, but renamed here to bring clarity to process descriptions in Chapter 3), where the research aims and questions are framed in collaboration with different research stakeholders;
2) *co-production*, where integrated research (or the planning or design processes as discussed in Papers 1, 2, and 3) is conducted as a continuous exchange and communication process among the participating research group and other stakeholders; and
3) *co-dissemination*, where the results are translated into comprehensible and usable information for various stakeholders, and an open discussion occurs on the valuation, applicability, and relevance of the results.

The use of the model is explained in more detail in Section 3.2. (Co-creation of Knowledge).



3 METHODOLOGY

3.1 General Methodological Approach

An action research case-study strategy was chosen as the methodological approach for this study to investigate what kind of results GI-related co-creation can deliver for sustainable urban planning and design processes (Deming and Swaffield, 2011). The background and use of the methodological approach are covered in this chapter. The epistemological position of the research is social-constructionist, presuming that the knowledge addressed in this dissertation is generated through experimental learning and is actively constructed by stakeholders internally and between one another (Crotty, 1998); thus, the knowledge is aligned with the use of the co-creation model (Mauser et al., 2013). This knowledge is nonetheless anchored in a world that exists beyond the subjectivity of an individual or group of individuals (Deming and Swaffield, 2011).

The research is in the field of landscape architecture and focuses on developing, planning, and managing new landscape architectural solutions for GI. In the larger framework, the research belongs to sustainability sciences at the intersection of social and environmental sciences involving the interaction of human and biophysical relationships. The case-study strategy has been chosen to investigate 'a contemporary phenomenon [GI in this research] in depth and within its real-world context' (Yin, 2014, p. 16).

Case-study methods are popular among urban researchers (Campbell, 2003) because the benefits of the case-study approach are well suited for urban contexts. Case studies are used in research situations when there is a difficulty in separating the phenomenon from its larger context, there is a little control over events, and the aim is to seek cause–effect understanding to guide contemporary intervention (Yin, 2014). These elements are characteristic of urban research that is seeking cause–effect understanding to guide planning intervention.

The urban research field also generally lacks the power and resources to test theories using controlled experimentation. Furthermore, urban research is not defined by a clear set of methods and does not have a dedicated set of data but instead uses multiple sources of evidence (such as data, interviews, and observation). Therefore, 'a case study can more flexibly represent the varied and conflicting voices of the city than a traditional statistical summary' (Campbell, 2003, p. 4). As urban research settings are composed of complex networks of social, economic, and political activity, case studies are more effective tools than statistical analyses to define best practices that can help to guide planning practices (Campbell, 2003).

In this research, each paper includes one or more real-life cases that have been the subject of empirical inquiry and data collection. Replication logic of the study has been to include only Finnish case studies with similar planning principles derived from national planning policies that represent advanced and actual urban situations dealing with GI. In three papers (Papers 1, 3, and 4), the case is a physical place where GI solutions are adopted, and in the second paper, the case is a development of a policy paper on the adoption of GI solutions (the city of Helsinki stormwater programme). In addition, two cases (Papers 1 and 2) consider the planning level and the other two cases (Papers 3 and 4) the design level in order to cover both the more strategic (planning) and the more concrete (design) stages of GI development.

Case-study methods are sometimes questioned because of the related replication challenges: cases are more appropriate for proving that something is possible than for revealing its precise likelihood (Campbell, 2003). The research cases have been meticulously selected based on critical analyses of existing situations to answer the research questions (1. to understand how to co-create GI within landscape and urban planning and design in Finland and 2. to determine what kind of further implementation is needed to strengthen the contribution of GI), which do not aim to generalise but rather to advance existing planning practices through case narratives.

The three cities in Paper 1 (Jyväskylä, Tampere, and Vantaa) were identified as having a growing interest in developing local GI strategies and practices within the built environment. The cities had several ongoing and future pilot projects concerning the use of green roofs, storm water detention, and biofiltration within the urban area (such as the Kangas district in Jyväskylä, the residential area of Vuores in Tampere, and stormwater pilots in Vantaa). For the co-creation process, each city was asked to select an urban area that was already planned for new development. The three sites were selected for the paper because of the growing interests of local policy-makers, city planners, and other stakeholders in developing GI strategies and initiating GI pilot projects.

The city of Helsinki, sites of the cases in Papers 2 and 3, is the biggest city in Finland and is part of the capital metropolitan region. It has a claim to be facing the most intensive urban environmental challenges in Finland. Climate change mitigation is of primary importance in the region, and the metropolitan area is aiming to be a forerunner in climate change adaptation (HSY, 2012). Furthermore, Helsinki was the first city in Finland to develop a stormwater strategy (2008), which has been used in other Finnish cities (Salminen, 2013). Paper 2 uses the process of revising the Helsinki stormwater programme as a case for studying barriers to shifting towards water-sensitive practices. Paper 3 focuses on the process of designing a new GI solution, the Vauhtitie wetland, which implements stormwater and climate adaptation strategies.

The city of Turku has been ambitious with its climate policies and has been chosen as the Best Mid-sized Climate City in Europe for 2020. Turku is implementing an ambitious climate plan, of which one of the main goals is to prepare for the impacts of climate change. The primary pilot site for climate adaptation in Turku is the Kirstinpuisto area, a former industrial site that will be transformed into a residential site. The Kirstinpuisto area's multifunctional stormwater management scenarios form the case in Paper 4. Practical stormwater management with the help of SUDS is a current topic in Finnish urban

planning, and the Turku case is a representative situation in which the city centre is being densified and therefore, a brownfield is being transformed for residential use.

3.2 Co-creation of Knowledge

The constructionist epistemological approach and the use of an action research case-study strategy with the definition of specific additional aims led to the selection of specific research methods in each case study (Fig. 7). Thus, the methods used for data collection and analyses vary to some degree from paper to paper while having a common grounding in *action research* (Deming and Swaffield, 2011). Action research involves actively participating in a process or situation under study. The starting point is practical action, in which the researcher takes part and affects the process while using scientifically recorded observations to provide data for analysis. As the aim of the research is not only to produce new knowledge but also to facilitate a transformation to a better urban system than the existing one, a more effective way to work with cases is to use the co-creation model (Mauser et al., 2013; Deming and Swaffield, 2011).

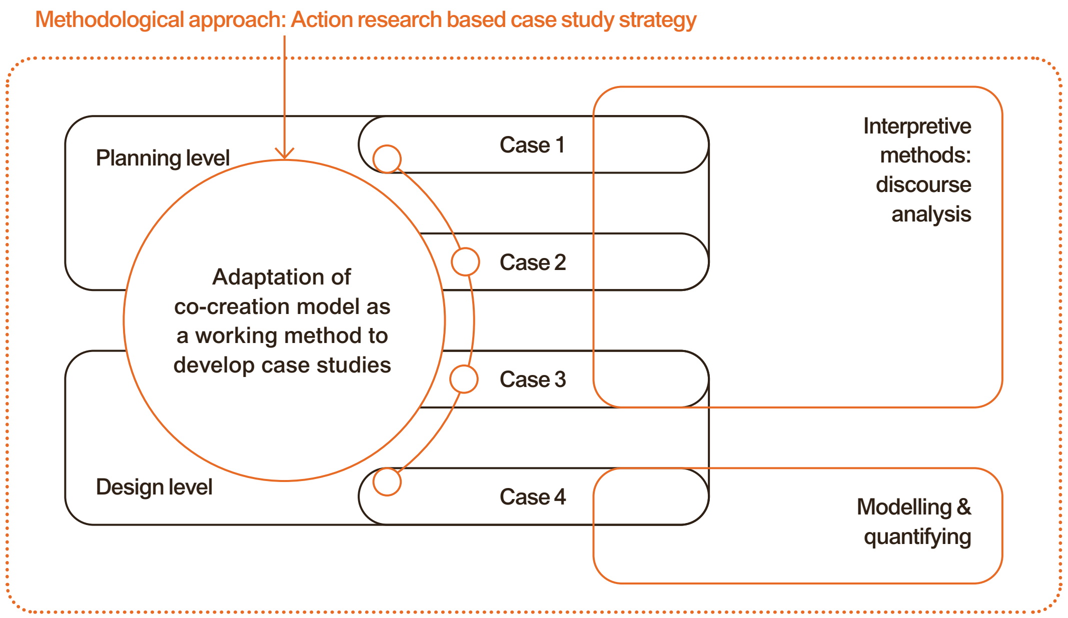


Fig. 7 The selected methodological approach and specific research methods of the dissertation and their relation to the co-creation model (adapted from Mauser et al., 2013).

As described in Chapter 2, GI is part of an emerging approach to integrating human and biophysical processes to deliver more sustainable planning and land-use practices. Moreover, GI-related literature emphasises the need for cross-sectoral collaboration and mutual learning to implement GI planning (Lennon et al., 2016; Ahern et al., 2014; Mell, 2010). Therefore, the conducted research was inherently considered an opportunity not only to find answers to research questions regarding existing GI practices but also to enhance the adoption of the GI-based approach in co-creative processes. In each case, the doctoral candidate was involved in the process of data production. The ways in which the doctoral candidate and other research group members participated in each of the case studies are comprehensively described in Sections 3.4–3.7, and the challenges of this approach in terms of the reliability and validity of the results are discussed in Section 3.3.

The co-creation model presented in Section 2.3 was employed to integrate a GI-based approach into the case studies, which are closely connected to real-life landscape architectural projects. The focus of the research is on the planning processes developed in the case studies (Papers 1, 2, and 3) or the characteristics of the design outcomes (Paper 4), thus the data collection method is linked to action research. The data collection processes and specific research questions for each paper are detailed in Sections 3.4–3.7, but first, both the use of the co-creation concept and the paper-specific research methods are explained in the following section.

Co-creation is a research method that has its roots in participatory design techniques that enable a wide range of stakeholders to contribute to the formulation of a case (Steen et al., 2011). Co-creation goes beyond the delivery of scientific evidence by deepening the equal collaboration between stakeholders and enabling mutual learning and the co-production of results (Mauser et al., 2013). Partnering with stakeholders ensures their inclusion in knowledge development in a process that can serve these same stakeholders (Opdam, 2010), thus making co-creation ideal for promoting a GI-based approach in urban planning and design processes.

3.3 Analysis Methods

The collected data were analysed using two primary research methods: content analysis (Papers 1, 2, and 3) and modelling with quantitative measuring (Paper 4). *Content analysis* is a method in which the understanding of a certain phenomenon or process is produced by moving reflexively between the data and the existing theoretical concepts (Deming and Swaffield, 2011) and can be defined as 'a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use' (Krippendorff, 2004, p. 18). Qualitative content analysis has a focus on analysing the content of a given text or texts and identifying the dominant narratives they contain. The aim is to create a picture of a given phenomenon that is always embedded within a particular context (White and Marsh, 2006).

In this dissertation, the content analysis method is used to better understand how GI, as a novel concept, has been understood and adopted and what difficulties have occurred in these adoption efforts. Furthermore, the method has enabled the doctoral candidate to better understand larger dynamics affecting the urban planning processes and the possible transition to SES thinking. The premise is that we can discuss the possible means and desired outcomes of the shift towards SES thinking in urban planning, and to enhance this shift, we need first to understand the factors affecting it.

In addition to content analysis, *quantitative measuring* was used in Paper 4 to study the multifunctionality of the Kirstinpuisto SUDS as part of the local GI. The methods for the modelling and quantitative measuring of the attributes of the co-produced drainage systems are explained in detail in Paper 4, but these methods were chosen to assess the degree to which the four criteria for multifunctionality set by water sector guidelines were met. Multifunctionality is the main feature of GI solutions (Hansen and Pauleit, 2014; Hansen et al., 2015) and represents one of the predominant promises and challenges of GI. As the desired results of the development project are plentiful, a mutual comparison can be challenging; thus, defining the levels of success is complicated. These issues are also discussed in Paper 3 in analysing the process of designing a new GI element. By quantifying and measuring success against the four criteria for

multifunctionality, it is possible to reveal some of the existing development challenges affecting the integration of a GI-based approach to urban planning and design.

In the following section, the data production and collection processes and the analysis methods of the case studies are presented. In addition, the researcher's involvement (action research) in the process is analysed. The results of the case studies (the benefits delivered by co-creation) are presented in Chapter 4, but in the following sections, the steps of the applied co-creation model (co-design, co-production, and co-dissemination, presented in Fig. 6) are elaborated.

The role of the co-creation model (Mauser et al., 2013) is to bring stakeholders together (Papers 1 and 2) and to create opportunities for mutual learning, knowledge co-production, and discussion, forming an area for data production and collection. In Paper 3, data collection occurs through a retrospective analysis of a co-created GI solution, and in Paper 4, the co-creation provides input for the generation of different scenarios, from which the data are collected. Co-dissemination took place through the research papers (included in this doctoral thesis), the site development, and the promotion of new ways of thinking among the participants.

The co-creation process in each case is displayed in a diagram. The main results of all of the papers are presented in Chapter 4.

3.4 Case 1: Understanding Green Infrastructure

In Paper 1, 'Multidisciplinary Collaboration and Understanding of Green Infrastructure: Results from the cities of Tampere, Vantaa and Jyväskylä (Finland)', the aim was to increase the understanding of GI by implementing GI strategies and concrete solutions in three case sites. The paper provides the main findings regarding the use of the GI concept on the planning level and addressed the following research question: How does a multidisciplinary collaboration among practitioners themselves and between practitioners and researchers support the understanding and development of GI within the new urban development? Furthermore, the paper contributes to the dissertation aim of understanding how co-creative processes promote the use of multifunctional GI in sustainable urban planning.

In this case study, co-framing was based on a literature review and the co-definition of the multidisciplinary collaborative process (Ariluoma et al., 2015) to enhance the collaboration of science and practice. The multidisciplinary collaborative process is a model developed by Ariluoma et al. (2015), a group that includes the author of this dissertation, and was articulated through questionnaires, a set of workshops, and homework (see Paper 1 for details). The co-production phase involved 23 official practitioners (architects, landscape architects, engineers, and experts in natural sciences) from three city planning departments and researchers from Aalto University (four landscape architects) in a series of workshops. The workshop series was a tool for cultivating multidisciplinary learning between practitioners from different fields and between practitioners and researchers to develop appropriate GI solutions for three urban planning cases. Data were collected in the workshops and from questionnaires that preceded and followed the workshop series.

In addition to the two above-mentioned workshops, the co-production between the 23 official practitioners and the four researchers included answering pre- and post-questionnaires, reading independently (including scientific and newspaper articles about urban biodiversity, health, and economic benefits), and performing tasks before and between workshops. During the workshops, participants were asked to familiarise themselves with GI elements at different scales and were invited to outline a vision by developing local strategies and plausible actions to introduce GI approaches and elements within the future development of the selected sites (Fig. 8). Furthermore, the planners were asked to detect obstacles and barriers related to GI development and to define new strategies and actions for developing GI within the case sites.

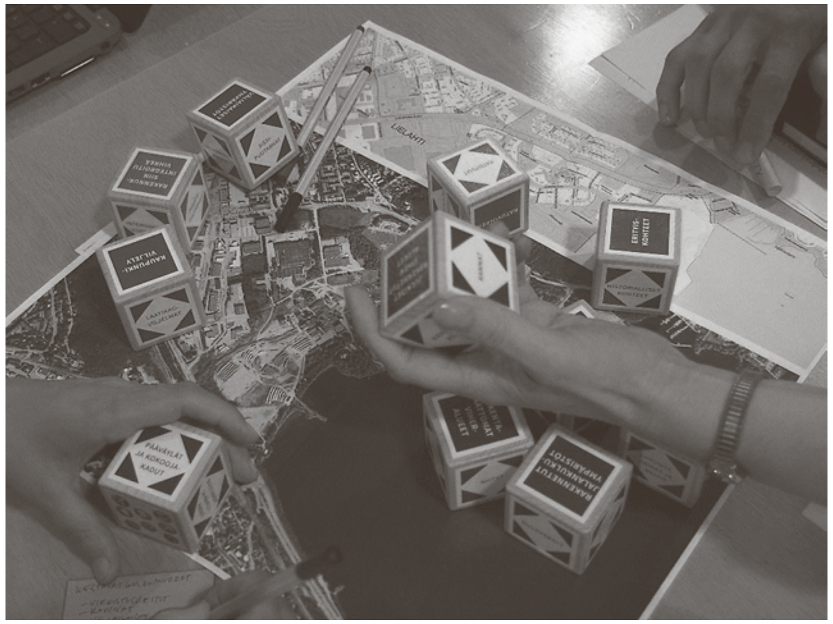


Fig. 8 Photo from the workshop where different kinds of GI elements were introduced to the participants through playful exercises.

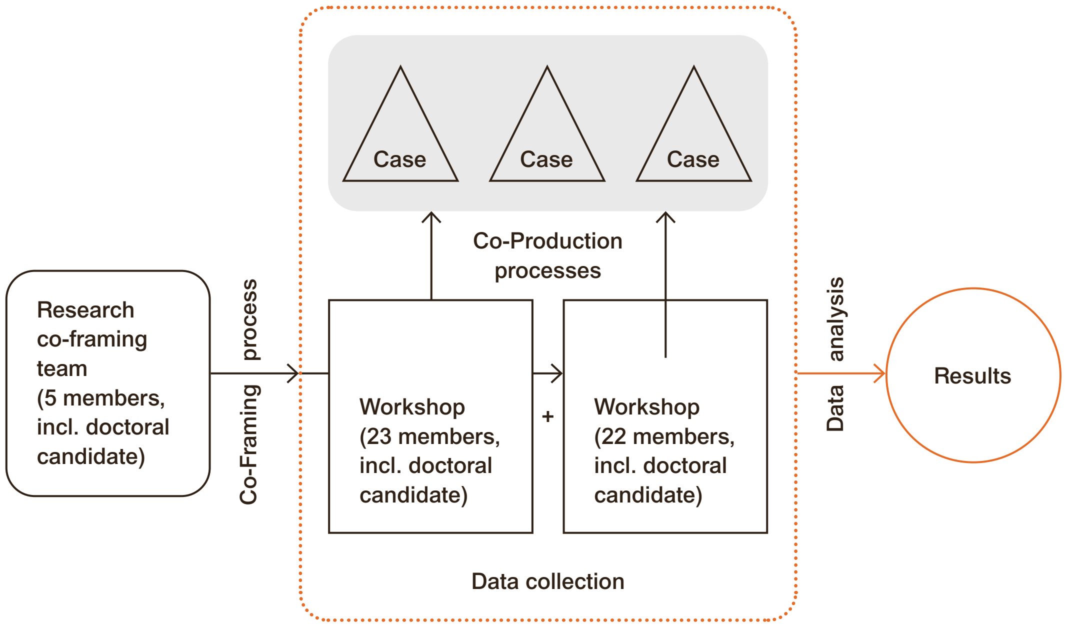


Fig. 9 Data production process of Paper 1. Three case-study sites were developed during a workshop series from which the data were collected. Data were then analysed through content analysis.

The role of the researchers included framing and organising the workshop series and developing the questionnaires participants used to reflect on the learning processes. Additionally, during the workshops, the researchers provided information and actively participated in the discussion by offering scientific knowledge and concrete materials to boost collaborative learning, aid envisioning, and encourage the implementing GI elements within the proposed case sites (Fig. 9).

Collected data included 13 hours of recorded workshop discussions and 22 written definitions of the GI concept, with descriptions of earlier experiences with the subject. The data were analysed to understand how a multidisciplinary collaboration supports the understanding and development of GI within new urban developments. Co-dissemination of the process through a scientific article was performed with Mina di Marino, an associate professor of urban and regional planning, Norwegian University of Life Sciences.

3.5 Case 2: Integrated Stormwater Management

In Paper 2, 'Barriers Preventing Development of Integrated Stormwater Management in Helsinki, Finland', the focus was the current state of understanding regarding water-related GI and existing barriers hindering the more effective use of GI-based approaches. Climate change, urbanisation, and the desire for resource efficiency have led to the search for and development of GI-based SUDS that are alternatives to traditional drainage systems and to a progressive shift towards water sensitivity, as explained in Chapter 2. The paper uses the process of revising the Helsinki stormwater programme as a case to study barriers related to this shift. The specific research questions addressed in this paper are the following:

1) What kind of barriers can stakeholders of public-sector stormwater management identify by themselves regarding the implementation of GI strategies?
2) Which other barriers can be identified?

Identification of the existing barriers helped make clear which technical or administrative changes must be made to promote GI, which, in turn, helped to clarify the conditions required for the effective use of the GI concept in urban planning. Additionally, the results of Paper 2 offer a supplemental understanding of the results of Paper 1 regarding the way co-creative processes promote the use of multifunctional GI.

Relevant data were collected during a co-production workshop, where the goals of the revised stormwater programme of the city of Helsinki were discussed. This workshop was part of the iWater (Integrated Stormwater Management) EU programme, which designed stormwater planning tools and approaches to support higher quality and more resilient urban environments (for more information, visit www.integratedstormwater.eu). Two researchers (the doctoral candidate and a PhD in environmental science) co-framed the working methods for producing data in the framework of the iWater project.

In the workshop, the research data were collected from group discussions on the implementation of the previously mentioned Helsinki Stormwater Program and on defining action points and responsible bodies for its implementation and monitoring. The new programme included four goals (1–4) from the previous program and one new goal (5) that tentatively emphasised the policy level, making the programme more ambitious and holistic (Fig. 10).

As displayed in Fig. 11, the researchers facilitated the co-creation process by framing and organising the workshop with 21 civil servants from the city of Helsinki. The specific role of the researchers was to contribute scientific knowledge to the process and to reflect

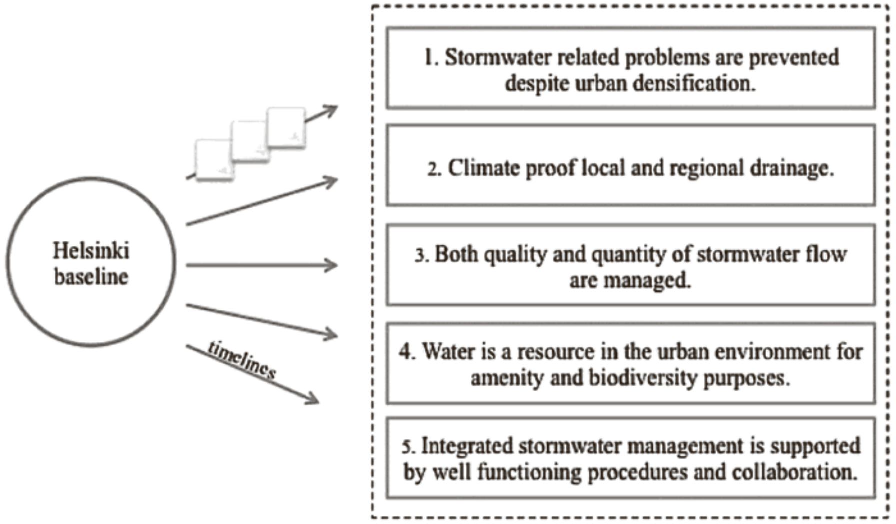


Fig. 10 The programme discussion goals in the workshop. The baseline situation is on the left, and the goals for the new program are on the right. Participants were asked to add Post-it notes with the proposed actions to the timelines drawn from the baseline to each of the goals.

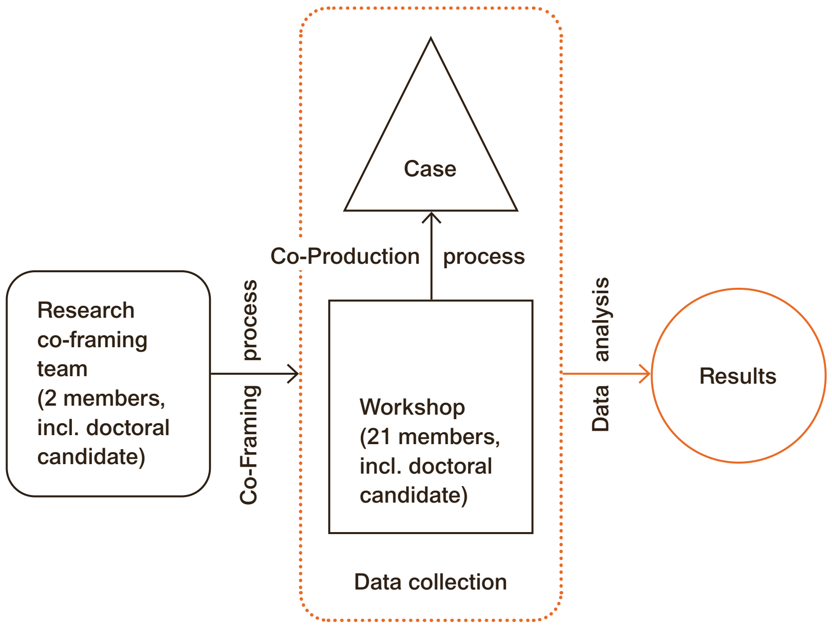


Fig. 11 Data production process of Paper 2. The case is the city of Helsinki stormwater programme developed in a workshop. Data were collected from workshop discussions and analysed using content analysis.

on the definition of goals according to the theoretical literature on the subject. Additionally, researchers participated as members of two of the four groups during the workshop. This participation allowed them to observe the group dynamics and the deliberations and questioning, which supported the subsequent discussions and facilitated the analysis of the recorded conversations.

The collected dataset included 16 hours of recorded discussions dealing with the proposed actions to achieve the revised programme goals, identify the responsible bodies, and prioritise the actions. Data were analysed to reveal distinctive themes that helped identify barriers to the implementation of integrated stormwater management.

3.6 Case 3: Multistakeholder Design Process

Paper 3, 'Multi-stakeholder Cooperation for Green Infrastructure: Creating Sustainable Value', used stakeholder interviews to assess the process of designing a GI solution for the Vauhtitie wetland. The aim was to retrospectively examine how collaboration and decision-making occur in a setting with multiple stakeholders and value perspectives. Furthermore, the study aimed to foster multistakeholder cooperation related to sustainability. The study also searched for specific methods and capabilities for developing common objectives in complex inter-organisational projects and for enhancing decision-making about value creation in the area of sustainability. Thus, this paper offers insight into a secondary aim of this doctoral dissertation: to understand what kinds of benefits knowledge exchange between stakeholders can deliver in terms of defining urban GI.

Fig. 12 The Vauhtitie wetland, a new type of GI structure collecting and managing stormwater from a new urban district of Pasila. Located in a park, it enhances the local biodiversity and recreational value.

Before the actual research process, the doctoral candidate was involved in the wetland design process (Fig. 12) as a consulting landscape architect. The design process consisted of several meetings with civil servants from various departments and with consultants from an engineering company. The process included a location and site analysis, a concept design phase, and a construction design phase. The meetings offered a framework for intensive negotiations regarding the expected outcome and its benefits. Co-production by stakeholders of a shared understanding of multifunctionality and goals proved to be challenging. The study of the design process consequently also contributed to the additional aim of the research: studying how co-creation can inform and support the processes of designing multifunctional GI.

The case study analyses the development of a new type of GI solution, and because the doctoral candidate had insight concerning the design process, the case proved to be a good example of co-creation (Fig. 13). The research was co-framed with another doctoral candidate, Riikka Tapaninaho, from Tampere University (Management Studies). The researchers chose in-depth individual interviews as the research method to conduct a retrospective analysis of different stages and outcomes of the design process.

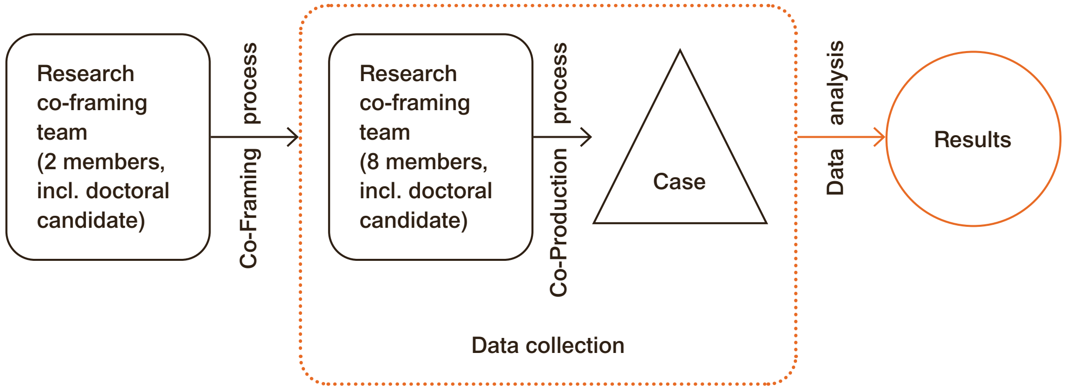


Fig. 13 Data collection process of Paper 3. The case was a new type of GI element, the Vauhtitie wetland. Data were collected through interviews of members of the private–public team that led or participated in the design process of the element.

The researchers conducted seven interviews with the wetland project team, resulting in a dataset of 7.5 hours of recorded discussions. The researchers conducted thematic analysis on the data, coding the data, creating themes based on coding and re-reading, and drawing a thematic map.

3.7 Case 4: Designing Multifunctional Sustainable Urban Drainage Systems

In Paper 4, ‘Can We Really Have It All? ——Designing Multifunctionality with Sustainable Urban Drainage System Elements’, the focus was on the challenges of measuring multifunctionality as a design outcome of a GI element. The delivery of multiple benefits is an essential part of both the GI-based and water-sensitive approaches (Fletcher et al., 2015; Hansen and Pauleit, 2014; Hansen et al., 2015). However, how the benefits relate to each other is vaguely defined, thus highlighting a lack of knowledge on how they could be promoted in the actual design process. Difficulties in measuring success arose in Paper 3 as well. In Paper 4, multifunctionality was studied with the help of a case study and related sustainable drainage system scenarios. The specific research question of Paper 4 is ‘How can the level of multifunctionality of GI be estimated during the design process?’

