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Ergonomics and Urban Green Infrastructure: Understanding Multifunctional Social-Environmental Systems

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Ergonomics and Urban Green Infrastructure: Understanding Multifunctional Social-Environmental Systems

by

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Report

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Abstract

Ergonomics and Urban Green Infrastructure: Understanding Multifunctional Social-Environmental Systems

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Although urban green infrastructure [UGI] is increasingly characterized as an asset because it simultaneously serves critical social and environmental functions, few planning tools or research approaches exist where multiple functions are integrated into a systemic spatial analysis. Accordingly, this report examines the utility of ergonomics as a methodological approach to integrate the natural and social sciences and forge a deeper understanding of UGI multifunctionality. Five administrative districts in Dresden [Germany] were selected as a study area to carry out this analysis. Mixed methods were used to categorize and measure various social and environmental functions of UGI cases, and outcomes analyzed for spatial clustering in GIS. Results from this study provide strong evidence that combining social and environmental variables can significantly inform the way UGI networks are perceived and valued.

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Introduction

Green infrastructure is becoming increasingly acknowledged as essential to human well-being by significantly increasing quality of life[1]. However, as green infrastructure networks fall under increasing pressure from land encroachment and climatic transitions, it is necessary to re-think the conventional processes by which development decisions are made and green spaces are maintained. In particular, design processes that integrate social and environmental needs will be increasingly vital for successful, green infrastructure planning. This is true not only from a conservationist standpoint, but also when considering the social use value of these environmental networks.

In this professional report, I consider the utility of ergonomics as a methodological approach for such integrated green infrastructure planning, as well as to better understand the multiple functions green infrastructure serves. Ergonomics – a discipline most typically applied in architecture and engineering – is concerned with understanding interactions among humans and other elements of a system in order to optimize human well-being and overall system performance[2]. In doing so, ergonomics considers both target functions and user experience to achieve engaging, innovative design, and attaches value to