The co-framing and co-production process was implemented by a group of three researchers (the doctoral candidate with another doctoral candidate, Ambika Khadka, and Senior University Lecturer Teemu Kokkonen from Aalto University’s Laboratory of Water Resources). The researchers collected data to answer the research question regarding the three co-produced scenarios, displaying alter-

native solutions for SUDS in the case site, which was the Kirstinpuisto residential area in Turku, Finland.

As displayed in Fig. 14, the scenario co-production was supported by a workshop held with local civil servants to discern the local ES demand and set targets for the development of the case-study area. The doctoral candidate participated in this workshop as a facilitator, providing the civil servants with scientific knowledge related to ES. The workshop also provided insight into the co-production process used to generate appropriate scenarios and understand local targets.

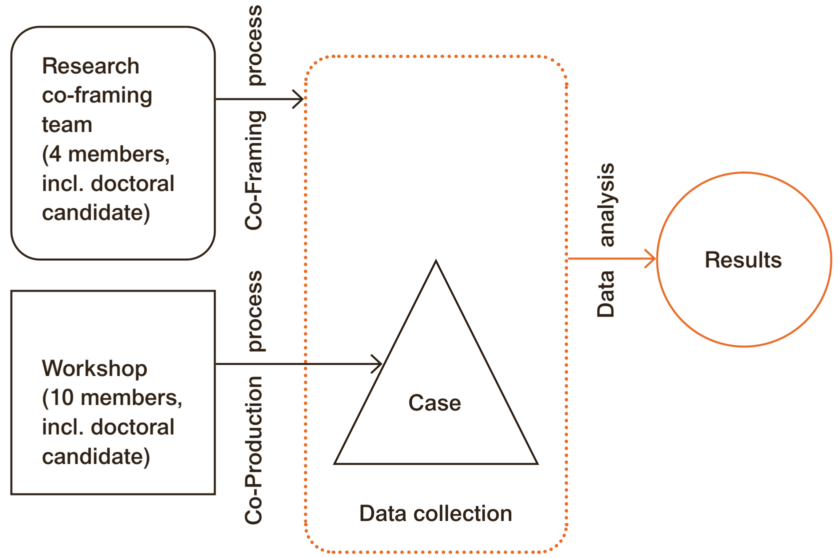


Fig. 14 Data collection process of Paper 4. Data were collected by quantitatively analysing three alternative scenarios co-produced for the case site. Co-production was informed by a target set workshop.

Fig. 15 Depiction of one of the scenarios (NORM) co-produced in Paper 4.

Three co-produced scenarios (RUN, NORM, and MAX) formed the dataset of the research. Each scenario had a different set of SUDS. In RUN, the existing pipe network was supplemented with open swales. In NORM, water detention SUDS were added in residential yards (Fig. 15), and MAX comprehensively maximised the number of SUDS elements. In each scenario, the analysis addressed the four criteria of multifunctionality, which were set by water management guidelines (C753 SUDS Manual): water quantity, water quality, amenity value, and biodiversity value.

Analysis methods included hydrological modelling for water quantity and quality management. Both amenity and biodiversity values were analysed using quantitative measuring in two phases. The amenity values were assessed based on their links to the mental health benefits provided by urban green and blue structures. The first parameter involved measuring the total area of SUDS elements with vegetation that is easily visible from residential windows or yards, streets, or other public spaces. The second parameter involved measuring the total area of surfaces in which people can perform activities or interact close to SUDS elements with vegetation.

As with amenity value, two parameters were used to assess the biodiversity value of SUDS scenarios. The first parameter used the structural heterogeneity index score developed by Monberg et al. (2018). The second parameter was derived from connectivity and the edge effect, because these factors also enhance biodiversity. In addition to the analyses, the mutual interconnections delivered by multifunctional benefits were discussed in the paper.

4

MAJOR FINDINGS

This chapter presents and reframes the main findings of the published papers by grouping the results of the papers under four themes: *growing capacities, critical barriers, multifunctionality,* and a *systemic approach* (Fig. 16). These themes are further elaborated on as they relate to the planning and design level according to the case studies. The themes contribute to the dissertation aim of understanding how to co-create GI and what kind of further implementation is needed to make GI's contribution more effective in sustainable and resilient landscapes and in urban planning and design. A discussion of these findings is presented in Chapter 5.

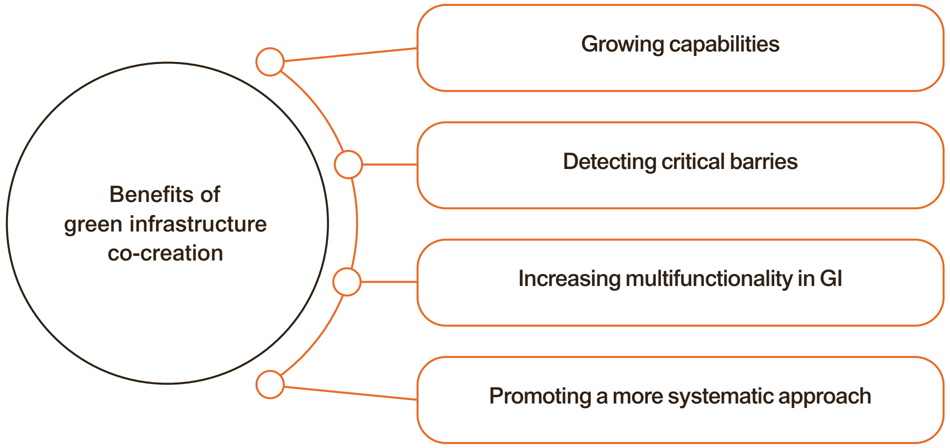


Fig. 16 The four themes under which the main findings of the papers are categorised.

4.1 Growing Capacities

The findings from the papers confirm that co-creation processes can positively affect the implementation of the GI-based approach and increase participants' capacities to apply scientific knowledge and combine science with existing practices. Most explicitly, the results of Paper 1 illustrate that co-creation facilitates developing and integrating scientific knowledge into planning, as an understanding of GI gradually evolved among participants (Fig. 17).

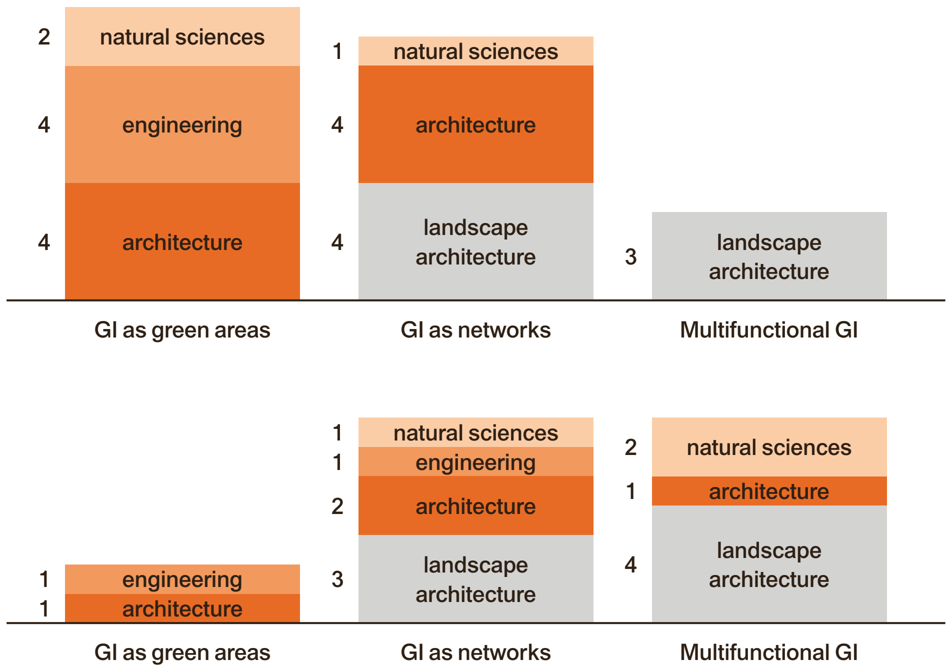


Fig. 17 Evolution in the understanding of the GI concept during a co-creation process organised around the multidisciplinary collaboration and understanding of green infrastructure in the cities of Tampere, Vantaa, and Jyväskylä (Finland). Top: before the co-creation process, bottom: after the co-creation process. (Paper 1)

For instance, as presented in Paper 1, at the beginning of the case-site co-production in the cities of Tampere, Vantaa, and Jyväskylä, the thinking of some practitioners was influenced by the traditional spatial and functional classification of single green spaces, which are still used in conventional planning practices. Afterwards, practitioners could recognise the importance of enhancing mutual social and ecological interactions and the benefits that people and local communities can obtain from GI. Moreover, the understanding of GI as a systemic entity that can be integrated within the built environment increased significantly, as displayed in Fig. 17 and as indicated in the following quote.

GI is an entity formed by green and blue elements that are part of the urban structure. GI includes processes and services that nature provides for humans. (Written definition of GI in a questionnaire after co-production workshops, Paper 1)

Furthermore, the overall co-creation process resulted in some changes to the policy approaches and land-use practices that were being applied in the case-study sites. A common understanding was generated among the participants about the need to incorporate GI development within public buildings and spaces. Additionally, the participants recognised the importance of involving constructors and considered new types of GI elements, such as green facades and green roofs.

In addition, GI co-creation facilitates understanding of the baseline situation and increases the comprehension of new concepts and approaches, as in the case of the cities of Tampere, Vantaa, and Jyväskylä (Paper 1) and the Helsinki stormwater programme development (Paper 2). In these cases, those involved identified possible improvements, such as the need for an easily accessible database with technical information.

Additionally, the results from Paper 3 revealed that the novel character of the GI made progress and decision-making particularly challenging in the Vauhtitie wetland design project. The co-production phase of the design, the incorporation of scientific knowledge about ESs, and the development of open discussions concerning GI benefits led to a mutual understanding of GI multifunctionality and crystallised in a successful project outcome. Furthermore, several organisational or individual abilities that foster co-creation were identified, such as the role of change agents and project management and the increased capacity to see the big picture or to step out of one's domain of expertise, as demonstrated by the following citation:

...all came a bit closer to each other, which was really good. What it comes to a good project, it is that all are inspired at least a little and try with a solution-oriented approach to create possibilities together and let us proceed. So, these people did not hold on to their own opinions too tight in the end. (Expert interview, Paper 3)

4.2 Critical Barriers

Through analysis of the co-creation processes, the papers also captured some of the critical factors and barriers affecting the effective usage of the GI approach in landscape and urban planning and design. Generally, as GI and SUDS are emerging concepts, knowledge-related barriers were detected on both the planning and design levels. In the workshop discussions analysed in Paper 2, it became evident that not all stakeholders shared the same skills and understanding. As a result, knowledge-sharing and management problems were identified, such as clinging to existing routines. These issues generate a path dependency, which is a situation in which socio-institutional routines of past practices prevent the adoption of better alternatives even when they are available.

In addition, the terminology of different types of SUDS elements is only vaguely known, and the details of practical management and the functionality of different SUDS components were not well understood. For example, as methods to decrease urban runoff, stormwater infiltration and permeable surfaces were mentioned much more often than detention structures.

Lack of knowledge was discussed in Paper 3 too. Despite the increased awareness of sustainability issues, interviewees expressed frustration about the lack of clarity of concepts related to sustainability, GI, and ESs. The interviewees asserted that neither general acceptance nor understanding of these concepts exists yet among stakeholders. Additionally, although sustainable development could be considered a guiding principle within the project, it was not used as a reference point by the participants. Furthermore, a general lack of roles and responsibilities was identified in both cases studied in Papers 2 and 3, which is an issue when questions of investment are discussed, as indicated in the following citation:

...Who is responsible and who pays? If we proceed, one is responsible to a certain point and another after that. How does this affect cost-sharing? So, who has the responsibility and for what? (Expert interview, Paper 3)

4.3 Multifunctional Green Infrastructure

As revealed through the co-creation processes developed in different case studies, among the barriers that hinder the implementation of the GI-based approach, one theme rises above the others: multifunctionality. Even though multifunctionality is regarded as one of the cornerstones of the GI-based approach and co-creation can help to manage it, as presented in Papers 1, 3, and 4, it is still constrained by various challenges. First, when the understanding of multifunctionality is limited, not all related benefits are considered, and not all potential stakeholders are recognized. The results of Paper 2 show that recreational possibilities and environmental benefits, such as the biodiversity provided by SUDS, were highlighted in several workshop discussions. However, additional ESs, such as air quality improvement, mitigation of and adaptation to climate change, energy savings through shading and insulation, and the reduction of the formation of urban heat islands, were not discussed in the same manner.

Because of the narrow understanding of multifunctionality, the full set of potential stakeholders is not recognized. It was commonly accepted among participants that the value of the benefits delivered by SUDS accrues only to direct stakeholders, such as those affected on the maintenance side. The monetary value of the potential ESs (such as health benefits) was not mentioned in the discussions. This impedes adoption of the GI-based approach. When the value of SUDS-related benefits is not completely understood, it is difficult to justify the SUDS-related investments, which are typically higher than those needed for traditional drainage systems given the novelty of the structures.

> *When thinking about investing costs and maintenance costs [of SUDS elements] how are they related? I'm not familiar with this at all.*
>
> *It is a bit tricky because a constructor is not normally responsible for maintenance. It doesn't matter to them if the solution is better or cheaper in the long run. They only go for something new if they are forced to do so.*
>
> *That is the reason why we should emphasise piloting when we are developing public open spaces. In the maintenance phase, the saving could be the possibility of utilising water in irrigation.*
>
> *Yes. Should you add the irrigation in the potential benefits here? (Workshop discussion, 26 April 2017, Paper 2)*

Second, co-production of case sites revealed that multifunctionality makes the measurement of the result ambiguous. The workshop discussions recognised the lack of indicators and methods to monitor the implementation of the GI-based approach (Paper 2). Similarly, the results in Paper 3 showed that, because of the lack general acceptance or understanding of GI-related concepts or preferred outcomes, the success of the project remains unclear. Valuable trees, biodiversity, recreational services, health effects, and climate change adaptation were all discussed during the co-production process along with water quality and quantity and investment costs, but the comparison of benefits was challenging.

Whereas the effects of a purely technical solution are easy to measure, ecological systems create several uncertainties and difficulties in measurement. Correspondingly, interviewees contended that it is difficult to discuss something that is challenging to identify and measure (Paper 3). Therefore, the outcomes of a GI solution are perceived to be ambiguous and difficult to predict and quantify and to lack cause-and-effect relationships.

> *Related to those non-material benefits, a system needs to be developed for them, how they are calculated, too.… Health effects, recreational effects, and landscape impacts and things, which do not have a price tag really. (Expert interview, Paper 3)*

Third, providing multifunctionality to match the local needs is challenging. In Paper 2, the workshop attendees shared the common understanding that stormwater runoff should be managed to achieve

maximum benefits in the urban environment. However, the attendees lacked knowledge of how to achieve this, as illustrated in the following discussion:

> *I have listed some very general and nonspecific principles here. In general, we should use more intensively green structures and infiltration and question the use of pipe drainage. Especially in the upper parts of the watershed, like, do we need to put water in the pipes every time? These measures are related to the implementation of the priority order. However, I haven't added who does it, or how it is done, or what is the practical action.*
>
> *Yes, these are very important issues. And it is very difficult to take it a step further. Like what would be the elaborated solution.*
>
> *Yes, [it is difficult] to name who does what. (Workshop discussion, 26 April 2017, Paper 2)*

The results of Papers 2 and 4 revealed that the stakeholders were not fully aware of the differences in SUDS solutions in terms of biodiversity. Co-production in Paper 4 showed that, in principle, SUDS that sustain the function of natural processes uphold biodiversity (Paper 4). For the needs of biodiversity, it is essential to design volumes, routes, and surfaces that enhance the water cycle and sustain biophysical structures, processes, and functions. The amenity and biodiversity values delivered by a scenario were highly dependent on the presence of SUDS elements.

The ability of SUDS to store and ensure the availability of water for vegetation enhances biodiversity through ecological processes. If the delivery of multifunctional benefits is not considered during the design process, it is quite unlikely any goals related to multifunctionality will be achieved. The SUDS elements potentially have a special role to synergistically provide for local hydrology, biodiversity, and amenity values if conditions for those parameters are understood and created during the design process. Moreover, co-creation should facilitate the integration of different types of knowledge, interests, concerns, needs, and expectations.

4.4 Systemic Approach

The demands for increased understanding of multifunctionality are paving the way to the recognition of a more systemic approach to facilitate the implementation of GI. As the GI-based approach is inherently complex, consisting of links and feedback within and between people and nature, the implementation of GI elements requires new types of decision-making and target-setting processes. However, as detected in the co-creation processes developed in all the case studies, challenges embedded in current planning and design practices prevent the use of a more systemic approach to promoting positive interactions between people and nature in the urban SES.

The findings in Paper 1 reveal that new issues such as stormwater management and the urban micro-climate need to be addressed more comprehensively in urban planning. However, rigid planning practices pose serious obstacles. The workshop attendees stated that the GI-based approach should optimally be incorporated at the intermediate stage of the planning process, between the well-established phases of master and detailed planning.

Architect 1: 'We actually need an "area development planning", in order to get a comprehensive picture of GI within and outside the selected site'.

Engineer: 'Maybe we could outline the green and blue networks at the upper level which would guide a detailed planning'.

Natural scientist: 'Yes, that would be essential. Although our lead has stated that the GI should be embedded in the master plan. However, the current master plan does not provide a wider and more concrete picture for the development of GI'.
Architect 2: 'At the moment, Finnish cities have a strategic master plan'.
Natural scientist: 'Yes, we would need an area development planning phase in between the strategic master plan and detailed plan'. (Round table, 1 December 2015, Paper 1)

This view is supported by the results in Paper 2. According to the workshop discussions, a holistic watershed-scale approach was lacking in urban planning, and stormwater management was only considered at the start of the detail-planning phase. In addition, as the details of practical management and the functionality of different SUDS elements were not well understood, they were considered more alternatives than complementary to each other. This hinders the integration of stormwater management into urban planning. Accordingly, in Paper 3, the interviewees criticised the dispersed nature of city planning and decision-making and called for the management of larger entities and the engagement of different actors.

The results of Paper 4 demonstrate that the co-produced NORM and MAX scenarios that combine several SUDS elements reduce both the peak flow and the total flow volume of stormwater by detention, evaporation, and infiltration (Table 1; see the explanation of the scenarios in Section 3.7). Furthermore, these scenarios provide better results than the RUN scenario in all measured qualities (Tables 2 to 4), indicating that the amount of managed water helps SUDS to perform better by other indicators as well.

However, if the amount of water is not in line with society's needs, flooding or drought can occur. Therefore, designing SUDS to create high amenity and ecological values in urban greenspaces without generating societal, environmental, or safety problems requires a thorough understanding of the hydrological process. This principle can evolve into a systemic approach in which the functionality of SUDS is enhanced by locating them not as individual elements or part of a strictly water-related treatment train but as part of the larger ecological or green network.

Events	Scenarios	Peakflow Rate with SUDS [l/s]	Current State Peak Flow (l/s)	Decrease in Peak Flow (%)	Reduction in Total Volume (%	Reduction in Flooding Volume (%)
	RUN	1493	1876	20.5	2.0	66.0
E1	NORM	989	1876	47.3	39.9	81.1
	MAX	458	1876	75.6	81.0	98.7
	RUN	1493	1834	18.6	1.4	65.0
E2	NORM	957	1834	47.8	25.6	81.8
	MAX	442	1834	75.9	67.8	98.9
	RUN	360	474	24.2	-8.8	91.1
E3	NORM	249	474	47.6	33.8	98.5
	MAX	94	474	80.3	82.0	100.0

Table 1 Water quantity: Changes in the peak flow, total runoff, and flood volume for SUDS scenarios compared to the current state. Rainfall data cover seven months (E1) consisting of an extreme event during summer (E2) and an intense event after summer (E3) (Paper 4).

	Unit	RUN	NORM	MAX
Turbidity	NTU	−1.6%	11.6%	46.5%
Total suspended solids (TSS)	mg/l	−0.4%	3.0%	12.2%
Chromium (Cr)	µg/l	−2.6%	18.3%	73.5%
Copper (Cu)	µg/l	−0.2%	1.7%	6.8%

Table 2 Reduction in mean turbidity and concentrations of chromium, copper, and total suspended solids for SUDS scenarios compared to the current state, reflecting the capacity for quality management.

	Elements	RUN	NORM	MAX
Visible SUDS elements	Swales	0.6	0.6	0.6
	Rain gardens	0.6	0.9	1.8
	Bioretention cell		0.1	
	Visible green roofs		0.4	0.4
		1.2	2	2.8
Active Spaces Close SUDS elements	Lawns	1.7	0.7	
	Urban Square	0.3	0.3	0.1
	Yards		1.9	1.8
		2	2.9	1.9
Total Score	(ha)	3.2	4.9	4.7

Table 3 Amenity values: Total scores of the analysed amenity values of SUDS scenarios (Paper 4).

Elements	RUN	NORM	MAX	Elements	RUN	NORM	MAX
Swales	11	11	11	Between two SUDS el.		940	875
Rain gardens	6	9	18	Between SUDS el. and lawn	875	410	
Bioretention cell		2		Total score	875	1355	875
Total Score	1.2	2	2.8				

Table 4 Biodiversity: Total scores of structural heterogeneity (left) and edge line (right) of SUDS scenarios reflecting biodiversity (Paper 4).

The research results from all papers indicate a need for continuous knowledge exchange and development work to set new administrative norms and practices that enable the valuation and integration of GI elements as a part of existing technical systems. The results from Paper 1 highlight that more concrete actions involving different types of stakeholders could increase learning about GI and the approval of GI strategies and actions. According to the results of Paper 2, a successful transition to the GI-based approach requires new formal and informal agents and networks that strengthen linkages across systems and enable knowledge exchange. Co-creation can encourage such an integrated approach.

Moreover, the results of Paper 3 suggest that in the design process of the Vauhtitie wetland, because the movement of water does not recognise administrative boundaries, the co-production involving different organisations was required for a successful result. Careful design and promotion of the ES approach were required to integrate new social, technical, and ecological functions in a culturally significant urban area. The design process express the ongoing systemic change, which invited co-creating stakeholders to deal with various uncertainties and accept the process of constant learning.

Likewise, Paper 4 demonstrates that optimising multifunctionality leads to a systemic approach. The NORM and MAX scenarios that combine several SUDS with different features provide better quantity and quality management in conjunction with higher biodiversity and amenity values. The results facilitate the understanding of the ways in which different variables and assessment criteria are interrelated (Fig. 18). The ability of SUDS to store and ensure the availability of water for vegetation enhances biodiversity through ecological processes. In turn, biodiversity and the amount of vegetation in SUDS enhance evaporation and infiltration, subsequently affecting water quality. Additionally, increased biodiversity positively affects the perceived amenity value, but an increased amount of water in urban greenspaces simultaneously requires higher design skills to provide amenity value.

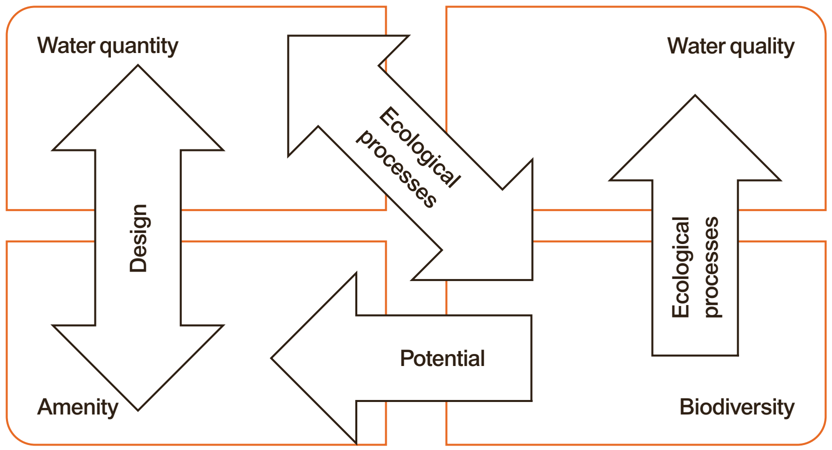


Fig. 18 The interrelations among multifunctionality criteria according to Paper 4.

A temporal dimension also exists in the provision of multifunctional benefits. Some of the expected outcomes can be precisely measured during the design phase (such as water quantity management) or later, after its realisation (such as the richness of plant species). However, some of the outcomes emerge through the dynamic interactions among new residents or users, new hydrological or soil conditions, maintenance procedures, and a changing climate. Moreover, these interactions reveal the processes affecting complex systems and the need to shift from linear certainties to adaptive and responsive systems. Strengthening the multifunctional benefits requires an understanding of the ecological processes and system dynamics in urban greenspaces. However, these concepts are still not familiar to all stakeholders, as revealed by the following citation:

Architect: 'There is a challenge when we want to achieve biodiversity conservation on the site and all around, but at the same time, we have huge ambitions for new buildings. What happens to the biodiversity then … in that conflicting game?'
Engineer: 'Well, green roofs … when we build high buildings, there will be unused land and space on the roofs'.
Architect: 'Yes, but is it then fully available to residents if nature is on the roof?'
Moderator: 'It could be, but how will all cyclic processes function when nature is all limited to the roofs?'
Engineer: 'Cyclic processes? What are those?'
Moderator: 'Like nutrient and water cycle'.
(Workshop in Tampere, 15 September 2015)

5 # DISCUSSION

5.1 Theoretical Implications

The GI-based approach has been identified as a promising framework to integrate natural processes within spatial urban development policies, and this approach could be enhanced by co-creation. This thesis helps us to understand how to co-create GI within landscape and urban planning and design in Finland and to determine what kind of further implementation is needed to make the contribution of GI more effective. In the appended research papers, the incorporation and implementation of the GI-based approach have been investigated through case studies at different levels ranging from strategic urban planning to the design of urban green areas.

The results of the research papers confirm the earlier understanding from the literature (Lennon et al., 2016; Faehnle et al., 2014; Ahern et al., 2014; Kopperoinen et al., 2014; Lafortezza et al., 2013; Mell, 2010; O'Donnell et al., 2017) that interdisciplinary co-creation with stakeholders potentially facilitates the generation of multiple benefits and further enables different stakeholders to reframe how they develop and manage the landscape. In addition, co-creation promotes the use of scientific knowledge as part of the planning and design processes and enables the evolution of a deeper comprehension of GI for all stakeholders (Pauleit, 2019; Haase, 2017).

Furthermore, the results indicate that co-creation facilitates understanding of the current barriers that hinder the implementation of the GI-based approach, and they offer a more precise scope as to where GI-related co-creation could be integrated into landscape and urban planning and design. The case study projects and related cities seeking to enhance the GI-based approach or concrete GI solutions face various challenges and should work on several areas simultaneously.

These results build on the evidence provided by Brown et al. (2013), showing that the implementation of the GI-based approach has been difficult because of existing routines, infrastructure, and institutions, which are persistent and highly interwoven. Co-creation brings together different skills and agendas, allowing the development of new approaches and solutions. Moreover, it enables the development of joint acceptance, as new GI practices benefit from the approval of a wide range of stakeholders, including some stakeholders who have not traditionally been interested in green areas or stormwater management, such as the health and education authorities (Ashley et al., 2015).

In addition to investigating how to co-create GI, this thesis has had two additional aims: to determine how co-creation can promote the development of more multifunctional GI in planning processes and to explore how co-creation can inform and support the design processes of multifunctional GI. Despite multifunctionality being acknowledged as the cornerstone of the GI-based approach (Hansen and Pauleit, 2014; Hansen et al., 2015), challenging definition of multifunctionality of GI elements was identified in this study as one of the key barriers to the approach's effective use and implementation. This is one specific outcome of this thesis.

The results show that the understanding of multifunctionality is still limited. Not all related benefits and their mutual interconnections are fully understood, and the recognition of possible stakeholders is still restricted. Furthermore, multifunctionality makes the measurement of the results of planning or design processes ambiguous, and challenges exist in providing multifunctionality to match local needs. These findings agree with the argument by Meerow and Newell (2017) that most GI-related research and planning has focused only on a handful of benefits. Likewise, Hansen et al. (2019) stated that the operationalisation of multifunctionality in planning and practical examples is still lacking.

According to the results, the difficulty in measuring the multifunctional effects of GI hinders the transition from the more traditional planning approaches to more systemic approaches in which technical systems are integrated with ecological systems. This confirms that we need a better understanding of the implicit characteristics of the desired multifunctionality and how it can be achieved (Wang and Banzhaf, 2018).

For example, when SUDS are used as a retrofit solution or as part of a new greenspace with the expectation that they will provide multiple benefits, a knowledge gap exists concerning the contribution of SUDS to the local biodiversity, such as knowing which elements support which species and habitats. This insufficient understanding of the multifunctional potential of GI elements (i.e. different types of SUDS) reveals that green structures and stormwater management are still perceived as separate issues instead of key components of complete SESs.

In addition, results confirm that the GI-based approach offers a new lens that can connect previously separate functions, such as recreation, drainage, and conservation, into a more complex SES combining not only urban hydrology but also potential ecological and sociological benefits through multifunctionality (Flynn and Davidson, 2016; Winz et al., 2011). Moreover, new functions, such as carbon sequestration and climate adaptation, have drawn increasing attention and thus bring new demands for multifunctionality.

As the comprehension of multifunctionality inevitably leads to a systems approach, co-creation of GI in the context of landscape and urban planning and design can accelerate the adoption of the GI-based approach by defining *an accelerating model* (Fig. 19) towards SESs. As stakeholders develop new capacities, they increase their ability to recognise additional critical barriers hindering the implementation of the GI-based approach. Many of these barriers are related to multifunctionality, which calls for a systems approach to successfully meet the need for SES thinking (Folke, 2016). A systemic approach implies that communication between stakeholders with differing backgrounds and interests must be strengthened to create new understanding and new relationships. Consequently, the promotion of a systems approach requires co-creation, which, if done successfully, leads to capacity building and the identification of further barriers, thus allowing adaptive governance (Assche et al., 2019).

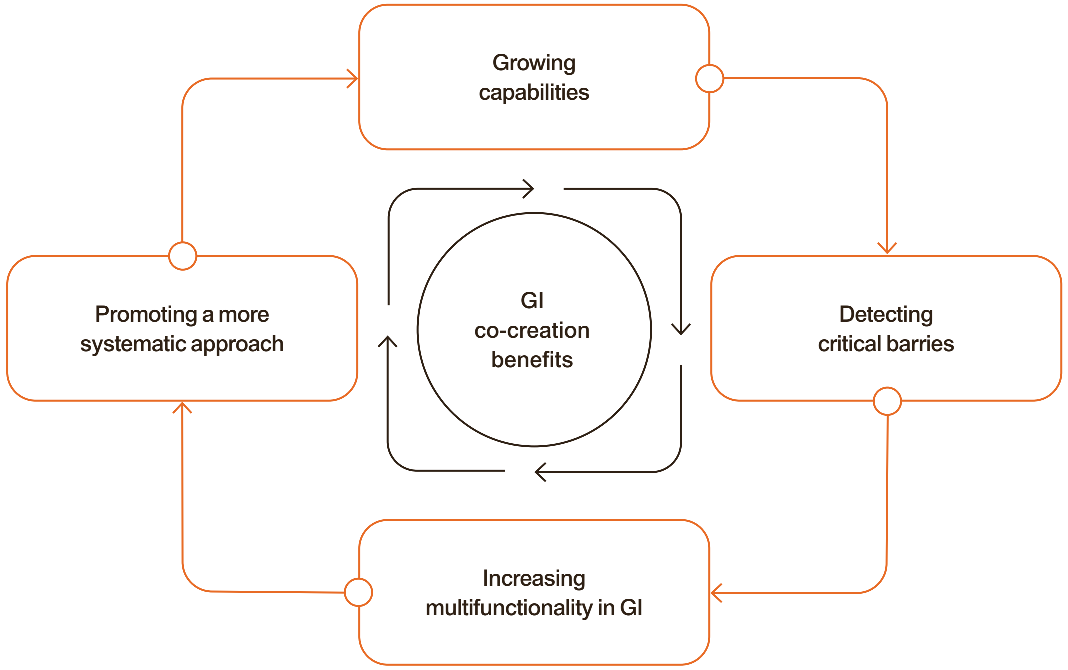


Fig. 19 The accelerating trajectory towards more performative and multifunctional GI enabled by co-creation. Co-creation enables increased capacity to detect critical barriers, which increases the understanding of multifunctionality, leading to a more systemic approach, further capacity building, and increased SES thinking.

5.2 Green Infrastructure and Adaptive Governance

It is interesting to examine the types of capacities generated through the accelerating model. The results show that planning and design processes that lead to the production of a multifunctional GI require a deep and interconnected understanding of various matters: local hydrology and water dynamics, ecological processes essential to biotic growth, and the ES demands of the local community. Furthermore, the mutual interactions of these matters must be properly addressed, confirming the notion by Fletcher et al. (2013) that the interactions between the components of the urban water cycle are as important as the individual components.

This implies the need for a deep comprehension and application of the ES cascade model (Potschin and Haines-Young, 2011), including the provision of ESs by biophysical structures, processes, and functions and the related benefits and value to society (Fig. 20). More critically, various effects of planning, design, construction, and maintenance of urban biological structures and processes on the provision of ESs are also clarified by co-creation.

The results of this study indicate that successful adoption of a GI-based approach requires a thorough comprehension and application of the ES cascade model, which applies not only to the small-scale design level and stakeholders involved directly in the local circumstances but also to the planning level and associated stakeholders. Co-creation expands the set of stakeholders to a larger group of experts, including experts who are not traditionally familiar with or who do not work with ecological processes, such as architects and traffic and civil engineers, as shown in Papers 1 and 3.

Through co-creation of GI, natural systems and the effects of human actions on them are introduced and explained to these new stakeholders, enabling the enlargement of their core competencies.

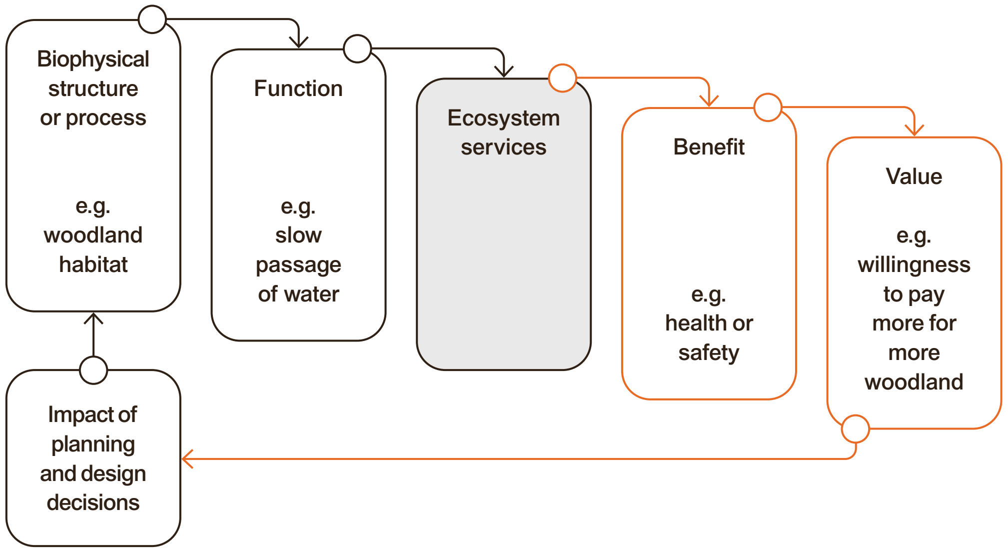


Fig. 20 Through co-creation of GI, natural systems and the effects of human actions on them are introduced to stakeholders, enabling the enlargement of existing competencies: the cascade model of ecosystem services helps us to understand that wellbeing of the nature is in line with human wellbeing and decisions in planning and design processes should be made accordingly (the cascade model adapted from Potschin and Haines-Young, 2011).

This approach challenges conventional urban planning practices in which social and ecological processes are often considered to be conflicting rather than synergistic forces (Kabisch, 2015); therefore, co-creation of GI can be considered a key and strategic game-changer, promoting systems thinking and leading urban development towards constant learning and other adaptive governance practices (Assche et al., 2019) and, therefore, towards more sustainable urban SES.

5.3 Practical Implementation

With the recognition of the accelerating model as a potential roadmap to transitioning the urban SES to sustainability and adaptive governance, new ways to enable co-creation of the GI-based approach should be sought. Both research results and the literature (Kambites and Owen, 2006; Wong and Brown, 2009; Lennon et al., 2016) offer advice for practical requirements that enhance the implementation of the GI-based approach through co-creation.

Earlier studies have shown that, at the beginning of any social transition, the work of a small group of frontrunners can be remarkable in introducing the basic skills, knowledge, influence, and resources required to navigate the transitional pathway (Dunn et al., 2017). Nevertheless, in the acceleration phase of transition, institutional work is essential. New approaches cannot be developed in isolation but must be socially embedded in the existing institutional context.

The existing context includes increasing institutional connectivity and governance across institutions at multiple levels, improving the operational connections and partnerships between different administrations, and improving the ability to experiment with scaling up innovations (Dunn et al., 2017). Most critically, it is essential to challenge the traditional planning and design practices that direct their attention to the provision of single functions. Instead, the enhancement of ecological processes and functions should structure

urban planning to secure ES provision and related multifunctional benefits and to increase the functioning of the city as a deep SES.

In this thesis, the co-creation of the GI-based approach has been tested, especially at the intersection of the urban landscape planning and water management sectors (Papers 2, 3, and 4). This has proved to be productive because water management is an issue that must always be solved within urban development projects. There the accelerating model created by co-creation has the potential to give a more forceful push towards a regime shift. In addition, climate change adds pressure to find new methods and solutions for urban water management and urban environmental planning, so it is highly recommended to use the co-creation of the GI-based approach as a working method to find and test multifunctional solutions to urban water and urban nature issues on different scales.

Furthermore, the results also enable us to reflect on the use of co-creation processes as an action research method – that is, when and in what contexts this approach is appropriate and effective. Results give evidence that co-creation increased participants' capacities to apply scientific knowledge and combine science with existing practices. In addition, the results imply that the local orientation of collaborative processes, for which the approach has been criticised (Sutherland et al., 2017), has become a strength when dealing with GI and urban sustainability. The process of designing a successful multifunctional GI always requires local-scale exploration and, as stated in the previous section, provides new insights into dynamic relationships between people and ecological systems. Understanding of this interaction on a local scale enables enlargement of that understanding to the planetary scale and could further empower the systems-level transformation. And in the end, cities are physical structures, where concrete sustainable solutions need to be designed and built from the roots level upward.

5.4 Limitations and Proposed Further Research

The research was based on a close collaboration with four cities in Finland where the local authorities were interested in exploring the potential that GI could have in urban development. Therefore, the results and limitations of this research should be understood within that scope. Cases studies represent typical and actual urban planning situations, which increases their utility. National planning policies that guide practical planning actions guarantee that findings can be adapted to other Finnish cities. However, the results were derived from Finnish case studies, which restricts the application of the results to local planning and design processes. Still, the main findings concerning the challenges related to the multifunctionality benefits provided by co-creation and the associated concept of the accelerating model are supported by the existing research and can be applied to a wider context.

The chosen research methodology, the action research case-study strategy, implied a deep involvement of the author, collaborators, and stakeholders in most of the activities, with subsequent effect on the replicability of the experiments. Action research is concerned with action and learning, and this was purposefully chosen as the overarching research method to gain in-depth knowledge about the implementation of the GI-based approach to transfer GI-related knowledge from research to planning and design practice and to advance the related regime shift.

However, there are some disadvantages to action research. First, there can be difficulties in distinguishing between action and research and ensuring the application of both, and second, it has been regarded as a highly resource-intensive method (Mackenzie et al., 2012). The researcher has a bigger role in providing information, facilitating the process, and agreeing on objectives and process transparency than would be demanded in more traditional research approaches. These issues were seen during this research. In particular, the workshop series organised for Paper 1 required time resources and substantial collaboration. Then again, if 'science needs to be positioned differently in the world, through integrating new ways of knowing into new ways of making decisions and acting across all spheres of social, economic, and political life' (Wyborn et al., 2019, p. 320), it self-evidently requires involvement and resources, distinct from more traditional research approaches.

Furthermore, lack of repeatability can be seen as one of the challenges with action research and the case-study approach (Mackenzie et al., 2012; Yin, 2014). Involving 60 people across five organisations and involving eight research colleagues from different disciplines (landscape architecture, urban planning, environmental sciences, administration, and water management) provides advanced interdisciplinarity and rigour in the study. The selection of specific research methods from content analysis to quantitative measurement with the elaboration of the co-creation model provides new possibilities for landscape architectural research to have an impact on the actual environmental and societal challenges. Moreover, the research confirmed the frequent need to combine different methods of inquiry and research in this discipline (Deming and Swaffield, 2011; Van den Brink et al., 2016).

The results of this thesis provide new possibilities for future research. First, it would be beneficial to gather further feedback from the research case studies, their future development, and involved stakeholders to analyse the long-term impact of the co-creation process. Moreover, as the multifunctionality of GI elements proves to be challenging, it is important to further study the ways different factors in multifunctionality interact with each other and how they can be assessed holistically. Understanding these factors and their relations facilitates designing and implementing GI and GI elements that contribute most to SESs.

In addition, further research is needed to determine the relevance and value of GI, ESs, and related networks, structures, and functions more objectively. The sustainability advantages provided by short distances in the ideal compact city should be evaluated against the space requirements of ecological processes and hydrology. The thesis includes co-creation processes involving civil servants, researchers, and professionals in landscape and urban planning and design. In future research, it would be advisable to enlarge the stakeholder groups to include other professionals and inhabitants as the direct beneficiaries of the GI-based approach and to test the relevance of co-creation and the associated accelerating model with them.

The enlargement of the stakeholder groups would further increase the multidisciplinarity of the research and tackle the criticism that has been levelled against co-creation processes as reinforcing the power of policy elites or those who have capacity to engage and thereby marginalizing those with alternative perspectives (Lövbrand, 2011; Turnhout et al., 2020). Designing future research projects in an appropriately inclusive fashion links to the concepts of environmental justice and capabilities, both related to ESs. Environmental justice will be achieved when 'everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work' (USEPA, 2017). In line with this, the capability approach sees that ESs comprise resources that are available

according people's capability (Polishchuk and Rauschmayer, 2012) that can differ among socio-economic groups. Therefore, the development of the city as a functional, deep SES requires an equitable, people-centred approach.

5.5 Final Conclusions

This doctoral dissertation examined how co-creation can support the definition of more multifunctional and systemic GI and what kind of further implementation is needed to make the contribution of GI more effective in sustainable and resilient urban transitions. According to the results and existing literature, the GI-based approach challenges planning traditions and the conventional methods through which we have envisioned and constructed our cities. Thus, through the provision of ESs, we can comprehend that natural systems in the urban environment can contribute so much more than just recreational possibilities or the conservation of habitats. The aim should be to steer urban development towards integrated land-use governance of the urban SES, where the potential for multifunctional ESs is realised by enhancing the positive synergies between abiotic, biotic, and social systems.

Recognition of urban SES can help align social and ecological systems so that they benefit from each other. However, both are complex systems that are difficult to understand and predict. Implementing the GI-based approach and supporting the planning and design of GI elements through co-creation helps to reorganise the effects of our actions and processes towards biophysical structures and natural processes in urban areas and to better provide the desired ESs. Thus, co-creation can support the use of the GI-based approach as a game-changer facilitating the ongoing regime shift to adaptive governance, enabling systemic change from technocratic and reductionist practices to a wider SES approach in both landscape and urban planning and design.

Bruno Latour (2017) stated that social and ecological systems are complex systems, marked by nonlinear responses to intervention, yet offering the possibility of new solutions and adaptations. Therefore, in the Anthropocene, it is important to recognise that co-creation has much to offer for new interdisciplinary knowledge creation, synergies, and innovations. Currently, the division between social and ecological is dissolving, and it is critical to comprehend that the GI concept can be an ideal ally to advance this progress.

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Paper 1 Elisa Lähde
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MULTIDISCIPLINARY COLLABORATION AND UNDERSTANDING OF GREEN INFRASTRUCTURE RESULTS FROM THE CITIES OF TAMPERE, VANTAA AND JYVÄSKYLÄ (FINLAND)

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Multidisciplinary collaboration and understanding of green infrastructure Results from the cities of Tampere, Vantaa and Jyväskylä (Finland)☆

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ABSTRACT

Over the last few decades, the concept of Green Infrastructures (GI) has been studied in several disciplines such as landscape architecture, landscape ecology and planning. However, scholars are still debating the best approaches to enhance the understanding of GI amongst practitioners. Indeed, a multi-disciplinary collaboration is needed to move beyond any obstacles to the development of GI. This paper presents a literature review that focuses on the barriers which still limit the adoption of GI, the concept of multifunctional GI, and the need for collaborative groups of professionals. In particular, the study explores the three Finnish cities of Vantaa, Tampere and Jyväskylä, which are currently addressing new GI strategies and introducing the Urban Green Infrastructures within the built environment. The study presents the results from a multi-disciplinary collaborative process that consisted of a pre-questionnaire, learning activities, workshops, as well as a post-questionnaire. 23 official practitioners (architects, landscape architects, engineers and experts in natural sciences) from the city planning departments as well as four researchers in landscape architecture and urban planning were involved in the collaborative process. The results show that an understanding of GI gradually evolved amongst participants. The findings also reveal that rigid planning practices still represent obstacles to the development of GI. Hence, new urban planning approaches to the GI are needed, as well as more concrete actions involving stakeholders. New activities should be used when developing GI, such as learning about GI, proposing GI strategies and actions, as well as reflecting on existing planning tools.

1. Introduction

Several disciplines have contributed to studies on Green Infrastructure (GI), such as landscape architecture, landscape ecology, and more recently, urban and regional planning. Furthermore, definitions of GI have been influenced by research conducted in the USA, UK, and Europe (Mell, 2016). Since the early 2000s, it has been defined as an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas, as well as greenways, parks and other conservation areas (Benedict and McMahon, 2001, 2006).

Lately, within the arena of scientific debate and policies, (see e.g., the European Commission, 2013) it has been stated that "GI enhances and synergizes benefits provided by nature" (Hansen and Pauleit, 2014, p. 516).

GI is considered to be "an interconnected green space network (including natural areas and features, public and private conservation lands and other protected open spaces), that is planned and managed for its natural resources and values and for the associated benefits to the population" (Benedict and McMahon, 2012, p. 3). While North American academics and practitioners emphasize the ecological function and value of GI, in the European context, scholars state that GI has been mainly used to tackle some urban issues, such as the high density of urban developments (Mell, 2016; Lafortezza et al., 2013).

In the European policy framework, GI has been defined as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (ES) (e.g., supporting soil formation and habitat and cultural services) in both rural and urban settings (European Commission, 2013, p. 3). A more comprehensive definition embraces additional aspects, "GI has been lately considered as 'an ecological and spatial concept for promoting ecosystem health and resilience, contributing to biodiversity conservation, and benefiting humans by promoting the delivery of ecosystem services. It incorporates green spaces (or blue, if aquatic ecosystems are involved) and other physical features

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in terrestrial (including coastal) and marine areas" (European Environment Agency, 2014, p. 10).

Within the existing literature, GI has been referred to by various terms, such as spatial and ecological connectivity, multifunctionality, interdisciplinary collaboration, and the delivery of ecosystem services (Lennon et al., 2016; Baró et al., 2015; Hansen and Pauleit, 2014; Ahern et al., 2014; Benedict and McMahon, 2012). GI has been used for enhancing the connectivity of green spaces (e.g., between parks, forest areas, wetlands and gardens). Spatial connectivity can support ecological conservation as well as the benefits for humans associated with GI, such as health, well-being and recreational activities (see the overview given by Lennon et al., 2016). Referring to multifunctionality, "GI planning considers and seeks to combine ecological, social, and economic/abiotic, biotic and cultural functions of green spaces", all types of green and blue spaces, such as natural and semi-natural areas, water bodies, public and private green space, including parks and gardens. This GI approach can be used for individual GI elements, a network of linked GI elements as well as an interlinked network of GI elements on the regional level (Hansen and Pauleit, 2014, p. 516).

In addition to ensuring its multifunctionality, a strategic and integrated GI process could help to guarantee multiple perspectives are included, such as those of ecosystem services and stakeholders' (Green Surge, 2015; Meerow and Newell, 2017). From the perspectives of urban and regional planning as well as landscape architecture, GI has often been acknowledged as a strategic approach to improve urban life in metropolitan regions and cities (e.g., challenges of urban sustainability and resilience) (Ahern et al., 2014). However, this has not always been reflected in concrete plans, resulting in scholars still debating on the best approaches to develop GI in metropolitan areas (Lafortezza et al., 2013). In this context, this study embraces the possibility that GI can help in creating a shared planning vision for networks of natural and semi-natural areas including related benefits (e.g., ecological, social, and spatial) (see e.g., European Commission, 2013).

Furthermore, as part of the ongoing scientific debate on GI approach, scholars have recently introduced the concept of Urban Green Infrastructure (UGI) which is a type of GI used within urban settings. UGI is "the interconnected web of vegetated spaces like street trees, parks and peri-urban forests that provide essential ES in densely populated areas" (Pearlmutter et al., 2017, V). The GI embodies the idea that the ES are vital to the cities, and within this approach, the UGI provides multiple benefits to people in the urban environment. While "the GI can have a major role creating spatial and functional interconnections between natural areas located in cities and surrounding rural areas" (Quintas, 2015, p. 189), UGI is a strategic network of planned and unplanned urban green and blue spaces, including street trees, parks, green roofs, green facades, rain gardens, urban forests and wetlands that provide essential ecosystem services in cities (Norton et al., 2015; Green Surge, 2015). UGI helps to develop living conditions by delivering Urban Ecosystem Services (UES), such as protecting air quality, regulating storm water, as well as supporting the diversity of species and contributing to the wellbeing of people (TEEB, 2011). The implementation of UGI can aid in facing several urban challenges (such as air pollution, temperature reduction and loss of urban biodiversity) (Norton et al., 2015).

By embedding this concept of UGI, this study touches on the current challenges in landscape and urban planning.

Despite the awareness that cities depend on healthy natural and semi-natural environments to provide a variety of benefits, there are still obstacles to the development of UGI (e.g., the ways in which to improve UGI in the planning system, as well as the ways to update and advance the existing green space planning). Planning UGI is not only a top-down strategic planning approach, but new forms ofinteraction need to be further explored between government bodies, citizens and other non-state actors (e.g., universities and institutes of research) (Green Surge, 2015), thus resulting in this call for a new understanding of GI multidisciplinary and collaborative approaches.

Although the development of UGI requires a multidisciplinary approach, there are still professional silos that limit an effective multidisciplinary collaboration (Lennon et al., 2016, Ahern et al., 2014). Recently, scholars have stated that conducting collaborative processes as well as creating constant feedback and reflections might further GI understanding amongst stakeholders within landscape and planning practices (Hostetler et al., 2011). However, further attention should be paid to the outcomes from multidisciplinary collaboration between academics and practitioners, as well as practitioners themselves (e.g., constant feedback, reflections and new approaches on GI).

Collaborative processes have been tested in the fields oflandscape ecology and landscape planning. On mentioning a collaborative process, Nassauer and Opdam (2008) proposed a social learning of mixed science-practice groups that can be used to support practitioners when handling scientific knowledge. The co-production of knowledge is meant to be grounded on a transdisciplinary approach, which suggests that science alone cannot solve the problems (Nassauer and Opdam, 2008). This approach can be used to review the current science-practice relationships, as well as create new collaborative processes for each situation by involving (in addition to landscape ecology and landscape planning) several disciplines, such as social and economic sciences (Opdam, 2010).

More recently, the need for multidisciplinary collaborative process has been brought to the attention of the landscape and urban planning debate in order to share learning and understanding of GI (Lennon et al., 2016; Faehnle et al., 2014; Ahern et al., 2014; Kopperoinen et al., 2014; Lafortezza et al., 2013). Lennon et al. (2016) developed a specific toolkit to promote GI thinking between engineers, landscape architects, ecologists and heritage officers in order to embed a GI approach into spatial planning practices. The workshop was used as a tool to explore the degree offamiliarity with the GI approach, as well as helping participants to move beyond professional barriers and create an informal learning arena (Lennon et al., 2016).

In this context, researchers can be seen as facilitators when collaborating with planners and local governments in outlining policies and programs for the development of GI (Hostetler et al., 2011). Collaborative processes should involve a wider range of stakeholders in landscape and urban planning, landscape architecture, ecology, architecture and urban design (Ahern et al., 2014). However, there are still difficulties from the researcher's perspective to provide notions and tools adequate to the implementation of GI. The mechanisms to transfer GI knowledge from research to practice need to be further investigated. In this context, it is also important to understand that the introduction of the GI to several disciplines, such as landscape architecture, landscape planning, urban planning, engineering, and urban design, does not occur in a straightforward manner. There are professional, cultural, planning and political contexts where the new knowledge on GI is challenged by the status quo of expertise (Di Marino and Lapintie, 2018).

We argue that there is a further need to explore new forms of the multidisciplinary collaborative process (oflearning and understanding of GI and proposing GI strategies and practices) which support different types of expertise, both academics' and professionals', thus enabling the transfer of the understanding of GI within existing and new planning practices. This multidisciplinary collaborative process can result in a mutual understanding and learning amongst practitioners and researchers. This process can be viewed as a mutual learning process that requires new trust, a multidisciplinary environment and new tools of active collaboration between researchers and practitioners. Thus, the paper addresses the following research question: How does a multidisciplinary collaboration between practitioners themselves, as well as between practitioners and researchers, support the understanding and development of GI within the new urban development?

To address the research question, the study presents a comprehensive literature review which, first, focuses on the understanding of GI, in particular on the barriers that still limit the adoption of GI within spatial planning; secondly, on the concept of the multifunctionality of GI and the need for collaborative groups of professionals. Furthermore, the study explores the three Finnish cities of Vantaa, Tampere and Jyväskylä. The reason for selecting these three cities is that there is a growing interest between policy makers, practitioners and academics in addressing GI strategies (e.g., spatial and ecological connectivity) and, most importantly, these cities are undergoing new processes of urban densification. In addition, the official practitioners have developed UGI solutions within residential districts or urban streets (such as storm water management projects and examples of green roofs) in which multi-stakeholders are or will be involved.

Our study is based on a multidisciplinary collaboration that lasted five months and involved 23 official practitioners from the city planning departments of the three Finnish cities of Vantaa, Tampere and Jyväskylä, as well as four researchers in the role of both moderators and facilitators. The multidisciplinary collaborative process consisted of several activities, such as a pre-questionnaire, presentations and selected readings, workshops and post-questionnaire. To this end, we need to specify that architects, landscape architects, engineers and geographers are actively involved in the Finnish planning context. Through these case studies, the article focuses on the ways the multidisciplinary collaboration between academics and practitioners can be beneficial to the understanding and development of GI. Findings from this study should be relevant to future planning practices.

2. Literature review

2.1. Understanding of GI: barriers in spatial planning, multifunctionality, and multidisciplinary collaboration

Approaches to GI have been framed and used within environmental policies at the national, regional and local levels (e.g., see the overview given by Mell, 2017) as well as in spatial planning (e.g., see the overview given by Lafortezza et al., 2013). Nonetheless, scholars are currently debating on the best approach to promote 'GI thinking' within the planning practices (Lennon et al., 2016). The notion of GI and related benefits, such as being close to nature as well as human well-being and health, need to be further acknowledged by local politicians, practitioners and communities (Lafortezza et al., 2013).

However, there are several difficulties when implementing an understanding of GI within planning practices as well as new land use developments (Lafortezza et al., 2013). Practitioners in landscape architecture, landscape and urban planning, and policy makers have traditionally dealt with recreational space provision and habitat conservation (Lennon et al., 2016). They do not yet possess a clear understanding of what constitutes GI (Matthews et al., 2015). One of the inherent qualities of GI is its complexity (see e.g., multifunctional GI) and ambiguity (Wright, 2011). The understanding of GI remains complicated due to the wide range ofissues for which the GI is employed (e.g., storm water management, health issues and air pollution) (Matthews et al., 2015).

In this context, several pilot projects on Urban Green Infrastructure (UGI) have been conducted with the aim of creating new knowledge and awareness amongst policy makers, local practitioners and communities (Green Surge, 2015). However, there are still several barriers that limit the adoption of UGI within spatial planning. Spatial planners and built environment researchers encounter difficulties in defining and operationalizing GI (Matthews et al., 2015). There are several green-space initiatives which are incorporated within the institutional agendas; however, practitioners and policy makers tend to interchange the term of 'green-space' and 'green infrastructure', thus weakening the concept of GI itself (Matthews et al., 2015).

In addition, understanding the ways in which urban ecosystems work, and the limits to their performance, is essential to the development of UGI (Elmqvist et al., 2008). However, the environmental structures and processes that are required to deliver UGI remain quite unclear to the practitioners and policy makers (Lennon and Scott, 2014). They have mostly concentrated on the socio-economic functions of UGI, thus there is a risk that the notion of UGI might be used for greening cities or greenwashing land use projects with little environmental value.

Moreover, there is a tendency to consider one function of GI at a time without considering the multiple benefits of GI (European Commission, 2012). Multifunctionality can contribute to achieve the aims of several policies and answer several stakeholders' needs (European Commission, 2012); it occurs when GI planning considers several functions of green spaces (such as ecological, social and economic/abiotic, biotic and cultural) (Hansen and Pauleit, 2014). Hansen and Pauleit (2014) provided a conceptual framework which consists of ecological and social conceptual components, such as the GI network, supply of ES and demand of benefits. The supply of demands from the stakeholders, including the hotspots of multifunctionality, should be embedded within the local planning strategies.

In this context, the project-based collaborations between academics, practitioners, local communities and environmental NGOs are considered relevant to the development of multi-functional GI (Ahern et al., 2014). A successful spatial approach to GI occurs when local communities are involved in the local plans of UGI (Lafortezza et al., 2013). Jerome (2017) examined the limitations in understanding multi-functional local GI. She stated that local stakeholders struggle to recognize the socio-economic and ecological benefits that UGI can deliver at the neighborhood or street-scale. GI sites at the community scale can supply a strategic level ofinterventions and provide concrete opportunities for development of the local environment. Indeed, a GI-community scale can describe a project around a shared vision or common interests. When dealing with UGI, the neighborhood-, street-, and micro-scale represent significant units of analysis. In fact, developers, planners and designers can discuss local circumstances and be engaged in all stages of the decision-making, since they know about the budget, time, and way local governments think (Norton et al., 2015).

Within the Finnish context, recent studies have been conducted by involving regional and local practitioners. Kopperoinen et al. (2014) used a semi-quantitative place-based method in order to assess local GI and refine the ways in which GI and ES can be represented. In addition, Faehnle et al. (2014) examined the ways in which residents can participate in a collaborative process with experts and local practitioners. In this case, the residents' experience was considered valuable input in informing the planning of UGI. Furthermore, public events and workshops have been used to collect feedback and challenges on the UGI themes and planning strategies by involving citizens and other stakeholders (Green Surge, 2015). Nonetheless, thus far in Finland, the use of GI remains at a rather abstract level within the regional planning strategies, while concrete planning practices at the city and neighborhood scales are still lacking. There is a need for further understanding of GI (e.g., potential, activities, functions, benefits and need) within local and place-based or relationship-centered contexts (Jerome, 2017).

3. Methods

3.1. The three cities of Vantaa, Tampere and Jyväskylä

The qualitative data were collected through a multidisciplinary collaboration with the three Finnish cities of Vantaa, Tampere and Jyväskylä. The cities of Vantaa and Tampere are located in the southern part of Finland, while the city of Jyväskylä is situated in Central Finland.

The reasons for selecting the three cities is their growing interest in developing local GI strategies and practices within the built environment. In addition, other reasons for their selection involve their introduction of new forms of multidisciplinary collaboration when dealing with the development of UGI. There are several ongoing and future pilot projects concerning the use of green roofs, storm water

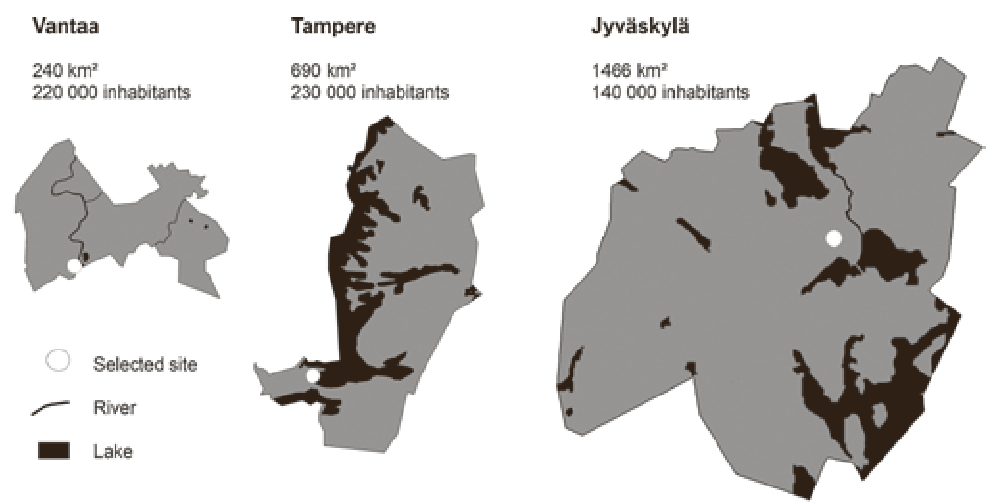


Fig. 1. The cities of Vantaa, Tampere and Jyväskylä: administrative borders, location of the selected sites and main water bodies.

detention, and biofiltration within the urban areas (such as the Kangas district in Jyväskylä and the residential area of Vuores in Tampere) in which multi-stakeholders are or will be involved.

In the three selected cities, one can see the challenges and strategies for urban green-space planning. Furthermore, the urban developments from the past years and ongoing urban densification processes have affected the provision of green spaces and simultaneously limited access to the existing green areas. However, the local policies are now currently more compact-city oriented. Thus, the intention of the planning offices is to encourage densification and more effective land use (e.g., diverse patterns, mixed-uses, quality of green areas and pedestrian scale developments). The general aim is to create more sustainable cities and reduce traffic emissions. However, each context is characterized by local practices as well as environmental, socio-political, economic and spatial pressures.

The presence oflarge logistic hubs in the city of Vantaa, such as the international airport and national main routes have broken valuable green area connections with the share offorests diminishing over time (City of Vantaa, 2012). Nevertheless, within the green agenda (*Viheralueohjelma*), the city of Vantaa has focused on improving urban biodiversity along the river of Vantaanjoki (Fig. 1).

The city of Tampere is characterized by the two lakes of Pyhäjärvi and Näsijärvi (Fig. 1) as well as several green areas (such as extensive forests and protected areas) that will be endangered by significant urban development projects (see e.g., the new urban districts of Hiedanranta, and Lakalaiva-Lahdesjärvi). On the one hand, some green areas will be more exposed to noise and pollution from the heavy traffic around the new urban districts, and the provision of green areas per capita is declining. On the other hand, the new master plan includes a focus on managing the quality of the green areas within the built-up areas and developing a wider green network for the whole city by connecting urban and rural green spaces (City of Tampere, 2017a).

The city of Jyväskylä is characterized by the presence of several lakes (such as Palokkajärvi and Jyväsjärvi) (Fig. 1). In February 2017, the Jyväskylä city council approved a new plan for the development of the Green Ring (*Kehä Vihreä*) which is a comprehensive network of existing parks and other green areas aimed to enhance recreational, spatial and ecological functions (City of Jyväskylä, 2017).

3.1.1. The three selected sites

Each city was asked to select an urban area that was already planned for further new development. The three selected sites were chosen because of the growing interests between local policy-makers, city planners and other stakeholders to develop GI strategies and initiate pilot projects on UGI.

The Kaivoksela site in Vantaa hosts commercial functions. On the eastern edge of the site, a green finger called "Keskuspuisto" (the central park), which is a large park reaching the city center of Helsinki, follows the Vantaanjoki River (Fig. 2). A small groundwater pond called "Vetokannas" is used for recreational activities (Fig. 3). The City of Vantaa will replace the commercial functions with office as well as residential and recreational functions (City of Vantaa, 2017).

The selected site of Hiedanranta is located approximately three kilometers from the Tampere city center and faces Lake Näsijärvi

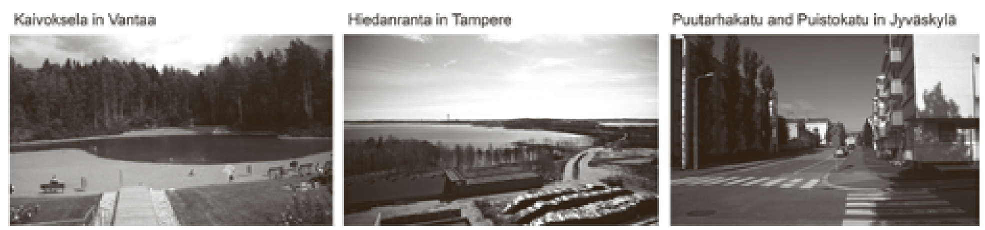


Fig. 2. Views of the three selected sites.

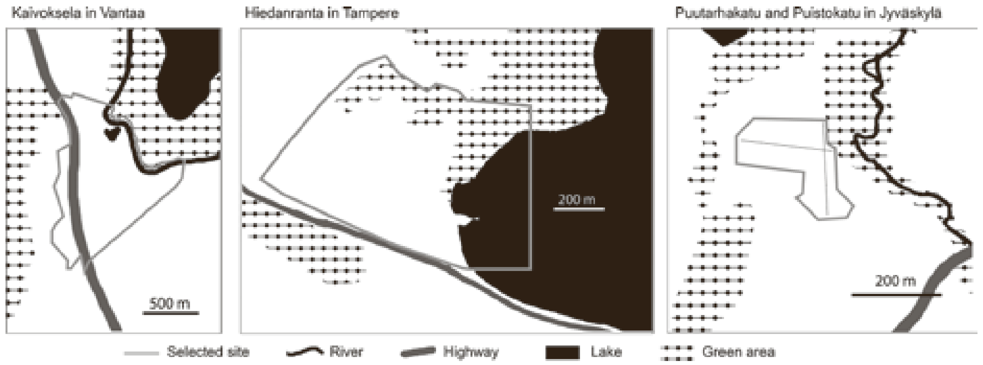


Fig. 3. Landscape features of the three selected site and surrounding areas.

(Fig. 2). The area is still occupied by industrial buildings which are partly used, by retail shops and an old manor house (with a garden, cemetery and chapel). According to the new master plan, the site is going to be transformed into a new residential and office district. The city wants to pilot new ecological approaches to the sustainable urban development of the site (City of Tampere, 2017b).

The selected site of Jyväskylä is close to the city center consisting of a renovation of two urban streets, Puutarhakatu and Puistokatu, and the nearby urban park Puistotori (Fig. 3). There is a risk of flooding on the site which is located on the lowest part of a watershed that drains into the river Tourujoki. Currently, the city of Jyväskylä wants to pilot new stormwater management projects as part of the street renovation (Tuomi, 2016). The development of the urban site will continue during a construction phase.

3.2. The multidisciplinary collaborative process

The multidisciplinary collaborative process lasted five months, from August 2015 to January 2016. 23 official practitioners were involved within the collaborative process for an average of 15 h. The multidisciplinary collaborative process was articulated into a pre-questionnaire, Input 1, first workshop 'the Vision', Input 2, final workshop 'the Path', and post-questionnaire (Fig. 4). Participants experienced the collaborative process (of understanding and learning about GI, as well as working and proposing GI strategies and practices) as an enriching encounter in which to build on one another's views (Ariluoma et al., 2015).

The moderators asked each city to invite participants from different professional backgrounds, consequently including various experiences and approaches to landscape and urban planning. The participants were gathered into three groups (from 5 to 8 components). The multidisciplinarity of each group instead of a single professional group was considered relevant to an understanding of GI and important for the collaboration itself. The participants from each group were also familiar with the selected site of their own city and informed about the future development of the site.

3.2.1. Pre-questionnaire

The closed questions within the pre-questionnaire aimed to learn more about the participants' background. They were: professionals in architecture (N = 8), landscape architecture (N = 7), engineering (traffic and structure, N = 4), and experts in natural sciences (geology, biology and horticulture, N = 3). Through open-ended questions, the participants were asked about their understanding of GI by defining the concept in their own words, the knowledge sources from which they had been informed about GI (e.g., articles, conferences and networks with colleagues), as well as the ways in which GI had been embedded within their own city.

3.2.2. First inputs

After the pre-questionnaire, the moderators supplied the 'first inputs' by presenting a comprehensive picture on GI principles, including GI benefits (de Groot et al., 2010). Moderators provided official practitioners with scientific readings (N = 10, see e.g., Cameron et al., 2012; Hanski and Haahtela, 2014) and the latest articles appearing in national and international newspapers about urban biodiversity, health and economic benefits. The additional source of newspapers was chosen because ofits informal and relatively simple language capable of easily communicating information to a large audience. Then, participants were asked to study a list of Ecosystem Services (ES) based on TEEB categorization (TEEB, 2011). The first inputs aimed at familiarizing participants with the latest knowledge on UGI and UES.

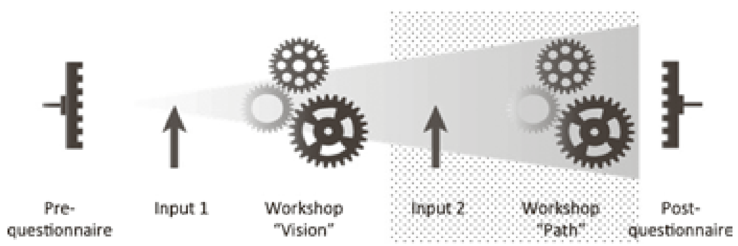


Fig. 4. The structure of the multi-disciplinary collaborative process.

3.2.3. Workshop vision

The first three workshops were held in the venues of the city planning departments of Vantaa, Tampere and Jyväskylä, respectively; while the final one was arranged in the public library of Tampere involving all participants from the first workshops. The first workshop lasted four hours while the final one lasted 5 h. 22 participants attended the first workshop: 6 official practitioners from Vantaa, 9 from Tampere, and 6 from Jyväskylä, respectively.

The moderators introduced the participants to a comprehensive list of GI elements divided into three categories: larger scale GI elements (such as forests and natural waterfronts), functional GI elements (such as playgrounds and urban farming allotments) and detailed scale GI elements (such as green facades and rain gardens). The participants were asked to familiarize themselves with the GI using manipulative materials, such as cubes on whose surfaces there were written the GI elements grouped into the three mentioned categories. Participants were asked to choose the GI elements that they wanted to preserve or introduce to the selected site. They wrote the motivation for selecting those GI elements on post-its and attached them to flipchart paper on a wall in the room. Finally, each group of participants outlined a vision by developing local strategies and plausible actions to introduce GI approaches and elements within the future development of the selected sites.

3.2.4. Second inputs

During the second inputs, participants were asked to choose GI elements from the list already introduced in the first workshop by selecting the ones with which they are already familiar. They were asked to discuss the local challenges they have already encountered when dealing with the development of GI (e.g., the conflicts with other stakeholders, or difficulties in becoming familiar with GI).

3.2.5. Workshop path

The final workshop was attended by 17 participants who had also attended the first workshop: 5 from Vantaa, 7 from Tampere, and 5 from Jyväskylä. Moderators introduced the concept of multifunctional GI, the multiple scale of GI implementation as well as GI connectivity by providing concrete examples from Finnish and international contexts. The planners were asked to discuss obstacles and barriers to GI development within the planning phases (e.g., strategic planning, master planning and construction phase). Then, the official practitioners were asked to deliberate on new strategies and actions for GI development within the selected sites.

In both workshops 'Vision' and 'Path', one or two researchers moderated and facilitated the group discussions, while the other researchers were more focused on writing extensive notes and photographing the workshop activities. The research team also audio-recorded the workshops, and afterwards, they transcribed the conversations into a written form that was amenable to being analyzed.

3.2.6. Post-questionnaire

Through the open-ended questions, participants were asked to explain in their own words their understanding of GI. In addition, the questions dealt with topics, such as the benefits of GI, and the planning phases that would be relevant to the development and management of GI. The aim of the post-questionnaires was to reflect on the learning and thought processes of the official practitioners.

4. Results

4.1. Findings from the pre-questionnaire

Participants were asked to define in their own words their understanding of GI. 23 participants answered the pre-questionnaire: 6 official practitioners from Vantaa, 10 from Tampere, and 7 from Jyväskylä, respectively. By analyzing the answers, it was found that participants defined GI using three main approaches: 1) limiting GI to single green spaces, including even non-vegetated structures; 2) referring to the dimension of GI connectivity and provision of ES; and 3) referring to the concept of the multifunctionality of GI. These three most representative approaches were named in Table 2 as 'GI as green areas', 'GI as network and ES' and 'Multifunctional GI'.

Official practitioners from different backgrounds (engineering, architecture and natural sciences) defined 'GI as green areas' referring to GI as single green spaces and including even street furniture and materials. One participant stated: "*GI are all the components related to the visual and aesthetic aspects of public spaces, for example, parks, furniture and materials.*" Participants were still influenced by the traditional spatial and functional classification of single green areas within the planning documents. One of them defined GI saying: "*GI are the green areas already represented within the maps*."

Within 'GI as network and ES,' it was found that participants with a background in landscape architecture, architecture and natural sciences referred to the dimension of connectivity and provision of ES. A practitioner answered: "The *green infrastructure is an entity formed by green and blue areas within the urban structure*". Another participant stated: "*GI includes the green network that we already have in cities. It can also be related to a traffic network".* However, participants were familiar with more established concepts of greenways, green structures and ecological networks. One of the participants said: "*The term 'GI' has not been widely used in my city. In most of the planning documents and maps, we still refer to other terms, such as green structure, ecological corridors, and recently, we have introduced ES*."

Only a few participants with a background in landscape architecture were familiar with the concept of the multifunctionality of GI. A practitioner stated: "*GI is an integral part oflandscape and nature at both micro and macro level (e.g., hydrological cycle and a single tree). Different elements in nature or within the urban structure can deliver ES, so GI does not address only one singular benefit, but we should be able to consider and include all potential ES benefits in planning*" The official practitioners who referred to the principle of multifunctionality recognized ecological, social, cultural, biotic and abiotic functions of GI.

4.2. Findings from the workshop 'Vision'

The official practitioners in Tampere and Vantaa defined the vision by outlining strategies and plausible actions for GI within the selected sites of Hiedanranta and Kaivoksela, respectively. Considering the upcoming construction phase of the selected site, the official practitioners of Jyväskylä created their own vision drawing upon more concrete GI interventions that could be added to the renovation of the two streets as well as the nearby park. The participants named the visions "Lakeside city" in Tampere, "Functional village" in Vantaa, and "Green stormwater street" in Jyväskylä, respectively.

Within the vision of "Lakeside city", the official practitioners of Tampere formulated several arguments on ways to preserve urban biodiversity and integrate the UGI within the future development of the selected site. However, by beginning with that, the participants struggled to identify the kinds of UGI elements which could be included in the site of Hiedanranta, which presents complex interactions (e.g., between vegetated and non-vegetated areas as well as non-uniform landscape topography). They emphasized aesthetic values and accessibility, rather than the UES that UGI could provide. The following passage is representative of this circumstance in which disciplinary silos limited the interactions.

> Architect: *There is a challenge when we want to achieve biodiversity conservation on the site and all around, but at the same time, we have huge ambitions for new buildings. What happens to the biodiversity then… in that conflicting game?*

> Engineer: *Well, high roofs… when we build high buildings, there will be unused land and space on the roofs.*

Architect: *Yes, but is it then fully available to residents if nature is on the roof?*

Moderator: *It could be, but how will cyclic processes function when nature is all limited to the roofs?*

Engineer: *Cycling processes? What are those?*

Moderator: *Like nutrient cycle and water cycle support services provided by green roofs.*

(Workshop in Tampere 15.9.2015)

After these initial hesitations, the discussion focused on Lake Näsijärvi which faces the site of Hiedanranta. In addition to recreational services, the official practitioners recognized the role of UGI that helps manage the stormwater and uphold the water quality of the lake. The participants agreed that in the future design of the waterfront (including promenades and squares) the UGI elements, such as green facades, green roofs, trees and other plants should be used to create a more favorable urban microclimate. Gathering around the post-its, official practitioners identified private yards as important UGI platforms capable of creating opportunities for residents to be involved, for instance, in urban farming.

Within the vision of "Functional village", the official practitioners of Vantaa identified the pond of Vetokannas and the recreational routes along the river Vantaanjoki River as the main GI that can deliver a wide range of benefits to the local communities within and outside the site. They agreed that future development should be dictated by existing ecological, recreational and cultural landscape elements; however, this has not happened thus far. The existing accessibility to the site does not even support recreational use of the pond. The official practitioners mostly concentrated on the spatial issue and ways to connect the green areas.

In addition, the group discussion stimulated the official practitioners of Vantaa to reflect on both prior and new knowledge. The participants also realized that their new knowledge on GI can be used to approach local policy-makers and be more effective in convincing them when making new decisions:

Moderator 1: *"Did the workshop provide new viewpoints"?*

Landscape architect: *"Well, I know a little bit about the GI notion. The workshop is a good initiative in the sense that we can understand much more profoundly UGI and potential developments. We need to think of a new approach in planning".*

Moderator 2: *"We know that some of you were already familiar with UGI."*

Landscape architect 2: *"Yes, we are learning so much and we can realize how many issues we should consider all together and communicate them to the policy-makers. The new knowledge is contributing to create a 'very good background' and will support more arguments when making new decisions with local policy makers."*

(Workshop in Vantaa – 31.8.2015)

Considering the advanced phase of the two streets of Puutarhakatu and Puistokatu, the official practitioners of Jyväskylä discussed the urban functions that should be physically integrated in order to transform the two streets into more livable places for pedestrians. Currently, the road and sidewalk spaces are mostly used for parking lots. Within the vision of "Green stormwater street", the participants first debated on the ways to integrate new UGI within existing parking lots, and new terraces for coffee shops and restaurants that could be placed along the two streets in the future. They were also aware that the integration of new UGI could produce local conflicts with shopkeepers, shop owners, and residents in the case of urban spaces invading existing parking lots. Initially, within the dialogue, participants mostly faced space issues for both parking and green areas:

Moderator: *"In your vision, you mentioned two objectives: 'decreasing the amount of street side parking' and 'offering enough parking space'. Are not these two objectives contradictory?"*

Natural scientist: *"Both are relevant along the two streets."*

Architect: *"An underground parking lot would solve the problem."*

Landscape architect: *"The two objectives are challenging, but both relevant to us. If you increase the amount of green, this will mean less space for parking."*

(Workshop in Jyväskylä 25.8.2015)

However, the official practitioners were aware of the flooding risk on the two streets which are really close to the river Tourujoki. Therefore, the participants responded to this issue afterwards by outlining UGI interventions (e.g., planting street trees and developing swales and bio-retention basins) that can enhance both spatial and ecological GI connectivity. At the same time, they realized that these UGI can be compatible with the multiple activities that are and will be performed along the two urban streets.

4.3. Findings from the 'Path' workshop

Participants reflected upon the development of UGI within the selected site and their own city. The official practitioners collaboratively proposed new approaches to develop UGI. There was a common understanding amongst the participants on the need to lead UGI development within public buildings and spaces. For instance, the official practitioners recognized the importance ofinvolving constructors:

Engineer: *"GI should be more integrated within the built-up areas. It would be nice to consider GI as one of the predominant objectives to be achieved within new urban development."*

Landscape architect 1*: "It might become a kind of 'megatrend'…. Yes, why not, we have not developed beyond this perspective."*

Landscape architect 2*: "You just need to find a proper way to ask constructors to develop UGI."*

Architect: *"The land is owned by the cities."*

Landscape architect 2: *"We should use the UGI approach when constructing public spaces and buildings, such as schools or kindergartens. It would be difficult to demand stakeholders and constructors develop UGI if we do not pioneer this approach."*

(Round table 1.12.2015)

Furthermore, practitioners reflected on the challenges ofincorporating UGI within the planning phase. They stated that GI should be incorporated at the intermediate stage of the planning process, between the well-established phases of master and detailed planning (which are defined by the national planning law Land Use and Built Act 1999), which they called 'area development planning':

Architect 1: *"We actually need an 'area development planning', in order to get a comprehensive picture of GI within and outside the selected site."*

Engineer: *"Maybe we could outline the green and blue networks at the upper level which would guide a detailed planning."*

Natural scientist: *"Yes, that would be essential. Although our lead has stated that the GI should be embedded in the master plan. However, the current master plan does not provide a wider and more concrete picture for the development of GI."*

Architect 2: *"At the moment, Finnish cities have a strategic master plan."*

Natural scientist: *"Yes, we would need an area development planning phase in between the strategic master plan and detailed plan."*

(Round table 1.12.2015)

4.4. Findings from the post-questionnaire

The number of participants slightly diminished during the final part of the collaborative process due to participants' lack of time. 16 participants filled the post-questionnaire (5 from Vantaa, 5 from Tampere and 6 from Jyväskylä, respectively). Nevertheless, the groups of participants remained varied (Table 2). While only a few participants still identified GI as single green areas (Table 2), the understanding of 'GI as network' was more comprehensive amongst the official practitioners. The spatial connectivity of GI was extended to a wider picture of GI elements, including the benefits for local communities. An official practitioner stated "*GI can be located on private or public areas as parks or green roofs, which forms a complex network that needs to be considered in urban communities and planning of such.*" Another participant said: "*As I understand green infrastructure is, for example, ditches, streams, forests, parks, trees, bushes, green roofs, and lush light traffic lines that are linked together within the built environment. That means that several natural elements can be found in the built environment.*"

The participants who defined GI by referring to the multifunctionality and delivery of ES pointed out the importance of processes and functions of GI. A practitioner said: *"GI is an entity formed by green and blue elements that are part of the urban structure. GI includes processes and services that nature provides for humans."* Another participant stated: *"GI is an urban green network that can support stormwater and other green elements as part of a well-functioning urban structure. GI also delivers ecosystem services."*

5. Discussion

The multidisciplinary collaborative process, consisting of pre-questionnaire, learning sessions, workshops and post-questionnaire, aimed to support the official practitioners from Tampere, Vantaa, and Jyväskylä in developing active reflections on GI, and identifying the main GI strategies and elements that could be incorporated within the built environment. In addition to acknowledging GI, the multidisciplinary collaboration helped both practitioners and researchers to reflect on the current planning tools and practices for the development of GI.

It is important to understand the professional, planning and environmental context in which the development of GI occurs (Mell 2017; Lennon et al., 2016; Lafortezza et al., 2013). In addition, this study highlights the need to further investigate the status quo of expertise and discover a way to move beyond the disciplinary silos (Di Marino and Lapintie, 2018). The study shows that the understanding of GI gradually changed and evolved amongst the official practitioners. Initially, when describing their own understanding of GI in the pre-questionnaires, the results showed that some practitioners' thinking was influenced by the traditional spatial and functional classification of single green spaces which is still used in traditional and rigid planning practices (see e.g., land-use and zoning reports and maps); hence, the term of GI was often interchanged with green areas (Matthews et al., 2015). They also emphasized aesthetic values and accessibility to the green areas. The connectivity of GI mostly referred to more established concepts, such as ecological networks, greenways and green structures, while only a few participants identified the multifunctionality concept of GI (see the results from the pre-questionnaire) (Table 1).

Afterwards, more familiarity with theories and notions of GI (through learning sessions and workshop activities) supported the newly acquired knowledge amongst official practitioners from different silos and their own thinking of GI (Table 2). However, the learning process resulted in a different level of understanding of the GI principles (Lennon et al., 2016). On the one hand, the participants who embraced the concept of connectivity outlined a comprehensive definition of spatial connectivity of GI. On the other, those official practitioners who acknowledged the multifunctionality of GI were able to recognize the importance of enhancing mutual social and ecological interactions, as well as the benefits that people can obtain from GI.

The use of the workshop was considered to be a tool for cultivating multidisciplinary collaboration and learning between practitioners from different silos and between practitioners and researchers (Lennon et al., 2016). This study illustrates that before and in between workshops, learning sessions (see Inputs 1 and 2) can support a more comprehensive understanding of GI. In addition, it is also necessary to monitor the learning process and facilitate constant feedback from the participants (Hostetler et al., 2011). In this sense, the study points out that the use of both pre-questionnaire and post-questionnaire can help to understand the effectiveness of the whole learning process and support further reflections on GI amongst the academics and practitioners involved.

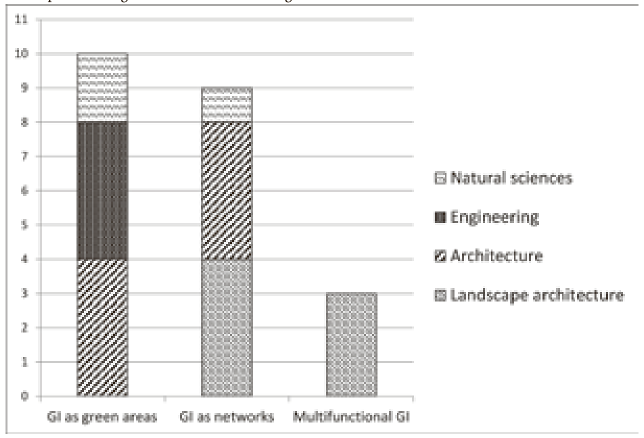
The community scale supplied a strategic level ofinterventions of GI as well as provided concrete opportunities for the development of the local environment (Jerome, 2017). Official practitioners were aware of local circumstances as well as the way of thinking oflocal stakeholders and governments (Norton et al., 2015). The findings show that the community scale of the three selected sites supported a common understanding of UGI amongst practitioners as well as more concrete actions. The understanding of UGI by the practitioners resulted in some changes to the evolving concept of GI as well as policy approaches and land-use practices. By focusing on concrete actions, practitioners became more aware of the possibility ofintegrating UGI with traditional public services and urban functions (see e.g., the proposed intervention in the selected site of Kaivoksela in Vantaa). However, practitioners realized that the integration of new UGI could produce local conflicts with shopkeepers, shop owners and residents in the case of green spaces and trees invading existing parking lots and new terraces (see the selected site of Jyväskylä). To overcome socio-political and economic pressures, the practitioners' understood that UGI should be compatible with the multiple activities that are and will be performed along the two urban streets. This study also suggests revising the concept of public services within the traditional land-use planning by adding the concept of UGI, and further promoting the spatial and ecological connectivity within the urban areas.

In addition to the understanding of GI between the disciplines themselves, and between academics and practitioners (Matthews et al., 2015; Benedict and McMahon, 2012), the findings reveal that there are further barriers and obstacles to the development of GI, such as inadequate planning tools. An intermediate level of planning was proposed in between the statutory strategic master plan and the statutory detailed plan, the so-called 'area-development planning' with particular emphasis by the official practitioners. According to them, the aim of this intermediate phase of planning is to guide the development of GI within the urban contexts by sharing a general view of GI in between strategic (overly abstract) and detailed (overly narrow) planning levels. For instance, this planning tool might provide the practitioners with a framework for the implementation of GI and inform the decision-makers about GI values within urban areas.

The findings from this study contribute to the current knowledge of GI, in particular, the practical challenges and conflicts ofimplementing GI in cities undergoing densification. The collaborative process and related methods can be experimented with in other Finnish and international cities presenting similar planning strategies (sustainable compact-city and urban greening). Hence, it would be important to understand the degree oflocal collaboration and awareness of GI values and benefits amongst those participating. The three selected cities had already drawn attention to the development oflocal GI strategies, indicating a ready fertile ground on which to build a shared vision. However, if such a socio-cultural ground is lacking, a further attempt would obviously be needed to create more local consciousness of the GI. This might result in intensifying some activities within the collaborative process (e.g., more training activities within Input 1 and a wider focus on GI benefits in Workshop 1).

Additionally, more established forms of collaboration need to be

Table 1
Participants' background and understanding of GI.



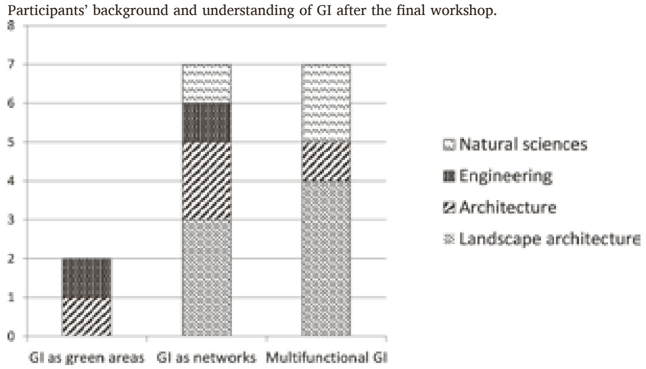
further explored in future research paths by involving a wider number of practitioners and academics from several perspectives as well as other stakeholders (such as planning, landscape, economy, ecology and sociology). In addition to academics and practitioners, future studies should extend the collaborative process to other community members (e.g., citizens, non-profit organizations, real estate developers and politicians) who were not included in this study. This wider collaboration might help to support a more comprehensive way of thinking about GI, as well as developing GI strategies and practices.

6. Conclusions

The aim of the study was first to present the ways in which a multidisciplinary collaborative process can support the understanding and development of GI amongst official practitioners themselves and researchers by analyzing several barriers that could limit the adoption of GI, such as the disciplinary silos, difficulties in interpreting GI and embedding it within planning practices. Then, the study discussed the results from a multidisciplinary collaboration between practitioners (architects, landscape architects, engineers and experts in natural sciences) and researchers in landscape architecture and urban planning, which consisted of several activities, such as learning about and understanding GI, proposing GI strategies and actions, as well as reflecting on existing planning tools. This multidisciplinary collaboration resulted in a gradual change of GI thinking amongst official practitioners from different backgrounds.

The disciplinary silos do not represent an insurmountable obstacle to the understanding of GI; however, there are further barriers and obstacles to the development of GI, such as rigid planning practices and inadequate tools. When describing their own initial understanding of GI, several practitioners referred to the traditional spatial and functional classification of single green spaces still permeating rigid land use practices. Later on, at the end of the first workshops, practitioners stated new ways should be further investigated to embed GI within the current planning practices, such as the 'area development planning' (in between the strategic master plan and the detailed plan). This intermediate phase of planning might be helpful in guiding the development of GI. In addition, cities should pioneer UGI development within the public space and buildings. This approach can help to promote more concrete actions and interventions for the development of UGI amongst constructors and developers. This study also revealed some changes in the evolving concept of GI (e.g., the ways in which traditional services and urban functions can be planned and designed by integrating the notion of UGI). This means addressing new issues, such as stormwater

Table 2
Participants' background and understanding of GI after the final workshop.



management, air purification, and urban micro-climate within more comprehensive planning practices.

All these themes are relevant to the development of GI and need to be further embedded within both research and practice. In addition, further research is also needed to establish a stronger and closer multidisciplinary collaboration between academics and practitioners, as well as other community members (e.g., citizens, non-profit organizations, real estate developers and politicians).

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Paper 2 Elisa Lähde
Kajsa Rosqvist

BARRIERS PREVENTING DEVELOPMENT OF INTEGRATED STORMWATER MANAGEMENT IN HELSINKI, FINLAND

Barriers Preventing Development of Integrated Stormwater Management in Helsinki, Finland

Elisa Lähde
Kajsa Rosqvist

ABSTRACT

In recent years, the development of sustainable urban stormwater management has been much in focus in several cities in Finland due to climate change and new regulations. Urban adaptation to climate change requires solutions that combine underground and aboveground measures and processes. However, the transition towards a water sensitive city, where multifunctional green infrastructure and urban design reinforce water sensitive behavior, is not trouble-free. Various barriers have been identified, such as a lack of knowledge as well as unclear roles and responsibilities among stakeholders.

In the city of Helsinki, the present stormwater strategy has currently been updated to an integrated stormwater program. For this purpose, a workshop was organized for civil servants and experts working with storm water issues in different city departments. In the workshop, different measures and solutions required to reach the goals of the new program were discussed in order to define adequate actions. The preliminary goals of the strategy were: 1) the prevention of stormwater related problems, 2) climate-proof local and regional drainage, 3) qualitative and quantitative stormwater management, 4) use of stormwater as a resource in urban environments, and 5) integrated stormwater management within city administration.

The workshop discussions revealed that civil servants and experts knew and understood quite well the main goals of the program. However, the participants displayed gaps in other areas of knowledge. There was a lack of knowledge on sustainable drainage components and their variety of delivered ecosystem services. Stormwater management is still comprehended as a technological challenge with the multifunctionality of green infrastructure solutions not being fully utilized in urban design. Several approaches are needed to continue the development of the water-sensitive city in Helsinki, including more real life examples, broader stakeholder involvement outside the building sector, and a critical examination of existing planning procedures.

Keywords: integrated stormwater management, SUDS, urban water management, green infrastructure, water sensitive urban design

1. INTRODUCTION

1.1. Sustainable urban drainage systems

Increased precipitation and changing rainfall patterns are predicted to be one of the major effects of climate change (IPCC 2014). In combination with on-going urbanization and diminishing green spaces available, urban runoff will undoubtedly increase. This will in turn increase the risk of flooding and decrease the quality of receiving waters. As sustainable urban drainage systems (SUDS) are able to improve stormwater management in both quality and quantity as well as deliver additional related benefits, SUDS have been developed and promoted by an increasing number of communities worldwide.

SUDS restore natural environments and use natural processes (infiltration, evapotranspiration, filtration, retention, and reuse) to mimic the natural water cycle of a site. In different contexts, these practices can be referred to by other similar terms, such as low-impact development (LID), best management practices (BMP), water-sensitive urban design (WSUD), low-impact urban design and development (LIUDD), not to mention green infrastructure (GI) (Fletcher et al. 2015). Some of these approaches more heavily emphasize water quality and quantity management (e.g., LID), and others the provision of ecosystem services (e.g., GI). In this paper, the term SUDS is used to describe all kinds of sustainable urban drainage systems that deal with surface water in an alternative way to mainstream conventional drainage practices.

SUDS can be categorized into structural and non-structural solutions. Non-structural solutions can include urban planning and education (Elliott and Trowsdale 2007). Structural solutions can be categorized according to their function (such as on source management components, conveyance components and infiltration/detention components) including green roofs, rainwater tanks, permeable surfaces, bioswales, rain gardens, planter boxes, and vegetated basins (Susdrain 2017). For the best treatment result, a treatment train should be used (Revitt et al. 2014). It is a combination of multiple, complementary SUDS components designed to meet the needs of a particular environment to achieve a better overall quality and quantity management.

Structural SUDS components are multifunctional and can, in addition to stormwater management, deliver various other ecosystem services. These include air quality improvement, mitigation of climate change by reducing greenhouse gases, energy savings by shading and insulation, reduction of urban heat island formation, and improvement of community livability (such as aesthetics, recreation, and improvement of habitats) (Demuzere et al. 2014; Scholz 2014, Scholz et al. 2013). Ecosystem services can help cities transition towards more sustainable environments, which might be resilient to changing conditions in the future (Lundy and Wade, 2011).

1.2. The transition process of cities

In addition to climate adaptation, a growing demand of savings in infrastructure costs has led to a greater interest in the added value of multifunctional SUDS (Wright et al. 2016). In order to promote SUDS and related benefits, many cities worldwide have composed their own stormwater programs or strategies. In the programs, priority is awarded to on source management and detention of stormwater over conventional systems. This so-called priority order of stormwater management enhances the natural hydrology of the site even in post-development conditions.

In Finland, sustainable stormwater management is required by law (MRL 1999), and almost all large and midsize cities have implemented the requirements by conducting their own stormwater programs. Helsinki, the capital of Finland, released its own stormwater strategy in 2008 (City of Helsinki 2008) making it the first city in the country to do so. An interdisciplinary city internal working group together with a steering group drafted the strategy in order to promote interaction between different departments of municipal government (Salminen 2013, 13). The aim of the strategy was appropriate and site-based stormwater management. However, implementation of the existing strategy has not been completely successful (Salminen 2013, 41); thus, the present stormwater strategy is currently being updated to an integrated stormwater program.

This paper investigates the preconditions required to achieve the aims of the new integrated stormwater program. Data for the paper has been collected during a workshop organized within the city of Helsinki in April 2017. The purpose of the workshop was to address the aims of the new integrated stormwater program and find actions to jointly reach these aims with 21 civil servants and experts representing the different departments handling storm water management within the city of Helsinki.

During the workshop discussions, the participants identified any barriers of implementation concerning the present strategy, and proposed consequent actions to overcome them. However, many of the barriers preventing implementation can be difficult to identify, because they are embedded within organizational cultures, practices and processes (O'Donnell et al. 2017). Thus, the research questions of the paper are: 1) What kinds of barriers can the participants themselves identify? 2) Which other barriers can be identified in the workshop discussions?

The aim of the paper is to define the baseline understanding of stakeholders within the different departments of the municipal government dealing with stormwater management. This will help to create appropriate actions for an integrated stormwater program and to transform Helsinki into a water-sensitive city. For other cities and authorities outside Helsinki, the results of the paper can provide a valuable case for comparison and help to identify their own barriers.

2. INTEGRATED STORMWATER MANAGEMENT

For already a few decades, the decentralized, on source approach has been a new paradigm in urban stormwater management (Marsalek and Chocat 2002). Previously, urban drainage was seen only as a problem, but related opportunities, such as increased biodiversity and climate adaptation, are currently widely recognized (Ashley et al. 2013). This type of approach, called integrated stormwater management, emphasizes a use of multifunctional on source controls, a transition from traditional drainage to green infrastructures, and a consideration of additional environmental benefits (Mailhot and Duchence 2010).

An integrated stormwater management approach has been implemented in practice particularly in the northern cities and states of North America, such as Vancouver, Seattle, and Portland, and in Australian cities, such as Melbourne. Since their involvement in SUDS beginning in the 1990s, these cities have already been actively monitoring the effects of integrated stormwater management on drainage servicing, land use planning and environmental protection (Hottenroth et al. 1999; Brown et al. 2013). During the past two decades, there has also been a remarkable number of successful examples of realized SUDS projects. However, wide-scale implementation of SUDS has been limited (Brown 2005) because many cities are still heavily investing in mainstream conventional drainage practices (Wong and Brown 2009).

Brown et al (2009) have created a framework describing the transition population growth and climate change, and it is essential for all cities to invest in solutions that will also "deliver [a] long-term sustainable outcome" in water management (Brown et al. 2009).

Barriers hindering the implementation of SUDS have been identified in different studies (Kim et al. 2017; Ashley et al. 2015; Thorne et al. 2015; Brown and Farrelly 2009; O`Donnell et al. 2017). There are technical barriers that include suspicion concerning hydrological performance, service delivery and maintenance. However, socio-institutional barriers are more serious. These include a lack of confidence that decision makers and communities will accept, support, and take ownership of SUDS (Thorne et al. 2015). Stakeholders' lack of knowledge hinders the planning and design of the solutions (Kim et al. 2017); moreover, despite several successful case examples, SUDS are still regarded as novel practices; the resistance to change existing practices also represents a relevant barrier (O`Donnell et al. 2017). Additionally, in the Finnish context, unstable procedures, unclear roles and responsibilities, a lack of knowledge and monitoring hinder the efficient implementation of integrated stormwater management (Salminen 2013, 41).

Different tools, models and frameworks have been designed to improve and facilitate communication and participation between different stakeholders (Ruiz et al. 2017). One of the most influential frameworks is the Three Points Approach (3PA), created by Fratini et al. (2012) and further developed by Sorup et al. (2016) and Digman et al. (2014), which aids in turning the problem of adapting to changing flood risks into a positive opportunity for the development and enhancement of urban areas. This is accomplished through utilizing the interactions and synergies between the surface water management system and society.

In the 3PA, three levels of stormwater management have been categorized for different rain events: 1) Technical optimization: where design standards for sewers and other infrastructure apply. This considers technical solutions which deal with defined design storms to prevent damage and meet service levels; 2) Urban resilience and spatial planning: involves dealing with extreme events, which becomes of necessity multi-disciplinary. The aim is to mitigate the impacts of future extreme events and allow adaptation; 3) Day to day values for small rain events: enhancing the value provided by options, awareness, acceptance and participation amongst stakeholders. Attention is paid to the way urban space is used and perceived.

The results of the three points approach are multifunctional solutions and opportunities for consensus in a decision-making process involving different stakeholders (Frantini et al. 2012). On a practical

level, the implementation of 3PA would mean that the potential benefits of the stormwater management are emphasized when dealing with design storms or smaller rain events. The management of extreme events should be integrated into urban planning projects, such as redevelopment of an area, with an emphasis on damage control and multifunctional infrastructure (Digman et al. 2014).

In Scandinavia, the cities of Malmö in Sweden and Copenhagen in Denmark are the leading cities implementing the integrated stormwater management approach. Despite similar climate conditions, the two cities have chosen different approaches towards stormwater management (Haghighatafshar et al. 2014). In Malmö, since the early 1990s, there has been a shift towards open solutions in stormwater management. The main objectives of the SUDS are to decrease and slow down the runoff flow in the urban areas ensuring that the existing piping network does not become overloaded (Stahre 2008, 14). SUDS have simultaneosly been used as a tool for urban improvement, for example, in Augustenborg (a local suburb).

Copenhagen, on the other hand, does not have a long history in SUDS, but due to intensive flooding in 2011, stormwater management is presently considered to be one of their priorities in urban planning (Haghighatafshar et al. 2014). The city has a new Cloudburst Management Plan (City of Copenhagen 2012), which proposes that public surfaces, such as parks, sport fields and open spaces, be used for temporary storage of stormwater during a heavy rain event. Flood protection of the city center is further emphasized by proposing additional measures, such as especial stormwater streets, waterways and underground tunnels, which could effectively lead stormwater to the sea and simultaneosly increase local greenery. Therefore, with 3PA in mind, Copenhagen has focused during the last few years on solving the problems associated with extreme rain, while design rain and local green infrastructure have been more underlined in Malmö (Haghighatafshar et al. 2014).

The examples from Copenhagen and Malmö show the means by which SUDS are successfully used as local solutions, which can be combined with conventional techniques and retrofitted into existing drainage systems. Furthermore, they underline the ways in which a classically engineered piping system promoting efficient drainage offers a technocratic solution that diminishes our understanding of and connection with nature (Winz et al. 2011). By contrast, SUDS combine drainage functions and vegetation, and their role can be expanded from solely stormwater management to cover ecological targets and built environment services, such as identity or amenity. Furthermore, SUDS could potentially form a novel link between ecological, social and technical realms, thus creating a complex social-ecological system (Hoang and Fenner 2016; Flynn and Davidson 2016; Dunn et al 2017) where the different benefits of a total urban water cycle are included.

This kind of system approach considers draining functions together with flood protection, public health protection, environmental protection, amenity and recreation, carbon neutrality, economic development, equity and long-term sustainability, thus enlarging the traditional scope of engineered solutions (Wong and Brown 2009). Thus, optimal outcomes in urban stormwater management will only be achieved if the dynamics of climate, land use, ecosystems and society can all be considered, because the interactions between the components of the urban water cycle are as important as the individual components (Fletcher et al. 2013). This leads to the requirement to develop new types of working models and collaboration. Urban stormwater management is an inevitably complex issue requiring an integrated, transdisciplinary approach and systems thinking.

3. METHODOLOGY

The data was collected in a workshop organized on April 26, 2017 in the City of Helsinki Environment Centre. The workshop was organized to support the updating process of the existing stormwater strategy for the city of Helsinki into an integrated stormwater management program. Twenty-one participants representing all technical departments of municipal administration attended the workshop. These included the Public Works Department, Environment Center, City Planning Department, Real Estate Department and Building Inspection Department (due to the organizational rearrangements these departments were renamed in the beginning of June 2017). Other participants included the City Executive Office, Helsinki Region Environmental Services Authority, and Aalto University. All participants deal with stormwater issues in their daily work.

Updating the stormwater strategy to an integrated program is part of the iWater – Integrated Storm Water Management project, which is financed by the EU Interreg Central Baltic program. A particular municipal stormwater group consisting of 11 members from the key technical departments within the city is responsible for the updating process, and it has outlined tentative goals for the new integrated stormwater program based on an earlier survey of the departments and organizations present

in the workshop (except Aalto University), the draft for the city's new strategy program (2017-2021) and the City of Helsinki Climate Adaptation Guidelines (2017-2021). The aim of the workshop was to inform various stakeholders within the city about the ongoing updating process and suggested tentative goals, while simultaneously discussing different needs and potential actions for the new program.

In the beginning of the workshop, the aim and schedule of the workshop were introduced to the participants. Then the participants were randomly divided into four small groups (1, 2, 3, and 4), thus ensuring that participants from the same department were not in the same group. Large paper charts were handed to every group (Figure 1). On the charts, the starting circle was drawn on the left side and the goals listed on the right. Between the starting circle and each goal a timeline was drawn. The first task of the participants was to list actions for achieving each of the goals and to add them in chronological order to the timeline with Post-it notes. Responsible bodies for the proposed actions were also added. Thereafter, two groups joined together presenting their own timelines to each other and identifying potential larger concepts. Finally, the identified concepts were prioritized.

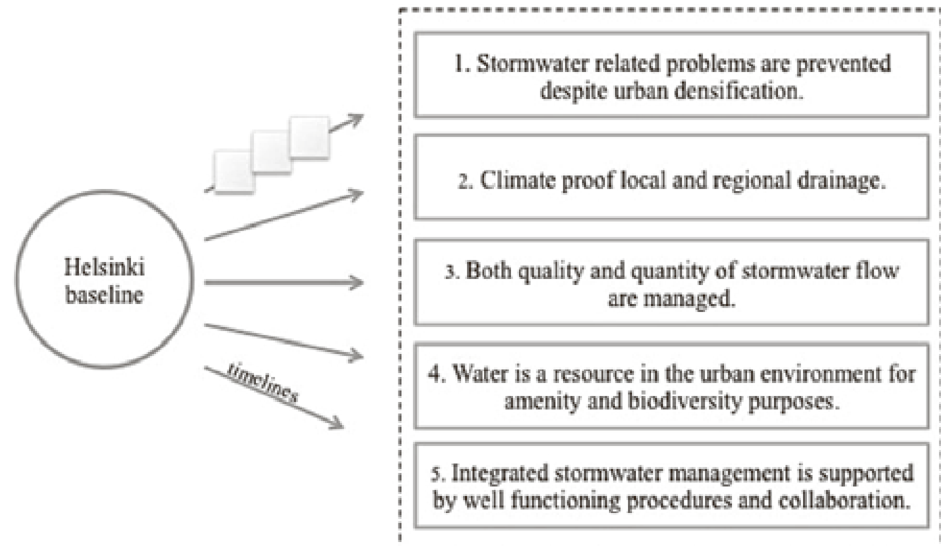

Figure 1: Image of the paper charts used in the workshop. The baseline situation is located on the left side and goals for the new strategy on the right. Participants were asked to add Post-it notes with proposed actions to the timelines drawn from the baseline to each of the goals.

The workshop lasted four hours including a 10-minute break for refreshments. Groups had a chairperson responsible for leading the discussion and ensuring that all the goals were handled. The discussions were lively with all able to contribute due to the small size of the groups. The workshop format helped to reflect on the aspirations and comparative knowledge of different participant groups. Researchers were among the members of two of the groups, but they refrained from consciously leading the discussion towards any specific direction or outcome. Discussions in each group during the filling of the paper charts were recorded and later transcribed. Participants also knew that discussions were being recorded. The data was analyzed to reveal distinctive themes that helped to identify the barriers for implementation of the integrated stormwater management.

4. RESULTS

4.1. Barriers identified by the participants

The participants were relatively familiar with the tentative goals of the integrated stormwater program. The discussion proceeded smoothly without misunderstandings or disagreements. This is not surprising, because goals 1-4 are the same in the earlier stormwater strategy and well known among those working with stormwater issues. The participants also shared the common understanding that stormwater runoff should be managed to achieve maximum benefits in the urban environment. Recreation possibilities and environmental benefits, such as biodiversity, were highlighted in several discussions.

Participants were able to recognize several barriers to effective stormwater management. The principal problem mentioned was the lack of knowledge on two levels:

1) On a technical design level, participants asked for recommendable Finnish examples of SUDS. Furthermore, a watershed-scale approach was lacking and stormwater management was only considered when entering the detail-planning phase. The need for an easily accessible database with technical information was mentioned several times. The database could show potential flood risk areas, as well as suitable places for stormwater detention and infiltration on a watershed scale. This would help planners to understand the effect of local urban densification projects on larger watershed hydrology.

2) On an administrative level, many knowledge related barriers were identified. It became apparent from several discussions that different stakeholders, such as planners, building supervisors, decision makers, developers, contractors or maintainers, do not share mutual skills and understanding. A good example here is a short discussion about the management priority order:

"I bet that if you go and ask developers about the priority order, they won't have a clue."
"But not all the planners will have one either."

Knowledge-sharing and management between different authorities and municipal organizations were seen to be problematic. Together with the general lack of roles and responsibilities, it hinders implementation of any existing strategy. Furthermore, the lack of indicators and monitoring was mentioned because it does not allow any feedback from accomplished actions.

The participants experienced that existing conventional practices and "the way things are done" are hard to change. Even the terminology related to a new approach can be challenging as revealed by a discussion about "natural stormwater management" (as SUDS is referred to in Finnish) and associated interrelations between the natural and technical systems:

"Which kinds of changes are required in our existing operational environment?"
"A change in attitude. It is a common thing to think that we don't want those puddles and ponds here."
"And terminology can be a bit difficult. Such as natural stormwater management, which creates stereotypically a vision of some sort of ditch in the brush and that is not wanted in an urban environment. We need more awareness, so that even if we carry out natural management, the solution doesn't necessarily need to imitate natural aesthetics. Natural processes can be integrated into a very urban context with compatible structures."

4.2. Additional uncovered barriers

Although participants independently named many hindering factors, there are two types of barriers that were not discussed, but which rose out of the recorded discourse. First of all, the terminology and functionality of different SUDS components are only vaguely known. Secondly, understanding about potential stakeholders is limited.

Although the goals of the stormwater strategy were familiar to the participants, the details of practical management and functionality of different SUDS components were not well understood. For example, as a method to decrease urban runoff, stormwater infiltration and permeable surfaces were mentioned much more often than detention structures; if infiltration were impossible because of the soil type, controlled conveyance was mentioned as an option. Furthermore, the participants did not necessarily possess the correct terminology as the following discussion concerning urban management options shows:

"I was thinking about those very small scale structures that could fit densely built areas. Like the ones they have in Malmö, in schoolyards and also on the streetscape, these built concrete channels with vegetation integrated. Or, how do you call them, the containers or such, which are located underground."
"Yes, geocellular storage tanks."
"Yes. And also utilization of roofs and facades. These should be known and used, and our basic operating model should be based on these kinds of solutions."

The concept of treatment train was not used in the discussion, which might be explained by the lack of practical knowledge. Different SUDS components were seen to be more alternative than complementary to each other. The participants had some understanding that components can create larger systems, but practical knowledge was not strongly evident. However, participants were themselves conscious of this barrier as the following discussion concerning the third goal reveals:

"I have listed some very general and nonspecific principles here. In general, we should use more intensively green structures and infiltration, and question the use of pipe drainage. Especially in the upper parts of the watershed, like, do we need to put water in the pipes every time? These measures are related to the implementation of the priority order. However, I haven't added who does it, or how it is done, or what is the practical action."
"Yes, these are very important issues. And it is very difficult to take it a step further. Like what would be the elaborated solution."
"Yes, (it is difficult) to name who does what."

3PA and differences in management actions between regular rain events and extreme rains were discussed in two groups. While it is well understood that the climate change will probably increase the need for flood risk management, the means to handle the extreme event management, the ways it differs from management of design rains or should be considered as part of spatial planning are not known in detail. Only one participant proposed especial multifunctional structures, where flooding could be allowed temporarily with the site being possibly used for other purposes at other times. A more common approach to the effects of climate change is better conveyance:

"We need to fix our stormwater drainage system"
"Does that mean reconsidering dimensions or what?"
"Well, that is quite difficult to say."
"But it doesn't help at all to make larger pipes on the source, water would only flow faster to the end of the pipe. We would need more sustainable drainage systems."
"Water detention maybe."
"Or we would need some sort of backup routes for excess water."
"Flooding routes."
"Yes, that's it. Flooding routes."

As a second uncovered barrier, the recognition of possible stakeholders is still limited. In Helsinki, the organizational structure of the municipal administration was reformed at the beginning of June 2017. Previous departments and municipal enterprises were reorganized into administrative sectors according to their functions. During the workshop, the organizational reform was under preparation and the participants firmly believed that the new organizational structure will solve problems related to collaboration and knowledge sharing between different actors in stormwater management.

However, the creation of strong integrated stormwater management practices requires acceptance from a wide range of stakeholders, including some not traditionally interested in drainage matters, such as the health or education authorities (Ashley et al 2015). These groups were not mentioned in the workshop discussions, although they are part of it, such as the city's climate change adaptation workgroup, because participants only concentrated on the planning and building sector operators. It is also a common understanding among participants that the value of benefits delivered by SUDS is targeted only to direct stakeholders, such as the maintenance side. In the following discussion concerning possible pilot structures, the monetary value of potential ecosystem services (such as health benefits) is not mentioned, but only the value of the collected water itself is recognized:

"If we were able to do pilot structures and people would see the benefits, the appreciation would follow. And it would be easier to build the next one, even if it was a bit more expensive."
"Yes. When thinking about investing costs and maintenance costs (of SUDS components), how are they related? I'm not familiar with this at all."
"It is a bit tricky, because a constructor is not normally responsible for maintenance. It doesn't matter to them if the solution is better or cheaper in the long run. They only go for something new if they are forced to do so."
"That is the reason why we should emphasize piloting, when we are developing public open spaces. In the maintenance phase, the saving could be the possibility to utilize water in irrigation. "
"Yes. Should you add the irrigation in the potential benefits here on the paper?"

5. DISCUSSION

The civil servants and experts of the city of Helsinki participating in the stormwater workshop mentioned relevant barriers to the implementation of the integrated stormwater program, such as a lack of knowledge, lack of native pilot projects and attitude challenges related to conventional practices. Based on the discourse, additional barriers were identified, such as a vague use of terminology, lack of understanding of the details of practical management or the functionality of different SUDS components. The results can be viewed in the light of SUDS presenting a new approach that will widen the previously technocratic traditional drainage system into a more complex social-ecological system combining not only urban hydrology, but also potential ecological and sociological benefits through ecosystem services (Flynn and Davidson 2016; Winz et al. 2011). In the past, water managers have often reduced this complexity by focusing on optimizing singular parts of the water cycle, such as piping drainage in isolation, without considering other dimensions of the total urban water cycle (Wong and Brown 2009). The results from the workshop in Helsinki reflect the challenges confronted when enlarging the scope from simple technical solutions to a more complex system.

Many examples show that integration of natural approaches for conveying and treating stormwater runoff in an urban environment has been difficult because existing routines, infrastructures, institutions and cultures are persistent and highly interwoven (Brown et al. 2013). The challenge of attitudes mentioned in the workshop are a sign of path dependency, a common phenomenon in sustainability-transitions (Markard et al. 2012) where socio-institutional routines of past practices prevent the adoption of better alternatives even when they are available. Furthermore, the vague understanding of the functionality of different SUDS reveals that stormwater management is still understood as a solely technocratic issue instead of regarding the opportunities of the complete social-ecological system. In the workshop, participants suggested that SUDS should substitute piping solutions without being able to name more specifically which SUDS function (e.g. source management, conveyance and infiltration / detention) could be used. Naturally, all the planners do not need to know the technical details, but an understanding of the basic management options would help to plan and route the movement of the water through built structures.

Since water in urban planning has traditionally been regarded as a one-dimensional element that needs to be removed from the urban space, it is demanding to comprehend SUDS as a multifunctional interface

between the technological, social and ecological structures. It requires new skills and further research (Flynn and Davidson 2016) to consider the best approach to match the demands of an ecosystem service of a unique planning site with the potential ecosystem service provision of a combination of SUDS components. However, this approach could be highly rewarding from an urban design point of view. If the functionality and potential benefits of SUDS are correctly understood, it is possible to create comprehensive treatment trains that have high amenity, recreational, identity and ecological values (Haase 2015).

As social-ecological system interactions, multifunctionality and the value of SUDS related benefits (mainly ecosystem services) are still not completely understood, it can be hard to justify SUDS related investments. Moreover, this limits recognition of possible stakeholders. For example, if the potential of health benefits, such as reduced particular pollution or encouraged outdoor activity, were internalized, the public health sector could also be identified as a potential stakeholder. In order to effectively create and implement the integrated stormwater management program, communication between different stakeholders needs to be strengthened and adaptive transdisciplinary practices developed (Ruiz et al. 2015). To advance the sustainable management of urban water, it is essential to bring together stakeholders with differing backgrounds and interests to create new understandings and relationships.

Consequently, knowledge gaps hinder an accurate consideration of the space requirements of SUDS components in land use planning processes. This is further emphasized when flood protection measures are integrated into the urban environment. Adequate spaces and routes for management of extreme rain events should be recognized and combined with other urban functions. Climate change requires new ideas for a dynamic approach (Digman et al. 2014) where a multifunctional infrastructure and shared spaces help to adapt to climate change. Indeed, climate change enhances the necessity to better link stormwater management into urban planning and design, because there is uncertainty about the quantities of surface water generated in the future (Ashley et al. 2015). In Helsinki, the existing barriers are currently hindering the creation of this linkage.

Nevertheless, the participants were able to identify two possible turning points for the development of integrated stormwater management: the need for pilot projects and new organization. Pilot projects are valuable as research literature and case studies encourage a learning-by-doing approach, where local niche innovations gradually grow into regime changes and further into new institutional structures

(Dunn et al. 2017; Brown et al. 2013). Piloting allows mutual learning and offers an opportunity to test and study solutions that fit into the local social-ecological system.

Participants possessed a strong faith in the new sector-based organization of the city of Helsinki. A new type of collaboration with different stakeholders can indeed result in overcoming knowledge-related barriers (O'Donnell et al. 2017). Earlier studies show that at the beginning of the sustainability transitions the influence of a small group of frontrunners can be remarkable in bringing the requisite skills, knowledge, influence and resources required to navigate or steer the transition pathway (Dunn et al. 2017). Nevertheless, in the acceleration phase of transition, institutional work is essential. New technologies cannot be developed in isolation, but need to be socially embedded into the local institutional context (Wong and Brown 2009).

In the end, neither a fully green nor entirely grey infrastructure approach to stormwater management will likely be optimal at any location (Winz et al. 2011). Instead, long-term solutions should be based on the best assets of both the grey and green infrastructure; in addition, the unique characteristics of a local social-ecological system dealing with urban water should be carefully considered (Flynn and Davidson 2016). When scrutinizing the development of the city of Helsinki towards more sustainable urban water management, one can detect emerging innovation processes and technologies, which have begun to destabilize the existing practices. As a successful transition into integrated stormwater management requires co-evolution between external systemic changes (such as the pressure of climate change), the activity of frontrunners, institutional development, and experiments (Dunn et al. 2017), it is critical to facilitate mutual learning, networking, diffusion and the embedding of new technologies in order to further accelerate the transition development.

The workshop also demonstrated that different organizations of the city already have active forerunners, who possess essential knowledge about new technologies and their possibilities. However, there will not be one single actor, agency or discipline that could resolve these complex urban water issues on its own (Dunn et al, 2017); instead, actors need to form networks and collaborate across departments and sectors. There is a need for new formal and informal agents and networks that strengthen linkages across systems and enable knowledge exchange (Wenn et al, 2015). In that sense, the city's internal stormwater group is already a good initiative for cross-sectorial networking. Nevertheless, there is still a need for a critical examination of the way existing planning procedures

support the formation and use of formal and informal linkages as well as creation of an adaptive administrative system.

The results of this paper are based on the single workshop event with a limited amount of participants. In order to gain a more in-depth understanding of the existing barriers to integrated stormwater management or the on-going transition process in Helsinki, the results could be used to compose a questionnaire or interview questions for a larger participant group. Especially the relation between the existing land use planning procedures and the stormwater management should be studied more carefully in order to enable the development of water-sensitive urban design practices and a deeper understanding of potential benefits delivered by an adequate use of SUDS. In addition, there might be some general policies that were not mentioned in the workshop, such as the new master plan of the city of Helsinki, or the demand for city densification that subliminally affects the way in which planners regard stormwater management.

6. CONCLUSIONS

The discussions in the workshop revealed that the civil servants and experts knew and understood well the preliminary goals of the new integrated stormwater program. However, the participants have other knowledge gaps preventing implementation of the integrated stormwater program. This lack of practical knowledge hinders the integration of stormwater management practices into land use planning, which complicates the climate change adaptation.

The purpose of an integrated stormwater program is to provide direction for future development plans and identify infrastructure needs. It was well understood among the workshop participants that a better urban environment is created if local hydrology can guide land use decisions. However, there is a lack of adequate tools to apply this principle in practice. Furthermore, a general lack of awareness is causing reluctance to change existing practices among various stakeholders.

It has been noted in this study that a desired transition to integrated stormwater management requires a systemic change from a technocratic approach to the implementation of a wider social-ecological system approach. Thus, the interrelationship of stormwater management must be considered with other sectors (such as energy, transport, health), and recognition of potential stakeholders should extend beyond city organization to other sectors, such as academia, industry, business, nongovernmental organizations, politics, and the local public. Collaboration with non-administrative actors would deliver a deeper understanding about SUDS related benefits, which in turn would help to close knowledge gaps and overcome the reluctance to support novel approaches. Changes in the existing planning procedures might be needed in order to enable extensive gross-sectorial collaboration.

In addition, it is important to understand that the five goals set as outcomes of the new integrated stormwater management program are still not the final phase. The city, its institutions and administration are engaged in a sustainability transition process where the new integrated stormwater management program is showing the direction and indicating a structural shift in the policies that govern the relationship between society and the environment. Nonetheless, work has just begun as examples of forerunner cities show that the development of a water sensitive city requires long-term and persistent action on a wide front, an adaptive approach, and a conscious building of active linkages in the new social ecological system.

* Note: The stormwater management program of the city of Helsinki was finalized during 2017 and will be sent to the city council for acceptance in 2018. Several of the identified challenges in this paper were transformed into actions listed in the program.

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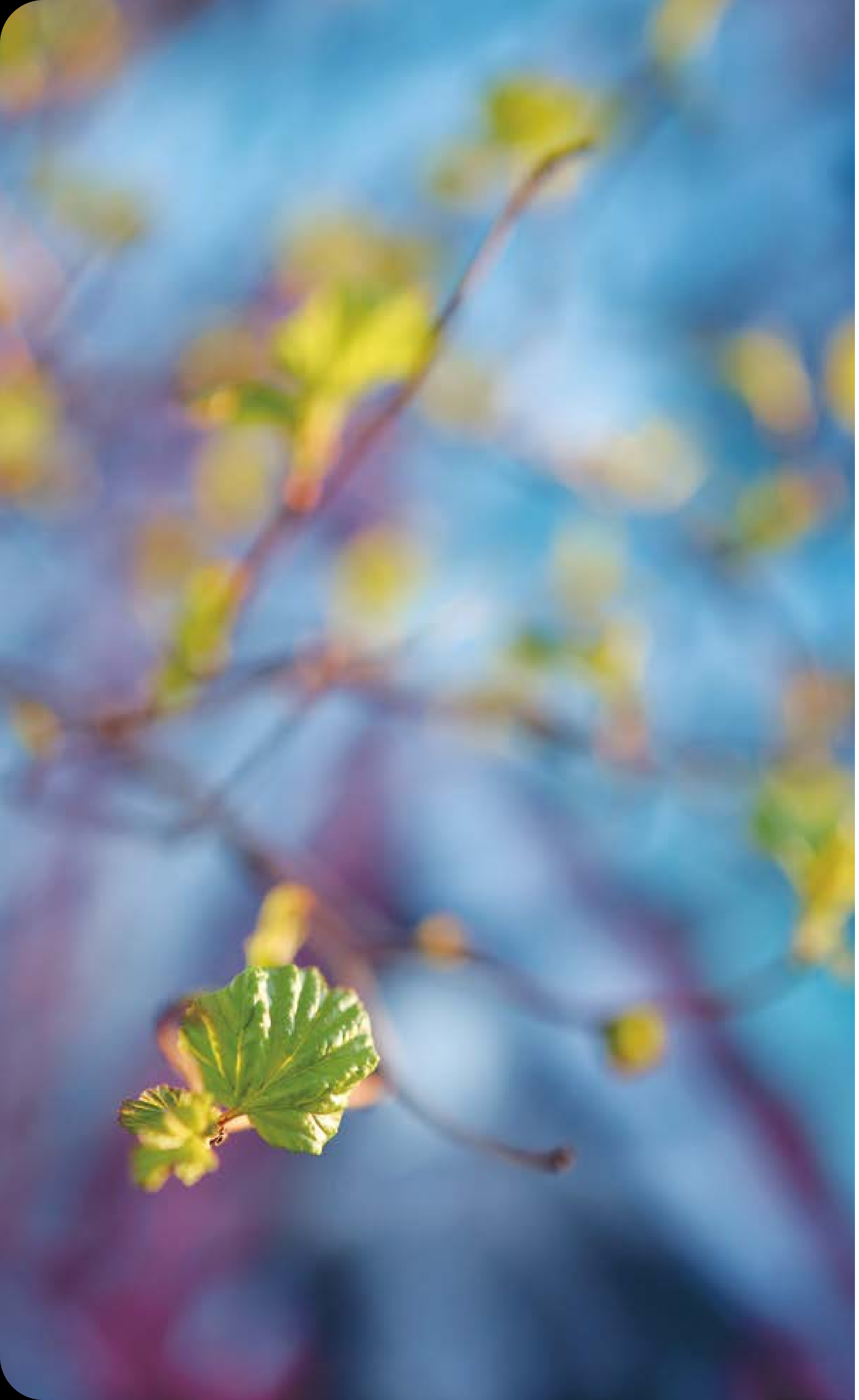

Paper 3 Riikka Tapaninaho
Elisa Lähde

MULTI-STAKEHOLDER COOPERATION FOR GREEN INFRASTRUCTURE: CREATING SUSTAINABLE VALUE

MULTI-STAKEHOLDER COOPERATION FOR GREEN INFRASTRUCTURE: CREATING SUSTAINABLE VALUE

Abstract

Purpose of this study is to analyze the design process of a new Green Infrastructure element, a stormwater wetland, and examine how collaboration and decision-making in a multi-stakeholder project happened. Realization of stormwater solution engaged several local and regional authorities and consultants representing a case where understanding and decisions about economic, social, environmental, and cultural value were required. The case study shows evidence of the ongoing transformation process of urban water management regime and current hydro-social contract both at the operational and regulative level. While progress and decision-making of the project were regarded challenging, creating a mutual understanding through open discussions and bridging the knowledge gaps of negotiating parties with the help of change agents and matter experts promoted sustainable decision-making. Transformative decisions demanded individuals to step out from their conventional field of expertise and deal with the uncertainties related to sustainability.

Key words

Multi-stakeholder Cooperation,
Sustainable Value Creation, Decision-making,
Green Infrastructure, Ecosystem Services

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RECENTLY, THERE HAS BEEN an increased interest in the examination of multistakeholder cooperation addressing sustainability and climate change challenges in various disciplines including management theory (e.g., Heikkinen, 2017; Hörisch et al, 2014; Sharma and Kearins, 2011) and urban design (e.g., Ahern & al, 2014; Lennon & al., 2016). Simultaneously, the urbanization as a megatrend has directed attention toward the well-being of humans and nature in urban environments. Especially, Green Infrastructure (GI) and ecosystem services have been acknowledged as useful approaches to contribute to human well-being as well as climate change mitigation in urban areas (Demuzere et al., 2014). While the importance of GI and ecosystem services have been acknowledged, the concepts are fairly new and still unstable (Lähde & Di Marino, 2018). More particularly, operationalizing ecosystem services and integrating the different and often irreducible values of urban ecosystem services into the decision-making within collaborative networks have proved to be challenging (e.g., Gómez-Baggethun & Barton, 2012; Lennon & Scott, 2014), remaining an under-researched area to date. Additionally, understanding better social-ecological systems (SES) and interaction of natural capital, provided ecosystem services and their impact on human wellbeing has been recognized as an important research area regarding urban sustainability and resilience (Moore & al. 2014).

The purpose of this study is to apply a multidisciplinary approach to analyzing the design process of a new GI element, a stormwater wetland, in Helsinki, Finland. In particular, the aim is to examine retrospectively how collaboration and decision-making in a setting with multiple stakeholders and value perspectives has happened. Realization of stormwater management solution engaged several local and regional authorities, consultants, and other stakeholders, resulting to intensive collaboration and negotiations about the expected outcome and its benefits. Creation of a shared understanding about multifunctionality and aimed end results among different stakeholders proved to be challenging and required mutual learning and stepping out of the traditional, organizational boundaries and responsibilities. Hence, the case represents an intriguing example of multi-stakeholder cooperation involving understanding and decisions about social, environmental, and cultural value considerations in addition to economic value. The case allows for examining interaction between social-ecological systems, hence the feedback loops between social actors and ecosystems, too.

The theoretical framework of the study is built around stakeholder theory and value creation representing organizational studies and management theory and GI and SES literature related to urban sustainability and stormwater management. With an intensive case study research, the focus is on creating a holistic understanding of the meanings in this particular case of multi-stakeholder cooperation

(Eriksson and Kovalainen, 2008). Despite the importance of a particular context, the study aims to participate in advancing multi-stakeholder cooperation related to sustainability as we are looking for methods and capabilities, which allow for developing common objectives in complex interorganizational projects and enhancing decision-making toward sustainable value creation. The case is perceived useful regarding theory, too. While the approach is more inductive than deductive, rich interpretation and understanding of the case has potential to inform theory (Dyer and Wilkins, 1991).

Stakeholder Value Creation

Interorganizational collaboration has been studied from different angles, focusing either on processes or outcomes, or both, of such efforts (see Sharma & Kearins, 2011). For this study, stakeholder theory and its main concept of value creation have been chosen to examine the process of decision-making and value creation, but also its outcomes (Freeman, 1984). Stakeholder approach has gained popularity within organizational studies to understand organizational decision-making and value creation regarding economic, social and environmental welfare. The very essence of stakeholder theory focuses on creating as much as versatile value as possible with and for all stakeholders instead of trade-offs (e.g., Freeman, 2010; Freeman et al., 2007).

Lately, stakeholder theory's applicability in sustainability management has been advanced. Hörisch et al. (2014) defined a framework, which emphasizes creation of mutual sustainability interests for different stakeholders through sustainability-based value creation for stakeholders within organizational networks, but also through education, and regulation. Recent case studies that examine multi-stakeholder networks addressing wicked socio-economic issues have have advanced theory development, too. For example, design of social interaction processes (Rühli et al., 2015), inductive identity formation (Schneider & Sachs, 2015), dynamic capabilities of sensing, interacting, learning and changing with regard to stakeholders (Dentoni et al., 2016), and using open-ended networks (Heikkinen, 2017) have been found central in sustainable value creation. Hence, stakeholder theorists have increasingly started to examine how value is created in the context of sustainability.

Green Infrastructure and Social-Ecological Systems

Green Infrastructure (GI) is understood as a network of high quality natural and semi-natural areas, which are designed and managed to deliver a wide range of ecosystem services and to protect biodiversity in both rural and urban settings (European Commission 2013). Ecosystem services are conceived as 'the benefits people obtain from ecosystems' (MA, 2005) and related to human well-being in many direct and indirect ways by providing basic commodities, and health and security benefits (Lennon & Scott, 2014). Additionally, they can enhance resilience and quality of life in cities and identify a range of economic costs and socio-cultural impacts that can derive from their loss (Gómez-Baggethun & Barton, 2013).

Through providing ecosystem services, GI can help in building resilience to the impacts of climate change, especially by implementing GI to urban water management. By doing so, significant and multiple benefits such as increased

biodiversity, a more favourable microclimate or increased amenity can be achieved with decreased costs (Ashley & al, 2013). However, the transition towards more sustainable urban water conditions is not straightforward. When environmental aspects and GI approach are added to urban water management, the hydro-social contract chances and a regime shift occurs (Brown & al., 2009). The distributions of functions and responsibilities can radically alter as new stakeholders such as environmental groups or community get involved causing potential conflict between professionals concerned with traditional values and those who are seeking to adopt new practices associated with environmental protection.

An urban water system can be understood as SES (Flynn & Davidson, 2016) that includes interaction between social institutions and norms, technical practices, and hydrological cycle in urban landscape. Water is natural capital potentially providing various ecosystem services, but also causing flooding or drought risks when amount of water is not in line with society's needs. As SES are inherently complex, consisting of links and feedbacks within and between people and nature, environmental changes such as decreasing water quality or climate change are causing changes in SES, described as regime shifts in hydro-social contract by Brown & al. (2009). SES changes can happen on the operational level altering day-to-day work and decision-making or on the regulative level, causing transformation in constitutional rules and conditions for governance (Barnes & al. 2017). The design process of the new wetland represents an operational level project, but simultaneously expresses the bigger transformation in our hydro-social contract.

PICTURE 1.
THE NEW STORM-
WATER WETLAND
IN AUGUST 2017.

Methods

CASE DESCRIPTION

The wetland design process is part of the stormwater management of a new urban development area (Keski-Pasila) close to the city centre of Helsinki. Technical pre-conditions require local stormwater infiltration, but as all stormwater cannot be handled on site, a large storm drain (1600 mm) is needed to convey surplus stormwater to Töölönlahti, an inland sea bay about 1,5 kilometer southwards. This drain is large enough to take once in 50 years' rainfall and it will be essential in preventing severe flooding in the massive underground structures of Keski-Pasila.

When overseeing the initial planning of the stormwater drain, Environment Centre was concerned of the effects of the runoff, and required a new stormwater wetland to be part of the draining system of Keski-Pasila. The receiving waterbed of Töölönlahti bay is surrounded by dense urban fabric. During the last ten years, some extensive refurbishment has been made and water quality in the bay has started to improve. As untreated surface runoff contains always some unwanted contaminants from urban functions, Environment Centre of Helsinki demanded that stormwater load coming from Keski-Pasila needs to be handled in a wetland in order to maintain the good refurbishment progress. Integration of a new GI element into the already commenced draining project required a strong intervention from Environmental Centre. However, with solid justifications in the behalf of water quality in Töölönlahti, other stakeholders understood and accepted the intervention.

When the wetland design project started, the aim was relatively clear and extensively accepted by the city authorities. Nonetheless, the design process itself was not straightforward. Helsinki Public Works Department was leading the project and City Planning Department, Environmental Centre and Helsinki Region Environmental Services Authority were the other participating actors. Also two groups of consultants were involved, hydrological engineers and landscape architects from two different companies.

The project begun with a location analysis and proceeded to concept plan creation including stormwater retaining capacity, and rough outline and structures of the wetland. In the final design phase, construction documents defining all the construction specifications of the wetland and the surroundings were prepared. The design process was finished in 2016 and the wetland park constructed in 2017. It now delivers regulating and cultural ecosystem services in the city centre with 60 new plant species, meadow habitats and purified, flowing stormwater.

METHODS OF DATA COLLECTION AND ANALYSES

The participants of each organization were contacted in 2017. Only one of the participants refused to participate, leading to an involvement of a person who had not initially been part of the project, but who represented the same organization and was familiar with the project. In total, seven interviews were conducted, five being female and two male. The age of interviewees ranged between 35 and 65. The length of semi-structured interviews varied between 35 and 92 minutes, resulting to 106 pages of transcribed material.

A thematic analysis was applied to data following an organic approach, where "coding and theme development processes are organic, exploratory and inherently subjective, involving active, creative and reflexive researcher engagement" (Braun & Clarke, 2016, p. 3). Data was transcribed and coded, themes were created based on coding and re-reading, and a thematic map was drawn. The whole analysis process was done in close cooperation between the authors. Each individual round of analysis was discussed and developed further together.

Results

The results of the study tell a story of an ongoing change toward more systemic thinking related to sustainability. The thematic analysis revealed that while progress and decision-making of the project were regarded challenging, creating a mutual understanding through open discussions and advisory consultancy concerning GI benefits were seen as the key methods to promote sustainable decision-making. Transformation of the existing practices was also dependent on the capacity of individual members of the process to act as change agents and others to step out from their conventional field of expertise.

The main results of the thematic analysis are summarized in Figure 1 and their closer descriptions in Table 1. The main theme of *Planning Framework* provide us with the context in which the planning was effectuated, highlighting the continuous negotiations what is of value between the project participants. The theme of *Capabilities* sheds light on the capabilities, competencies and roles, which were considered important for the project success. Finally, the themes around *Systemic Change* narrate the ongoing change efforts and strucle when moving toward more systemic and long-term thinking at the regulative but also at the operational level.

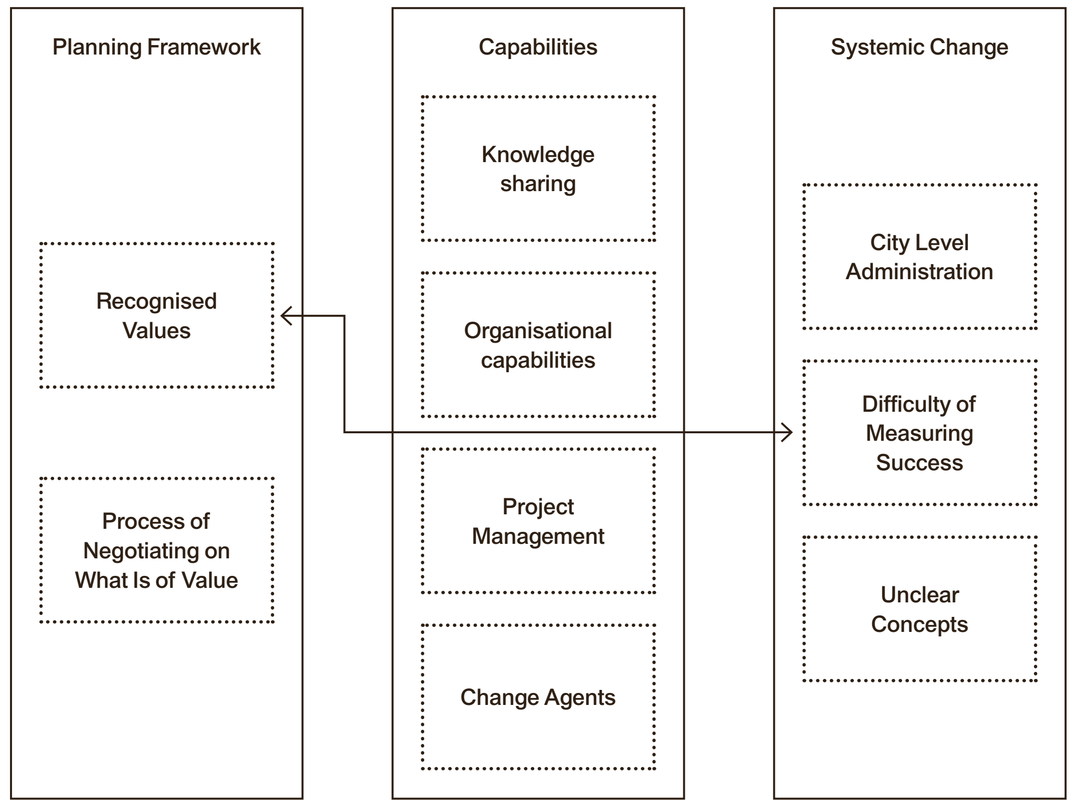

FIGURE 1.
THEMATIC MAP

Main Theme	Subtheme	Subtheme Description
Planning Framework	Recognized Values	Values or functions that set aims for the project or needed to be negotiated. Most essential was the water quality of Töölönlahti (the game changer).
	Process of value negotiations / what is of value	Due to the various values and actors involved, negotiating on what is of value was essential feature of the whole project. This discourse describes different phases of negations.
Capabilities	Organizational Capabilities	Features the project organization (or some parts of it) that helped to reach project aims. Qualities such as right kind of professional skills, ability to see the big picture, collaboration and communication skills, high interactivity.
	Knowledge Sharing	Description of importance of knowledge sharing as supporting act.
	Change Agents	Description of work or acts by individual participants of the process that had influenced in highly positive way.
	Project Management	Features of the project management that helped to reach project aims. Responsibilities such as well gathered background information, right constituencies involved in the project, programmed and well done work plan, efficient information sharing within the project and clear decision-making practices.
Systemic Change	City-Level Administration	Description of administrative framework in the city. Reflects strongly the on-going management of change. Decision making and participatory process has changed during the Vauhtitie project, and the end result would not be similar any more.
	Unclear Concepts	Named concepts that are related to green infrastructure / sustainability, but that are considered to be confusing or undefined. Nobody referred to e.g. sustainable development as one of the values regarding the wetland project itself.
	Difficulty of Measuring Success	Discourse that reveals the difficulty of integrating technical system into ecological system. Impacts of the project are hard to measure and hard to compare as they are not as straightforward as with pure technical system (e.g., with draining, the aim is to keep structure dry and the impact is easy to measure). Discourse is related to large variety of recognized values.

TABLE 1.
THEME DESCRIPTIONS

PLANNING FRAMEWORK

The design project of a stormwater wetland started a process of continuous negotiations about what is of value and to whom. The negotiations about different values can be perceived as a framework where the actual planning of stormwater solution occurred. The most important value affecting decision-making, the actual game changer, was the water quality of Töölönlahti. In historically and culturally important place in Helsinki, the potential changes in the water quality in the bay was something all negotiating parties wanted to avoid.

While the stormwater wetland primary function was seen in managing Pasila area stormwaters efficiently without affecting water quality in Töölönlahti, other values and benefits (i.e., sub-theme of Recognized Values) were recognized, too. For example, valuable trees, biodiversity, recreational services, health impacts and climate change adaptation were discussed. Within value negotiations, an engineer-technical solution was examined in relation to values of aesthetics, beauty and novelty. Value of surprise was noticeable, too. A technical solution being interesting, better and more beautiful than expected affected positively participants' opinions about the solution.

> *There will be a hard usage pressure for a small bay, and at the same time, it is an important spot for the city as well. It is landscape-historically valuable and needs to be respected. There are events organized there. It is important for people, important for politicians, it is quite a sensitive place...And then there would be some kind of an environmental problem because of decreasing water quality, that risk nobody wanted to take in the end.*
>
> *...it is something new and still ecological, it still can be beautiful...*

While various values related to the stormwater solution were recognized, the negotiations of what is of value proceeded in different phases, highlighting the agency and importance of different actors in different phases. To start with, stormwater wetland was not identified and defined as a needed solution in the beginning of the Pasila construction project. The constructions in the area had started before the city-level stormwater management strategy and programs even existed. Hence, stormwater management was not a common feature to be considered in a city planning project.

After Environmental Centre became involved in the process, the environmental aspects were drawn on the project agenda. High-level authority was listened to, and decision about the stormwater wetland was made. The design process was described to include many different opinions, but even tough negotiations and different point of views were considered important. Interviewees highlighted the need for all participants to express their opinions and to be heard. Finally, the negotiations resulted into a decision that all were able to agree on. However, forming the understanding of what is of value in the stormwater solution has continued until, and continues after, the system was built.

I think it was really good that there were different kinds of opinions, in fact, there the opinions should be and be presented. There were people completely against and absolutely for, and then people in between, there was everything on a large scale.

The main obstacles in the negotiation process were related to "working in silos" -mentality, limiting responsibilities of an actor to his or her organization's domain and ideological thinking. The responsibility questions were also linked to budgets, raising the questions how much the solution costs and who pays.

...who is responsible and who pays? If we proceed, one is responsible to a certain point and another after that. How this affects cost sharing? So, who has the responsibility and of what?

It was also found difficult to evaluate the actual costs of the solution as it required adopting a long-term perspective. Several interviewees contended that cost calculations should include life-cycle cost estimations and qualitative values in addition to one time investment costs. The interviewees felt also the pressure to balance the needs of different stakeholders that they represented as public organizations.

Project realities and recognition of possible risks affected decision-making, too. The decision was needed about the solution so that the Pasila construction project could have continued. A certain level of hurriness gave pressure to participants to come up with a decision. Additionally, the risk of not having stormwater management corresponding to today's standards started to look too a high to be taken.

Because we have that high value, this Töölönlahti, I think that the justifications helped a lot, that it was well prepared that presentation material, well justified and there was some research behind about the water quantity and the effects of water delay on water quality, and that they were read here by our collaboration and residence parties, so there were no complains, it did not raise any opposition, so there was nothing contradictory…

CAPABILITIES

Certain organizational capabilities, knowledge sharing, project management, and the role of change agents were regarded important for the project success. High emphasis was given to the the project management and project organization's capabilities. Qualities, such as right kind of professional skills, ability to see the big picture and step out of one's own domain of expertise, as well as collaboration and communication skills, were called for at the individual level. The project organization was seen to function at its best with high interactivity and free flow of information. In essence, knowledge sharing was perceived as an essential supporting act in the project decision-making.

...all approached a little each other, which was really good. What it comes to a good project, it is that all are inspired at least a little and try with a solution-oriented approach to create possibilities together and let us to proceed. So, these people did not hold on to their own opinions too tight in the end.

The participants unanimously requested for good project management and conceiving the project as part of a bigger program portfolio with its interdepecies. Especially, adequate background information, involvement of right project members, well-programmed work plan, availability of information, and clear decision-making structure and schedule were emphasized as important for a project success.

...project management skills are needed, that you can see things from everyone's perspective and solution-wise identify those interests and their weightings, how they are situated within the project, where should we aim for, what are the affecting issues and how they are taken into a consideration there.

In addition to capabilities of the project organization, the participants identified the need for change agents who are able to influence multiple value decision-making positively. The change agents affect, for example, through raising awareness and knowledge level, giving formation, and acting as neutral mediators between the negotiating parties.

SYSTEMIC CHANGE

The design project of the stormwater wetland occurred in the middle of a more profound change process at the city-level regarding stormwater management (i.e., sub-theme of City-Level Administration). The interviewees criticized the dispersed nature of city planning and decision-making, and called for management of larger entities and activities of different actors. However, the awareness of climate change adaptation and stormwater management were seen to be increasing continuously as the city-level strategies and programs had been developed and even reiterated since the construction started in Pasila area. Participants emphasized that cooperation and decision-making with regard to city- and project-level planning would not be the same anymore as the new strategies and programs had been created and were being implemented in different organizations.

… If the planning of that area started today, I believe that we would follow our stormwater program…

...that kind of evaluation was not conducted before, and it (the water drain) was put somewhere and that was enough. But it came out terribly too late now, in a phase which was too late. We need to learn from this, when stormwater planning is done or we build something larger city area, it needs to be planned well and early enough that we do not realize something too late...

Other sub-themes, which relate to systemic change, are Unclear Concepts and Difficulty of Measuring Success regarding sustainability. Despite the increased awareness of the sustainability issues, frustration was expressed about the unclarity of concepts related to sustainability, green infrastructure and ecosystem services. The interviewees asserted that there is no general acceptance nor understanding of these concepts among different actors yet. Additionally, whereas one would think of sustainable development as a guiding principle within the project, it was not used as a point of reference, but was discussed only by those interviewees whose own organizations considered it strategically important.

> *Sustainable development as a concept is very broad and everyone understands it in their own way, it is quite an abstract concept... that kind of a word monster… ecosystem services is that kind of a word, too, used when and where ever...*

The difficulty to measure the impacts of a stormwater management solution was also creating strucle to move from more traditional approach to a new one, in which technical systems are integrated to ecological systems. Whereas the effects of a purely technical solution are easy to measure, ecological systems create several uncertainties and difficulties in measuring. In essence, the impacts of a GI solution are seen to be ambiguous, difficult to predict and quantify, and lacking cause-and-effect relationships. However, the interviewees wished for a development of measurement in the area, for example, through observation and cooperation with maintenance. Difficulty of Measuring Success as a theme relates to a sub-theme of Recognized Values, too. Interviewees contended that it is difficult to identify and discuss something, which is hard to identify and measure.

> *Related to those non-material benefits, a system needs to be developed for them, how they are calculated, too. … health effects, recreational effects and landscape impacts and things, which do not have a price tag really*

> *From this perspective, we have considered to implement some kind of a follow-up there, so we could have some facts at some point — does it have any impact after all?*

Discussions

The purpose of the study was to analyze the design process of stormwater wetland and examine how collaboration and decision-making in this multi-stakeholder setting happened. Our results show that the wetland design project was relatively challenging to all stakeholders because of its novel nature. However, many capabilities, such as knowledge sharing and solid project management enabled steady progress. During the design project, it became clear that as the movement of the water does not recognise administrative boundaries, the operational collaboration and mutual learning between different administrative organizations were required for a successful end result. Especially, taking into account long-term investments and demands for new allocations

of resources and shared budgeting required intense interaction. Additionally, careful design and promotion of ecosystem services approach was required to integrate social and ecological functions in a culturally significant urban area.

In particular, the case tells a story about an ongoing systemic change, which enforced cooperating stakeholders to deal with various uncertainties and accept the constant process of learning. Additionally, the results of the study show that, as there is no general acceptance nor understanding concerning GI related concepts or prefered outcomes, success of the project remains unclear. In traditional drainage systems, the end result is easy to measure (service reliability of used technical system), but as GI is by nature multifunctional, the outcomes can be various and valued either during the implementation or long afterwards. The results hint that the regime shift in urban water management is still underway. On the regulative level, normative prioritisation of desired outcomes is still lacking, thus on operational level, univocal measurement for success does not exist either.

THEORETICAL CONTRIBUTIONS AND MANAGERIAL IMPLICATIONS

As a multidisciplinary study combining both management and urban design literatures, it confirms many previous findings on multi-stakeholder cooperation related to sustainability as well as GI and ecosystem services. Dealing with complex sustainability issues within multi-stakeholder settings has often been linked to need for broad stakeholder engagement, acceptance of different opinions without the right answers, unclear conceptions and ambiguous sustainability measurement, knowledge gaps at individual and organizational level, continuous learning, and the importance of change agents or neutral mediators (e.g., Sharma & Kearins, 2011). In particular, the case illustrated how different value perspectives were considered and discussed in the context where traditional organizational boundaries do not apply anymore. While various, unquantifiable benefits of ecosystem services have been perceived as difficult to be incorporated into decision-making (e.g., Lennon & Scott, 2014), the participating constituencies succeeded to elaborate and decide on a solution with sustainable value. Additionally, the case demonstrated how the “working in silos” -mentality with limited roles and responsibilities was diminuted as an ambitious solution was looked for.

As an example of sustainable value creation, this study especially contributes to a conceptual framework developed by Hörisch et al. (2014), who have advanced stakeholder theory’s applicability in sustainability management. First, the results of the study reinforce the interlinkages between different mechanisms, which are suggested to enhance creation of mutual sustainability interests for stakeholders. The case shows how sustainability-based value creation for stakeholders (operational level), education (operational and regulative level), and regulation (regulative level) are interconnected and needed for long-term, sustainable outcomes. Second, the case illustrates how mutual sustainability interests can be developed in practise in a multi-stakeholder setting. The results highlight the blurring organizational boundaries, which create a context where organizational agency is replaced by individual and collective efforts, and matrix project organizations and capabilities become more important. An elevated, ambitious, multifunctional end result appeared to appeal to decision-makers, showing at least some evidence of changing values at the individual, organizational and societal level. Hence, a solution without trade-offs hindered the often dominating economic, quantifiable values and brought different stakeholders with different opinions together for a sustainable agreement.

The study has managerial implications, too. First, the results give insights to decision-makers at the regulative and city-administrative level. The study shows the importance of managing and coordinating city-planning activities with a helicopter view. Implementing climate change mitigation strategies into city-planning requires systemic thinking, identifying relevant interdepencies, and acting beyond organizational responsibilities and budgets. Additionally, proper implementation of city-level strategies and programs needs to be ensured.

Second, the importance of operational level cooperation needs to be recognized as it informs regulatory processes in the long run. At the operational level, program and project management capabilities become central, especially related to solution-oriented and timely decision-making and ensuring that all relevant stakeholders have been heard. In the case of social-ecological systems, a close examination of the current and potential effects on nature, is needed, too. Third, at the individual level, actors involved in similar kind of projects need to have adequate information and competence to make decisions, and challenge their current ways of thinking.

LIMITATIONS AND FUTURE RESEARCH

An intensive case study has its limitations, especially regarding theory development. Adding similar case studies into the research setting could allow for analyzing possible regime shift occurring at different levels more thoroughly. This study could have profited also from having all relevant participants within the interview data. As a limitation to this study, one of the main actors refused to participate. Other relevant stakeholders, who did not participate in actual negotiation processes, could have been interviewed, too.

Considering the ongoing, systemic change in sustainability related projects at city-level, similar projects could be interesting research avenues to investigate how city-level strategies and programs, and regulation changes affect value creation in the future. Additionally, a longitudinal approach to this case could be applied in order to examine the phenomenon of sustainable value creation in ecological-social context in long run. A close investigation of the wetland's maintenance and its actual effects could provide us with evidence of often abstract and uncertain provision of ecosystem services.

CONCLUSIONS

The case study focused on analyzing the design process of a GI element, stormwater wetland, which was identified as an necessary construction in order to preserve the water quality in a cultural important bay area in Helsinki. The particular interest of the study was to examine how collaboration and decision-making happened in a setting, where various stakeholders participated in decision-making throughout the project. The main results describe the ongoing change toward more systemic thinking related to complex sustainability issues, in which continuous discussions and negotiations of what is of value are found to be the utmost importance. Additionally,

change agents and matter experts had clear effects on project success, bridging the knowledge gaps between the negotiating parties. Transformative decisions, on the other hand, demanded individual members of the project to step out from their conventional field of expertise and responsibilities, and to project something as abstract as potential benefits of ecosystem services.

In particular, the case study shows evidence of the ongoing transformation process of urban water management regime and current hydro-social contract that come out both on the operational and regulative level. As the transformation is occurring on the regulative level, there is emphasized need for collaborative value creation on the operational level in order to set new administrative norms and practises. Our results implicate that currently there is a lack of full consensus concerning the desired outcomes or how they are measured in the new regime. It seems that in the regime shift the new desired outcomes of the regulational level are at least partly informed by pilot projects, thus collaborative value creation happening on the operational level. In essence, the results emphasize the need for continuous, collaborative efforts in negotiating and creating common understanding of different value perspectives in the context of social-ecological systems.

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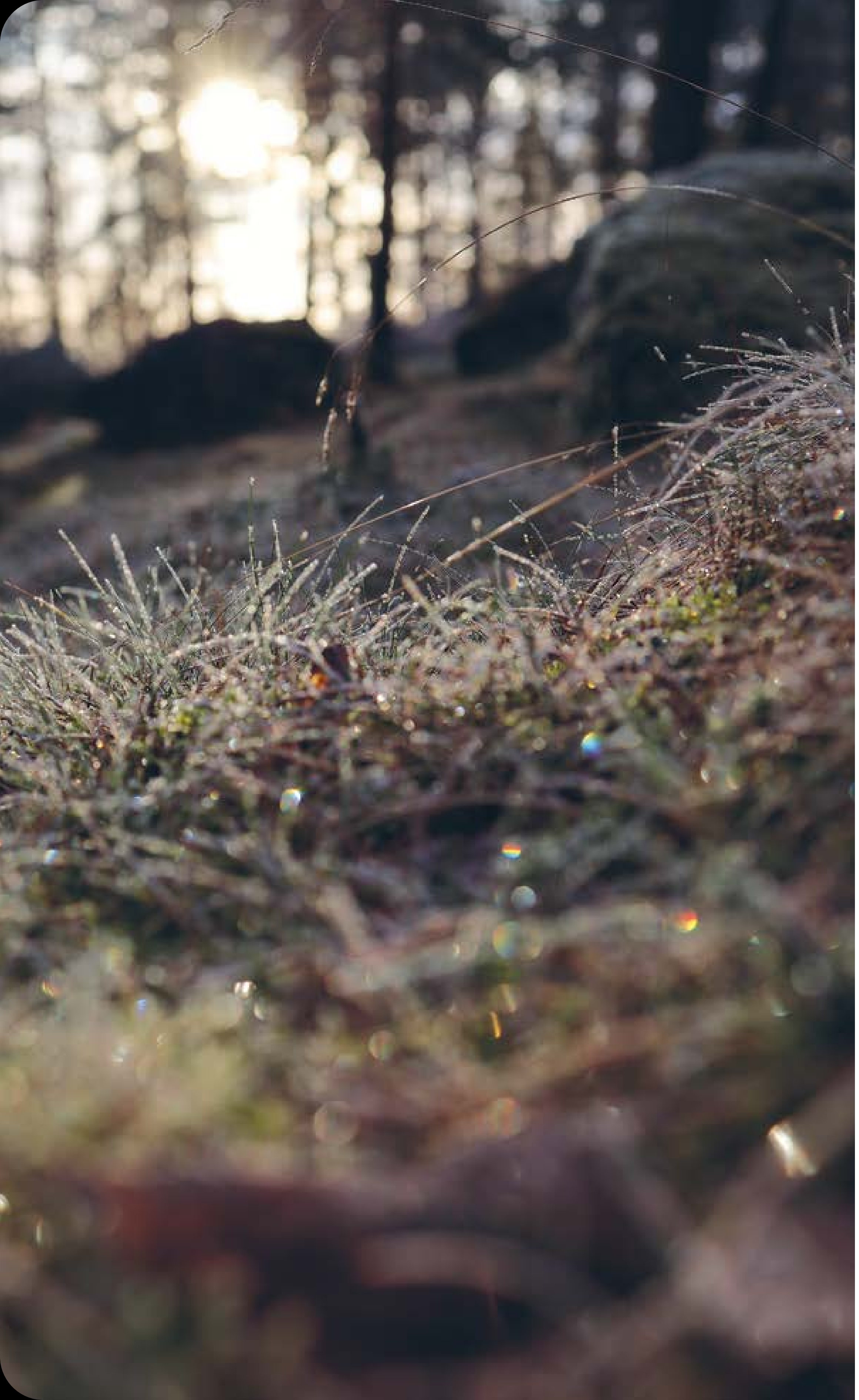

Paper 4 Elisa Lähde
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CAN WE REALLY HAVE IT ALL? — DESIGNING MULTI-FUNCTIONALITY WITH SUSTAINABLE URBAN DRAINAGE SYSTEM ELEMENTS

sustainability

MDPI

Article

Can We Really Have It All?—Designing Multifunctionality with Sustainable Urban Drainage System Elements

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Abstract: Multifunctionality is seen as one of the key benefits delivered by sustainable urban drainage systems (SUDS). It has been promoted by both scientific research and practical guidelines. However, interrelations between different benefits are vaguely defined, thus highlighting a lack of knowledge on ways they could be promoted in the actual design process. In this research, multifunctionality has been studied with the help of scenario analysis. Three stormwater scenarios involving different range of SUDS elements have been designed for the case area of Kirstinpuisto in the city of Turku, Finland. Thereafter, the alternative design scenarios have been assessed with four criteria related to multifunctionality (water quantity, water quality, amenity, and biodiversity). The results showed that multifunctionality could be analyzed in the design phase itself, and thus provided knowingly. However, assessing amenity and biodiversity values is more complex and in addition, we still lack proper methods. As the four criteria have mutual interconnections, multifunctionality should be considered during the landscape architectural design, or else we could likely lose some benefits related to multifunctionality. This reinforces emerging understanding that an interdisciplinary approach is needed to combine ecological comprehension together with the system thinking into SUDS design, locating them not as individual elements or as a part of the treatment train, but in connection with wider social ecological framework of urban landscape.

Keywords: stormwater management; multifunctionality; landscape design; water sensitive urban design (WSUD)

1. Introduction

During the last decade, with the emergence of the concept of green infrastructure (GI) and its recognition as a network of natural and semi-natural areas delivering multiple benefits [1] into urban landscape planning, multifunctionality has subsequently crystallized as a defining criterion for ascertaining the quality of this urban landscape [2–6]. As it has become desirable for the capacity of the urban landscape to expand to provide multiple benefits, multifunctionality has emerged as an aspect of great importance. This has been further enhanced by the compact city ideology promoted by agencies, such as the UN's New Urban Agenda [7]. Indeed, this compact city structure reduces opportunities for urban greenspaces and inevitably requires them to be multifunctional [8].

As the GI approach becomes adopted, there is an on-going and simultaneous transformation towards water sensitive urban design (WSUD), due to climate adaptation and water quality issues [9]. WSUD offers an alternative to sewer based urban drainage systems and covers a series of ecosystem service based approaches to urban stormwater management. Furthermore, it encourages the use of

above-ground solutions, such as rain gardens, swales, green roofs, and wetlands (i.e., technologies called sustainable urban drainage systems (SUDS)); in fact, the delivery of multiple benefits is an essential part of the approach [10]. The role of SUDS is to harvest, infiltrate, slow, store, convey, and treat runoff on site [11] to sustain the existing local hydrology.

In addition, along with direct water-related benefits, SUDS possess the potential to create synergies with other functions in urban areas. An increased amount of vegetation combined with visible water provides several ecosystem services, such as habitat provision, erosion control, microclimate regulation, recreation, and aesthetical experiences [12,13]. However, there is no precise understanding of the ways multifunctionality and a combination of benefits can be promoted with SUDS in an urban landscape, due to related research concentrating mainly on the evaluation of individual benefits [14,15]. Moreover, studies that simultaneously touch on hydrological and ecological benefits do not consider the design process, but mainly evaluate existing structures [10,15].

This paper examines opportunities to design multifunctional urban greenspaces by integrating SUDS elements into the urban landscape. The aims are to shed light on the preconditions required for the provision of different SUDS related benefits, and further discuss the ways they can be addressed in the landscape architectural design of urban greenspaces. This paper answers the question of how the multifunctionality of SUDS can be estimated during the landscape architectural design process. The results are discussed to additionally understand the relations between different criteria of multifunctional SUDS, as well as ways of consequently incorporating this understanding during the design phase.

A scenario analysis is the method chosen with the research being conducted in three phases. First, three scenarios have been created representing three different strategies of stormwater management: (1) substituting part of the pipe network with open swales, (2) adding SUDS elements that allow water detention, and (3) maximizing the amount of SUDS elements on the site. This is based on an approach that combines SUDS elements into differing treatment trains allowing the formation of a portfolio of options, which contribute to a variety of benefits [16]. The scenarios have been designed based on a case study area of the site of Kirstinpuisto in Turku, Finland; each of them is composed of a varying combination of SUDS elements to create three different treatment trains.

In the second phase, methods to measure the potentially provided benefits (stormwater quantity and quality management, amenity, and biodiversity) are studied and tested with the three scenarios. Finally, possible synergies or conflicts among different benefits are scrutinized and discussed, including the potential of the landscape architectural design process to provide multifunctional greenspaces through stormwater management.

2. Multifunctional SUDS

Multifunctionality is defined as "an integration and interaction between functions" [17] (p. 655) or as an ability of GI to "perform several functions and provide several benefits on the same spatial area" [3]. Multifunctionality is also described as the capacity of GI to provide multiple ecosystem services (ESS) [18]. In the ESS approach, benefits are commonly divided further into provisioning, regulating, and cultural ecosystem services, according to the Common International Classification for Ecosystem Services, with the understanding being that by simultaneously providing these, it could help achieve several environmental, social, and economic urban policy aims [19].

The ESS approach is closely linked to the cascade model of ecosystem services [20] stating that without correct biological structures, processes, and functions, the provision of ecosystem services is incomplete. Furthermore, the provision of services leads to human well-being and valuation of the provided services (e.g., monetary value). Hansen and Pauleit [4] have underlined that in GI approaches, the term "functions" can be confusingly used to mean the same as "services," whereas in the ESS concept, "functions" are understood as an intermediary step of the biophysical structures and processes needed to provide ESS. In this paper, "functions" and "services" are understood in line with the ESS cascade model, highlighting our dependency on well-functioning urban green elements. Such elements should be planned, designed, and managed in a way that is "sensitive to, and includes provision for, natural features and systems" [3].

Although multifunctionality is regarded as being essential and its connection to biological structures and functions is commonly recognized, the conflicts or synergies between different benefits have not been adequately studied. Meerow and Newell [21] have argued that most green infrastructure related research and planning focus only on a handful of benefits, despite a major demand for the use of GI to mediate between different and potentially conflicting demands [19]. If multifunctionality is seen as the main feature of GI, which delivers solutions to urban environmental challenges and maintains the quality of life [6], it is essential that research is the framework through which we understand the potential synergies or conflicts among its assigned benefits as well as the limitations of providing them through landscape architectural design.

More specifically, urban planning and design outline facilities for urban multifunctionality. In the context of a green infrastructure, it means the integration of systems supporting vegetation growth, such as water, vegetation, or carbon cycles. However, the operationalization of multifunctionality in planning [4,22] and practical examples are still lacking in GI planning and design.

CIRIA, a well-known and respected British forum for water sector industry improvement, has defined the multifunctionality of SUDS. In its guidelines [11], CIRIA has provided four criteria for the design of SUDS—water quantity, water quality, amenity, and biodiversity (Figure 1). Despite these guidelines, the design, implementation, and maintenance of SUDS often emphasize drainage functions over its additional benefits [16,23]. Moreover, when measuring SUDS multifunctionality, a mostly natural sciences approach has been utilized to explore and enumerate the provision of quantity and quality management; in addition, amenity and biodiversity provision have been less well researched [12,14,15,24]. Thus, the authentication of multifunctionality with SUDS in landscape architectural design of urban greenspaces still lacks precise indicators. In this study, the design criteria provided by the aforementioned C753 SUDS Manual [11] are utilized as a framework to define the multifunctionality of SUDS solutions.

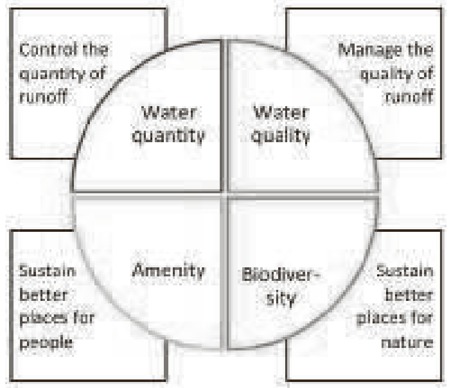

Figure 1. According to CIRIA [11] multifunctionality of sustainable urban drainage systems (SUDS) based on the simultaneous existence of four criteria; quality and quantity control, biodiversity, and amenity. However, any mutual interconnections are not presented (figure adapted from CIRIA [11]).

SUDS are inherently multifunctional structures if the criteria are considered sufficiently early on and are fully integrated into the urban design [11]. In the following section, each of the criteria is shortly introduced together with an understanding of the ways they can be promoted through design. Additionally, the four criteria provided by SUDS are not independent of each other [14,15,25]; thus, mutual interconnections are also clarified.

Being part of the drainage network, the primary function of SUDS is to control water quantity [13] to prevent both flooding on-site and in downstream areas. Additionally, on-site water quantity management helps to preserve the natural hydrological functions of a catchment. We are aware that different SUDS elements possess a varying effectiveness to perform run-off regulation [26]; for example,

bioretention cells infiltrate water and slow down surface flow together with vegetation that additionally intercepts and evaporates water [27]. In the design process, varying SUDS elements can be chosen and combined depending on the qualities of the site; for example, if there is an abundance of space available, aboveground elements can be used, but if the urban structure is very dense, green roofs might be needed. Furthermore, both the location in the watershed and runoff coefficient affect the amount of stormwater, which then specify dimensioning of elements and choice of vegetation.

On-site water quality management safeguards water quality in the receiving surface waters and ground waters. This impacts the living conditions of a variety of water-related flora and fauna as well as the wellbeing of local residents. The overall impact of a site on water quality is dependent on types of pollutants, the peak flow pollutant concentrations, and the total pollutant load in the runoff [11].

SUDS elements provide water quality improvements by reducing sediment and contaminants from runoff either through settlement or biological breakdown of pollutants. Multiple plant-related mechanisms, such as phytoextraction and phytodegradation [27], are important for biological treatment and pollutant removal. Again, different SUDS have different impacts; i.e., bioretention cells are effective in filtration, sedimentation, adsorption, and plant uptake [28], while extensive green roofs have a varying ability to retain pollutants depending on the season, substrate type, event size, and rainfall regime [29,30]. If the functions of different SUDS are known, it is possible to match the right SUDS elements to meet local stormwater quality management needs in the design process.

Amenity is related to the attractiveness of the site and the provision of recreation and leisure services [12]. Echols and Pennypacker [31] have listed amenity goals as being education, recreation, safety, public relations, and aesthetics. Furthermore, visible water and SUDS increase the amenity of urban green areas [32]. The amenity values experienced in existing urban greenspaces can be measured by scoring systems [13] or by investigating public perception (i.e., with questionnaires, such as those conducted by Bastien et al. [33]). During the design process, amenity values are challenging to measure, but opportunities for recreation, education, and human contact with nature, can be maximized by enhancing ease of public access and social interaction.

In addition, increased biodiversity affects perceived amenity in positive ways [12,34]; hence, SUDS with vegetation potentially adds amenity values. These values are increased by using above-ground SUDS and linking stormwater management to other functions in urban landscape [32]. Thus, already in the design phase, the proximity of SUDS elements to other structures, such as pathways, urban squares, and residential buildings allowing interplay with water, can actualize amenity values.

Biodiversity supports human wellbeing in various direct and indirect ways as biophysical structures, including functions related to biodiversity, are essential for ecosystem service provision [35]. Urban biodiversity relies on urban greenspaces in which human activities affect ecological processes [36]. In urban conditions, the land use changes, and the transformation of technical and social infrastructures as well as management practices can cause a loss of biodiversity [37].

Furthermore, biodiversity is based on ecological processes including decomposition, nutrient cycling, and fluxes of nutrients and energy [38], in which the hydrological cycle and water availability are essential features. Thus, SUDS contribute positively to local biodiversity [14,39], but for vegetation, it is a risk to consider SUDS only as a part of urban drainage systems. SUDS with vegetation, as with any biophysical structure, require physical inputs of nutrients and water to provide ecological functions [16]. Habitat heterogeneity, biomass production, and biodiversity benefit from the storing and infiltration of rainwater into the soil, instead of turning it into surface flow [15,38,40,41].

Similar to amenity values, there are ways of measuring the biodiversity of existing greenspaces [32,33,42]. In the landscape architectural design process, conditions for biodiversity are created through the vegetation and microbiology of soils; in this way, the implemented design later provides a platform for animal diversity. However, in the design phase, it is difficult to measure future level of biodiversity as it depends on factors, such as the level of maintenance and scale of ecological succession once the design has been realized [43]. Nevertheless, there are some factors that support development of local biodiversity and could be enhanced in design. Structural habitat heterogeneity that is created by abiotic and biotic components of SUDS solution is associated with a high degree of biological diversity, and can already be used as a proxy for biodiversity [39] in the design phase. Furthermore, biodiversity correlates with the size of the habitat, edge effect and connectivity of habitats [2,42]. When emphasizing the biodiversity aspect of SUDS elements, it is important to relate them to neighboring habitats and the larger ecological network.

3. Case Study and Methodology

This section introduces the case site of Kirstinpuisto and three stormwater management scenarios, as well as presents the methodology used to assess water quantity and quality by modeling. It is followed by the presentation and testing of two new assessment methods for amenity and biodiversity values. The results are shared in Section 4.

3.1. Kirstinpuisto Site and the Scenarios

In order to assess the multifunctionality of different treatment trains combined from SUDS elements, three scenarios were created. Each of the scenarios includes a different composition of the SUDS elements, designed together in the context of the Kirstinpuisto site. The site is part of a large brownfield area close to the harbor of Turku that will be gradually transformed into a highly dense residential site. A detailed plan is underway (Figure 2).

The planning principles of Kirstinpuisto, 14 ha, are to create a lively neighborhood with good cycling and pedestrian connections to the city center. Most of the existing land uses will be transformed except for some land uses in the southern corner of the site. A thirty-five meters wide park forms the central axis through the site and four to six storied residential buildings will be built adjacent to the park. Traffic moves along two main streets, which intersect in the middle of the site. The main urban square is located by this intersection. On the streets, the pedestrian traffic is separated from the cars by green strips. The northwest corner of the site is left for parking and recreation.

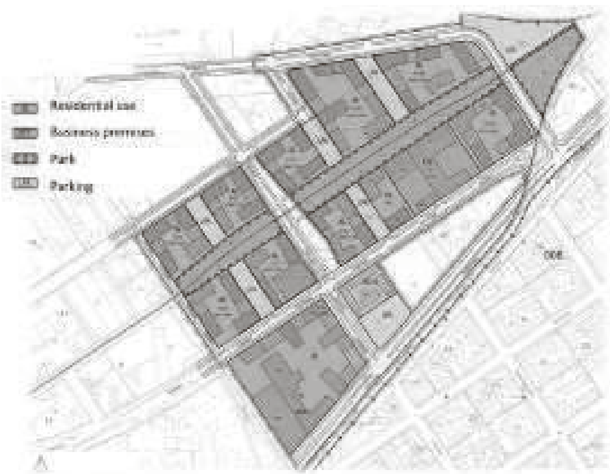

Figure 2. Detail plan draft of Kirstinpuisto site (figure adapted from the City of Turku).

The site has an existing drainage network, which will remain to be used in future, thus including it as part of the scenarios studied. The existing drainage network has had stormwater flooding issues in the past primarily due to the shortage of the existing drainage capacity. The aim of the scenarios is to create an alternative hybrid model utilizing the SUDS approach to substitute for the existing and malfunctioning drainage network.

The soil type on the site is clay, potentially rendering infiltration an ineffective stormwater management strategy; nevertheless, storing water would allow for some infiltration into the soil.

The site is ideal for the study, because the general aim is to turn former brownfield sites from industrial use into residential areas; therefore, some new urban greenspaces need to be created in this conversion for residential use.

To increase the knowledge base concerning the green infrastructure solutions among local authorities as well as to gather understanding of local interest towards the site, an ESS workshop was held in August 2016 with city planners. The aim of the workshop was to familiarize participants with the concept of ESS and discern local demand. As a result of the workshop, five aspects rose to the fore: (1) the creation of a recreational and restorative living environment is important for future residents; (2) stormwater quality and quantity management are both essential on the site; (3) innovative green infrastructure solutions can help to create new identity to former brownfield area; (4) a diverse urban green will safeguard important regulating services, such as microclimate regulation, habitat provision, and pollution control; and (5) all previous goals can be achieved with a multifunctional and connected green structure. Based on these five points, three scenarios were designed to supplement the plan of Kirstinpuisto, which indicates the location of building masses and street network.

The scenarios have been designed to be realistic concerning the planned urban functions and Finnish building regulations. However, the space requirements and design of the SUDS elements have retained a rather simple and formal level for modeling purposes. The three scenarios (presented in Tables 1–3) have been entitled *RUN* (supplementing the existing pipe network on streets and in the central park with open swales), *NORM* (adding SUDS elements that allow water detention especially on residential yards), and *MAX* (maximizing the amount of SUDS elements everywhere—in the central park, residential yards, parking areas, and close to business premises).

Scenarios have been designed on top of each other, thus retaining the main features from the previous one(s). Available space and building regulations concerning features, such as emergency services access, have set the boundary conditions for the location and dimensioning of SUDS elements. Left over space outside SUDS elements is assumed to be asphalt or other hard surface expect in the park, in which it is assumed to be lawn with random singular trees. In order to estimate the fulfilment of the four criteria of multifunctionality in the scenarios, each of them were estimated in four different ways presented in the following sub-section.

Table 1. Description of RUN (supplementing the existing pipe network on streets and in the central park with open swales) scenario.

Scenario	Intent	Range of SUDS	Area (ha)
RUN	Selection of the SUDS elementes is based on the main objectiv: to delay and conduct water away from the site through above-ground vegetated structures and a supplementing pipe drainage network. Additionally, there are rain gardens to promote on-site treatment.	Vegetated swales	0.6
		Rain gardens	0.6
		SUDS Total	1.2

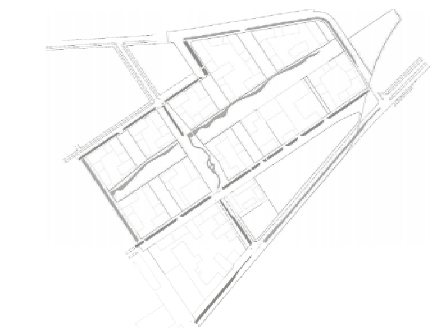

Table 2. Description of NORM (adding SUDS elements that allow water detention especially on residential yards) scenario.

Scenario	Intent	Range of SUDS	Area (ha)
NORM	Scenario is an upgrade of RUN. It utilises a multiple SUDS approach and additional SUDS are selected based on their ability for local detention, without compromising other urban functions, such as traffic connections and recreation. Bioretention cells are constructed in the yards for stormwater treatment and paved parking lots are replaced with permeable pavement. Use of SUDS is limited to prevailing conventions of the city of Turku; for example, green roofs are only integrated into one-storey buildings.	Vegetated swales	0.6
		Rain gardens	0.9
		Green roofs	0.4
		Bioretention cell	0.1
		Permable pavements	1.3
		SUDS Total	3.3

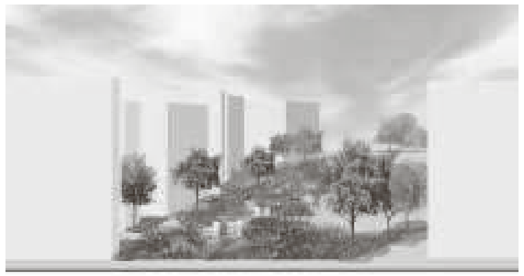

Table 3. Description of MAX (maximizing the amount of SUDS elements everywhere—in the central park, residential yards, parking areas, and close to business premises) scenario.

Scenario	Intent	Range of SUDS	Area (ha)
MAX	Scenario is an ambitious upgrade of RUN. The amount of SUDS elements have been maximised and selected based on their ability to store and infiltrate stormwater: all roofs are green and all yards and parking lots are covered with permeable surfaces or extended rain gardens. The internal park area is fully utilised for stomrwater management.	Vegetated swales	0.6
		Rain gardens	1.8
		Green roofs	3.3
		Permable pavements	3.3
		SUDS Total	9.0

3.2. Water Quantity and Quality Assessment through Modeling

This study models the current state and the three designed SUDS scenarios using the stormwater management model (SWMM) (EPA, Washington, DC, USA [44]) to assess the impact of SUDS on water quantity and quality. SWMM [44–49] is a widely used tool for single event and long-term simulations of different water balance components, such as surface runoff, flood volume, discharge, and losses in urban areas. Losses refer to water lost from the system in the form of evaporation and infiltration. The SWMM model was first parameterized for the case study area in its current state, with the model subsequently being calibrated against two rainfall-runoff events (SC1 and SC2) and validated against one rainfall-runoff event (SV1) measured on-site between October 2017 and January 2018 [50]. The performance of the SWMM model was evaluated using the Nash-Sutcliffe efficiency (*NSE*) [51]. The calibrated model was then applied to the three SUDS scenarios presented in Tables 4 and 5 using SUDS parameters adopted from studies conducted in Finland [50].

The effects of SUDS scenarios on water quantity were studied for a seven-month period (E1) consisting of an extreme event during summer (E2) and an intense event after summer (E3). Rainfall data for E1, E2, and E3 are available from a station operated by the City of Turku (Table 4). The station is located about 5 km away from the case study area.

An adaptive neuro-fuzzy inference system (ANFIS) is a fuzzy inference system formulated with a learning algorithm [52]. Proposed by [53], ANFIS is based on the first-order Sugeno fuzzy model. In this study, the five water quality input variables (Table 5) were first clustered by the fuzzy c-means clustering algorithm to place them into different classes. The fuzzy c-means clustering allows a set of data to belong to one or two classes. ANFIS was utilized by defining the Sugeno reasoning and a number of rules to develop a prediction model for turbidity by using these classes. The Sugeno model utilizes “if then” rules to produce an output for each rule. ANFIS uses the input and output variables to construct a FIS whose membership function (generalized bell) parameters are tuned using a back propagation algorithm [52]. Thus, the FIS can learn from the training data (AT1). The measured four input variables and one output variable were used to train (AT1, Table 4) and test (AT2, Table 4) the ANFIS model. The ANFIS model consists of five blocks [52]:

1. A rule base containing a number of if-then rules.
2. A database which defines the membership function.
3. A decision-making interface that operates the given rules.
4. A fuzzification interface that converts the crisp inputs into “degree of match” with the linguistic values, such as high or low.
5. A defuzzification interface that reconverts to a crisp output.

The input variables for the ANFIS model were the 10-minutely rainfall, discharge, temperature, and electrical conductivity with the output variable being turbidity measured continuously on-site from November 2017 to January 2018 by Luode Consulting (Table 5). The rainfall was measured with a Vaisala Rain gauge, discharge was measured with an acoustic StarFlow sensor, and water quality variables measured continuously with an YSI multiparameter sensor placed in the same manhole with the flow sensor. In addition, 16 grab samples from the study site and surrounding areas representing different land uses including forest, railway station, and brownfield areas were collected. From the samples turbidity, total suspended solids (TSS) and metals, chromium (Cr), copper (Cu), lead (Pb), zinc (Zn) were analyzed in the laboratory. The performance of the ANFIS model was evaluated using the coefficient of determination (R^2) and the Nash–Sutcliffe efficiency (NSE). The rainfall data available for event AT1 was used to simulate the discharge output for the current and three SUDS scenarios with the calibrated SWMM model [50]. Subsequently, the trained and tested ANFIS model was used to predict turbidity for the three SUDS scenarios for event AT1.

Table 4. Rainfall events used in the stormwater management model (SWMM) and adaptive neuro-fuzzy inference system (ANFIS) model simulations.

Events	Rainfall Depth (mm)	Start Date Time	Duration	Peak Intensity (mm/10min)	Return Period	Model
SC1	35	11.11.2017 11:00	7:00	2.0	-	SWMM calibration
SC2	26	26.12.2017 20:10	8:50	1.2	-	SWMM calibration
SV1	18	04.01.2018 20:10	6:04	0.6	-	SWMM validation
E1	450	May 2012	7 months	-	-	SWMM scenarios
E2	71.0	27.08.2012 00:00	6:04	18	95 years	SWMM scenarios
E3	42.0	04.10.2012 00:00	12:00	9	30 years	SWMM scenarios
AT1	46.8	13.12.2017 23:40	24 days	0.7	-	ANFIS training and ANFIS scenarios
AT2	19.6	15.12.2017 19:00	10 days	0.7	-	ANFIS testing

Table 5. Basic statistics of the measured water quality input and output variables.

Variables	Min *	Max **	Mean	SD ***	Median	Type
Rainfall depth (mm)	0.4	27.7	2.4	2.6	1.3	Input
Discharge (l/s)	0.0	0.700	0.017	0.058	0.0	Input
Temperature (°C)	1.7	12.4	6.6	1.3	7.2	Input
Electrical conductivity (µS/cm)	33.0	701.0	497.7	152.0	557.0	Input
Turbidity (NTU)	0.1	560.3	27.4	60.4	2.4	Output

* Min, minimum; ** Max, maximum; *** SD, standard deviation.

The effects on water quantity are quantified as changes in peak flows, total flow, and flood volume in the three SUDS scenarios as compared to the current state for E1, E2, and E3 along with losses for E1. For the long-term period (E1), the empirical cumulative distribution of flow rate is analyzed. The simulated flow rate below 0.025 l/s is considered zero.

Similar to water quantity, the effect of SUDS on water quality has been assessed using the ANFIS model for the current state and for the three SUDS scenarios. This study used turbidity as a proxy indicator for water quality after establishing significant correlations between turbidity and total suspended solids (TSS) and concentrations of chromium (Cr) and copper (Cu). The linear regressions for the 16 grab samples are shown in Figure S2. Turbidity is a measure of water clarity and the extent to which the material (e.g., soil, pollution, metals, and solids) suspended in water decreases the passage of light through the water. Memon et al. [54] showed a high correlation between turbidity and suspended solids in the stormwater runoff specifically in a construction site. They suggest turbidity be used as a substitute for total suspended solids (TSS) due to the ease of continuous measurement as compared to laboratory measurement for TSS. Likewise, Nasrabadi et al. [55] used continuous turbidity as a proxy for evaluation of metal transport in river water after establishing meaningful correlation between turbidity and TSS.

3.3. Assessment of Amenity and Biodiversity Values

Amenity and biodiversity values are inherently different from water quantity and quality management as the former two are much more related to the surroundings of SUDS elements: functions, materials, and environment impact amenity and biodiversity values as described in Section 2. The amenity values are assessed based on their links with mental health benefits provided by urban green and blue structures. Green and blue structures affect mental health through various mechanisms [56,57]—viewing and observing green and blue areas yield a restorative impact, environmental health (clean air, less noise) affects residential health and opportunities to perform physical activities, and social interaction also impacts health.

The provided health benefits of each scenario were assessed by applying two parameters (Figure 3). The first parameter involved measuring the total area of SUDS elements with vegetation easily visible from residential windows or from yards, streets, or other public spaces. Green roofs on top of one story buildings were included, but not from multistory houses. Permeable pavement was not counted, as there is no vegetation to observe.

The second parameter involved measuring the total area of surfaces in which people can perform activities or interact together close to SUDS elements with vegetation. Residential yards were included, if SUDS elements were present and in the immediate proximity of the user of the yard. The lawn areas allowing sports and leisure activities were included. The second parameter indicates the extent to which SUDS elements overwhelm other functions in yards or public open areas. If water management structures are too extensive, play areas, pathways, and squares enabling physical exercise and social interaction can be hard to fit in.

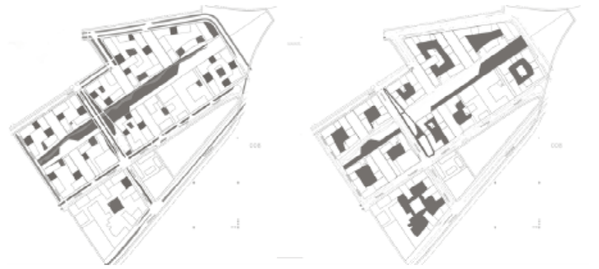

Figure 3. Diagram of NORM scenario presenting two parameters of amenity assessment: area of visible SUDS elements (left) and active spaces with vegetated SUDS elements close by (right).

Similar to amenity, two parameters were utilized to assess biodiversity values of SUDS scenarios (Figure 4). The first parameter utilized the structural heterogeneity index score developed by Monberg et al. [39]. Their study developed an index score for different types of SUDS reflecting the structural heterogeneity potential to "assess potential ecological benefits of SUDS during the design phase". The index scores are based on an expert analysis and reflect the capacity of SUDS elements to host abiotic and biotic components that increase structural heterogeneity. Thus, the same index scores are utilized in the study to evaluate the ability of treatment trains to enhance biodiversity by measuring their potential to enable structural heterogeneity. The approximate value for biodiversity is calculated by multiplying index scores with the surface area of each SUDS structure, thus reflecting the importance of size of habitat.

Figure 4. Diagram of NORM scenario presenting two parameters of biodiversity assessment: SUDS elements with structural heterogeneity index value (left) and edge lines of two vegetated surfaces (right).

Monberg et al. [39] provided an index score for six different types of SUDS including swales (Index score 1.8) and rain gardens (Index score 1.0). The bioretention cell has been embraced as a dry basin (Index score 2.2), which is described to be "depressions ... with straight edges designed to delay water and drain slowly until dry" [39] (p. 5). Green roofs were not included in Monberg's study, and permeable pavements do not host any vegetation, thus, receiving an index score of 0.

The second parameter is derived from connectivity and edge effect as these factors also enhance biodiversity. The edge line of each SUDS element uniting with other vegetated surface (other SUDS element or lawn) was measured reflecting a connection to other green structures as well as the ability to create conditions for edge effect, that is, changes in species structure at the boundary of two habitats. Edge lines to non-vegetated surfaces were not measured, as they do not create ecological network connectivity.

4. Results

4.1. Water Quantity

The SWMM model for current state revealed a consistent performance in reproducing a measured discharge with the Nash–Sutcliffe efficiency of 0.69 and 0.82 for the calibration events (SC1 and SC2), and 0.86 for the validation event (SV1). Modeling showed that all scenarios had an impact on water quantity. Table 6 displays the changes in peak flows, total runoff and flood volumes for SUDS scenarios as compared to the current state for a seven-month period (E1), a short-extreme rain event (E2), and a short-intense rain event (E3). The RUN scenario is efficient at conveying stormwater aboveground in a vegetated channel in a controlled manner resulting in the reduction of 65–91% in flood volume. Thus, the RUN scenario is a good conveyance system, which also helped to reduce peak flows (18–24%) for all simulated events. However, for NORM and MAX scenarios, both peak flow and total flow volume of stormwater are reduced. The MAX scenario is the most efficient in reducing both peak flow rates and total volumes in the drainage network, even for the short-extreme event (E2). Furthermore, it produces negligible flooding for both simulated events.

Table 6. Changes in peak flow, total runoff, and flood volume for SUDS scenarios compared to the current state. Increase in losses also shown for the seven-month period, E1.

Events	Scenarios	Peakflow Rate with SUDS [l/s]	Current State Peak Flow (l/s)	Decrease in Peak Flow (%)	Reduction in Total Volume (%)	Reduction in Flooding Volume (%)	Increase in Losses (%)
E1	RUN	1493	1876	20.5	2.0	66.0	1.2
	NORM	989	1876	47.3	39.9	81.1	30.9
	MAX	458	1876	75.6	81.0	98.7	58.9
E2	RUN	1493	1834	18.6	1.4	65.0	–
	NORM	957	1834	47.8	25.6	81.8	–
	MAX	442	1834	75.9	67.8	98.9	–
E3	RUN	360	474	24.2	-8.8	91.1	–
	NORM	249	474	47.6	33.8	98.5	–
	MAX	94	474	80.3	82.0	100.0	–

For the seven-month period, E1, all SUDS scenarios showed a decrease in peak flow as well as a reduction in total and flood volumes as compared to the current state. The reduction of volume can be seen as an increase in losses, which comprise the total evaporation and infiltration. Losses are dominated by infiltration in NORM scenario and evaporation in MAX scenario (Table 6). For the short-extreme event, E2, the total runoff volume is reduced for all scenarios; this is mainly due to the temporary storage of stormwater in the SUDS as contribution by losses is negligible. The temporary storage provided by SUDS also helped reduce peak flow and volume for E2. The increase in the runoff volume in RUN scenario was due to the increased imperviousness from 63 to 80% from the current state. Despite the increased imperviousness due to the planned development, the RUN scenario still diminished the peak flows as a result of the stormwater retention and delayed conveyance in the

vegetated channel. Thus, the SUDS in studied scenarios has helped manage water quantity on site through controlled conveyance in the RUN scenario as well as temporary storage and losses from the system in the NORM and MAX scenarios.

Figure 5 shows the cumulative distribution of SWMM model simulated flow rate for the current state and the three SUDS scenarios for the longer simulation (E1). From Figure 5a, it can be seen that the share of zero flows clearly increased for scenarios NORM and MAX, whereas only scenario MAX seems to be effective in decreasing high flow rates (Figure 5b).

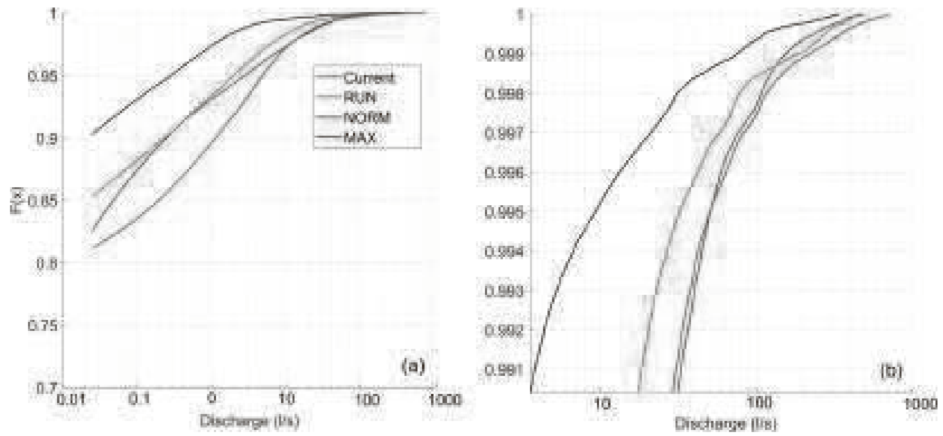

Figure 5. The cumulative distribution of the flow rate for the current state and the three SUDS scenarios for the longer simulation E1 (**a**) and zoomed-in cumulative distribution of the high flow rates (**b**).

4.2. Water Quality

The 95% confidence intervals of slope for TSS, Cr, and Cu excluded zero (Table 7), indicating that there is a significant relationship between turbidity and each of the TSS, Cr, and Cu.

The ability of SUDS scenarios to affect the flow volumes (Figure 5) indicates their ability to manage water quality on-site as turbidity reaches high values with high flow volumes. The trained ANFIS model has the coefficient of determination (R^2) and the Nash–Sutcliffe efficiency (NSE) of 0.86 and 0.78, respectively. The statistics for the tested ANFIS model are 0.74 and 0.59 for R^2 and NSE values, respectively. The comparison of measured and predicted turbidity for calibration and validation periods is shown in Figure S1.

Table 7. Reduction in mean turbidity, and concentrations of total suspended solids, chromium, and copper for SUDS scenarios compared to the current state.

	Unit	RUN	NORM	MAX	Linear Relationship	Coefficient of Determination (R^2)	a* (95% CI ** of a)
Turbidity (T)	NTU	−1.6%	11.6%	46.5%		–	–
Total suspended solids (TSS)	mg/l	−0.4%	3.0%	12.2%	$TSS = aT + 46.763$	0.89	0.404 (0.332, 0.477)
Chromium (Cr)	µg/l	−2.6%	18.3%	73.5%	$Cr = aT - 4.10$	0.95	0.067 (0.061, 0.073)
Copper (Cu)	µg/l	−0.2%	1.7%	6.8%	$Cu = aT + 15.411$	0.83	0.064 (0.049, 0.079)

* a, slope of regression line; ** CI, confidence interval.

The results show that the model performed consistently for both calibration and validation datasets. The correlation between turbidity and total suspended solids is 0.89. The correlation between turbidity and concentration of chromium and copper is 0.95 and 0.83, respectively (Figure S2). The MAX scenario is able to reduce 46.5% of the mean value of turbidity with a corresponding reduction in mean concentrations of TSS and metals of 7–73% when compared to the current state of the catchment. The corresponding reduction in mean value of turbidity for the NORM scenario is 11.6%. The reduction in water quality indicators is the highest for MAX followed by NORM. However, for RUN scenario, the turbidity value increased by 1.6%, and the concentrations of TSS, Cr, and Cu increased by 0.2–2.6% (Table 7). This is likely to be a result of increased imperviousness leading to larger flow volumes, and the positive relationship between flow volume and turbidity identified in the ANFIS water quality model.

4.3. Amenity

Amenity values consist of two parameters: the surface area of visible SUDS elements and the surface area of active spaces close to SUDS elements. For each scenario, both parameters are presented in Table 8 together with the total score. The MAX scenario delivers the highest amenity value through visible green and blue structures, but the other scenarios deliver more opportunities for physical activity and social interactions close to SUDS elements. Thus, the NORM scenario promises to deliver the highest amenity values as it contains both abundant visual interest and space for active interaction with one's surroundings.

Table 8. Total scores of amenity values.

	Elements	**RUN**	**NORM**	**MAX**
Visible SUDS elements	Swales	0.6	0.6	0.6
	Rain gardens	0.6	0.9	1.8
	Bioretention cell		0.1	
	Visible green roofs		0.4	0.4
		1.2	2	2.8
Active Spaces Close SUDS elements	Lawns	1.7	0.7	
	Urban Square	0.3	0.3	0.1
	Yards		1.9	1.8
		2	2.9	1.9
Total Score	(ha)	3.2	4.9	4.7

4.4. Biodiversity

Biodiversity values also consist of two parameters. The potential structural heterogeneity of the scenarios is calculated by multiplying the index score of each SUDS type with their surface area with the results being presented below in Table 9.

Table 9. Total scores of structural heterogeneity (left) and edge line (right).

Elements	**RUN**	**NORM**	**MAX**	**Elements**	**RUN**	**NORM**	**MAX**
Swales (18)	11	11	11	Between two SUDS el.		945	875
Rain gardens (10)	6	9	18	Between SUDS el. and lawn	875	410	
Bioretention cell (22)		2		Total score	875	1355	875
Total score	17	22	29				

The RUN scenario has only two different types of SUDS elements (swales and rain gardens) with the total structural heterogeneity reaching 17. Swales have a high index value of 18, indicating good opportunities for habitat enhancement by increasing abiotic and biotic components through design, but as the surface area is low, the end score remains moderate. In the NORM and MAX scenarios, the total score is higher as surface areas as well as the range of adapted SUDS elements in NORM are higher.

The values of the other biodiversity parameter, namely the edge lines of two vegetated surfaces, are presented in Table 9. The length of the edge line is equal for RUN and MAX, with the difference

being that in RUN, the edge is between the swales and lawn, while in MAX, it is between the swales and rain garden. The edge line length is considerably longer in NORM, which also consists of different types of edges, hence providing better preconditions for connectivity and edge effect, as well as onwards for biodiversity.

5. Discussion

The aim of the research was to study means of assessing multifunctionality during the landscape architectural design process. A widely used SWMM model was parameterized for assessing the impacts of SUDS scenarios with respect to the water quantity criterion [44–49]. Likewise, data-driven ANFIS model was used for assessing the impacts of SUDS scenarios with consideration of the water quality criterion [52]. Amenity and biodiversity values of different types of existing SUDS structures have been assessed in earlier studies [13,32,33], but analyses of landscape architectural designs are rare. In this study, a biphasic assessment was created for both values.

One major consideration is that the amenity and biodiversity values delivered are dependent on the surroundings of SUDS elements. Therefore, the results reflect the qualities of the detail plan draft—the residential blocks are in a row next to the central park and all the adapted SUDS elements on the streets or in the park are easily visible from the apartments. Nevertheless, inner yards are mainly visually closed from the park and if there are no SUDS elements in the yards, neither amenity values related to green and blue structures are delivered. The same feature also hinders opportunities of creating a connected network of green and blue structures that would deliver high biodiversity values.

Moreover, the results are to some extent theoretical, especially concerning biodiversity values. The greatest weakness of the study is poor recognition of the benefits deliverable by green roofs. As there was no index value of structural heterogeneity available for green roofs [39] and they were not directly connected to other vegetated structures, green roofs were not taken into account in the biodiversity assessment. Nevertheless, we know that green roofs have a good potential to enhance local biodiversity [58,59].

Based on the results, the MAX scenario is the most multifunctional option. It works well with water quantity and quality management and delivers high biodiversity values and almost as high amenity values as the NORM scenario. This leads to a discussion of the interrelations of the different criteria. Although the ability of SUDS to provide multifunctionality is continuously enhanced by both the research literature and practical guidelines and links, the interrelations and possible synergies between the four criteria are seldom discussed [19,21,22]. The individual results of the four criteria do not directly indicate a mutual interrelationship between them. However, some processes in SUDS clearly overlap concerning the criteria; for instance, evapotranspiration serves for stormwater quantity control like in MAX scenario, but occurs through vegetation whilst simultaneously supporting microclimatic control for the needs of people. Therefore, it is important to study the ways in which the criteria are interrelated in order to provide a more holistic understanding concerning the provision of multifunctionality in the landscape architectural design process.

The results show that NORM and MAX scenarios that combine several SUDS with different features provide better quantity and quality management in conjunction with higher biodiversity and amenity values. This confirms the relationship between different criteria presented in literature [15]; the ability of SUDS to store and ensure the availability of water for vegetation enhances biodiversity through ecological processes. In turn, biodiversity and the amount of vegetation in SUDS enhance evaporation and infiltration, subsequently affecting water quality. Additionally, increased biodiversity positively affects perceived amenity, but an increased amount of water in urban greenspaces simultaneously requires higher design skills to provide amenity values [32].

Understanding these mutual interconnections and relations presented in Figure 6 will help to design and implement simultaneous functions of the four criteria. Based on the results above, three principles can be outlined for promoting multifunctionality. First, designing SUDS requires a thorough understanding of the hydrological process in order to create high amenity values in urban greenspaces.

The results indicate that SUDS elements with a high capacity for run-off regulation and water detention should be implemented to enhance water quality management. However, such SUDS elements are only occasionally filled with water. Open water is seen to hold the greatest value in urban design, but as SUDS elements often tend to be dry, the design should be adaptable to prevailing hydrological process and create added value in all rain situations as well as during possible dry seasons.

Secondly, if vegetated SUDS play a major role in landscape architectural design as design elements, we need more knowledge about their differences in terms of biodiversity. In principle, SUDS that sustain the function of natural processes, thus promoting structural heterogeneity of habitats, uphold biodiversity. For the needs of biodiversity, it is essential to design volumes, routes, and surfaces that enhance the water cycle as well as sustain biophysical structures, processes, and functions. This initiates a holistic approach in which the functionality of SUDS is enhanced by locating them not as individual elements or as a part of the treatment train, but in connection with the larger ecological or green network. This is closely related to enhancing local biodiversity that requires extra attention during the design phase together with a multidisciplinary approach [39].

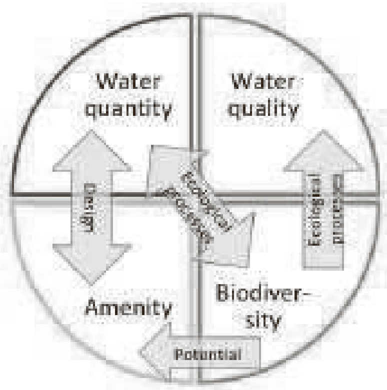

Figure 6. Mutual interconnections of the four criteria.

Thirdly, all four criteria can be assimilated into the ESS concept [14] as water quantity and quality management are strongly related to the regulation of the water cycle and purification service. Furthermore, amenity is related to the provision of cultural ecosystem services. The fourth criterion, biodiversity, is a more complicated issue. When examined in the framework of the cascade model [20], biodiversity is not an ecosystem service, but rather a requirement for it, marking this pillar as being fundamentally different from the others. However, in green stormwater infrastructure related research, biodiversity is commonly regarded as a supporting service and used together with habitat provision [14].

The assimilation of the four criteria into the ESS concept will help to understand the relation of SUDS to other systems. In order to strengthen ecosystem service provision, an understanding is required of the ecological processes and system dynamics in urban greenspaces [38]. Furthermore, sustainability advantages provided by short distances of the compact city ideal should be valued against the space requirements of ecological processes. This underlines Ahern's [2] notion that the concept of sustainability changes as cities are understood and accepted as dynamic systems.

An urban area, such as Kirstinpuisto, consists of both physical infrastructures and social structures composed by its residents. Concurrently, the area is still a catchment and also a part of the wider ecosystem, as are all urban sites [9]. As an outcome, it is an example of a social ecological system (SES) [60], in which the hydrological cycle can be combined into urban functions with the help of multifunctional SUDS. However, multifunctionality is not self-evident, but requires a focused approach [6]. The results of this paper indicate that a balanced approach is needed to consider different preconditions, interrelations, and possible outcomes in the landscape architectural design process.

SUDS elements are widely used practical implementation of GI in urban development. GI has the ability to work as a platform for different systems, such as hydrology, transportation, and tourism [6], as well as to support sustainable urban development [4]. In that framework, SUDS elements have a special role to collectively mediate local hydrology, biodiversity, and amenity values, if conditions for those parameters are created during the design process.

Kirstinpuisto is a good example of a new urban space; a former brownfield site with almost non-existent green areas will be transformed into a residential area with requirements for public urban green areas. SUDS elements are needed for its stormwater management, but it can also play a more significant role creating biodiversity and amenity values. As the benefits of new multifunctional SUDS are considered, one must be aware of the challenges with multifunctionality. Some of the expected outcomes can already be precisely measured during the design phase (such as water quantity management), or later after its realization (such as plant species richness). However, some of the outcomes will accrue through a dynamic process together with new residents, new hydrological or soil conditions, maintenance procedures, or with a changing climate.

The results of the study reinforce Jack Ahern's notions about the safe-to-fail design approach [61], in which urban landscape is understood as a system that can be guided to perform different functions. We need more understanding of the process of that guidance as well as of the intrinsic characteristics of the desired multifunctionality [6]. Especially knowledge concerning the contribution of SUDS to local biodiversity (which elements support which kind of species and habitats, and the ways it can be matched with an existing green network) is essential as SUDS is used in increasing amounts as a retrofit solution or as a part of new greenspaces with desire for multiple benefits.

6. Conclusions

This paper studied the multifunctionality of three stormwater management treatment trains that were composed of differing SUDS elements. The four criteria of SUDS design (water quantity, water quality, biodiversity, and amenity) were used to measure multifunctionality. The aim was to understand how SUDS scenarios could enhance multifunctionality of urban greenspaces as well as how this should be considered in the design process with an application to a case study area.

There has been a lack of holistic knowledge concerning the generation of multifunctionality as a part of the landscape architectural design process of stormwater management. This paper discussed and tested indicators for different criteria with the results indicating that the links and feedback between the SUDS criteria should be considered more profoundly. A deeper understanding of the interconnections between urban hydrological processes and the provision of natural functions of a site is needed to increase biodiversity and related benefits in urban greenspaces.

Furthermore, the study introduced that existing modeling tools can be utilized for the assessment of water quantity and quality criteria while such tools to assess amenity and biodiversity values delivered by SUDS elements are not available at the same level. In addition, both amenity and biodiversity depend much more on the framework where SUDS elements are adapted. These results reflect that we are more familiar with those uncomplicated features of SUDS elements that resemble a traditional pipe network. By contrast, study methods for both the assessment of complex criteria and complete understanding of the desired multifunctionality need further development.

The results confirm that multifunctionality criteria are interconnected. If biodiversity criteria have failed, it has a degenerative impact on both the amenity and water quantity management potential of the site. This suggests that if the delivery of multifunctional benefits is not considered during the design process, it is quite likely to ruin any chances of achieving goals related to multifunctionality. On the other hand, through a skillful analysis of local preconditions and with site specific design decisions, we can enhance multifunctionality.

The study can be seen as a remark to open a conversation concerning how we can assess different criteria of multifunctionality that are not commensurate by nature and not even necessarily equal. There is an obvious need to deliver more easily adaptable measuring methods for the values different

SUDS elements involve, especially concerning biodiversity. Furthermore, a fitting multicriteria analysis for SUDS elements is needed alike.

Finally, the desired provision of multifunctionality requires not only an acknowledgement of the interdependencies of its different aspects, but also a consideration of other urban functions. A careful coordination of these functions in the design process is essential, if multifunctional SUDS elements are to be successfully applied to a dense urban structure. This ultimately leads towards a system thinking approach.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/11/7/1854/s1, Figure S1: Measured vs. predicted turbidity for training and testing period in ANFIS model, Figure S2: Correlation between turbidity and total suspended solids (a), concentration of chromium (b) and concentration of copper (c).

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We are undeniably living in an era of enormous environmental crisis with climate change and species extinction as the most outstanding features of it. These issues challenge our societal systems and relationship with nature. In addition, more than half of the planet's population live in urban areas, where environmental problems tend to culminate and where counteractive efforts should be concentrated. How can landscape architecture solve these urgent issues?

This dissertation provides new scientific knowledge concentrating on collaborative planning and design of urban socio-ecological systems. It presents how the co-creative processes of planning and design of green infrastructures can be used as a platform to increase both their multifunctionality and the joint understanding of urban socio-ecological systems as a basis of sustainability.

The book presents an accelerating model towards sustainable social ecological systems as a result of four case studies. The model can be used as a concrete tool to boost co-creation in the planning and design of multifunctional green infrastructures that contribute to climate adaptation and urban biodiversity.

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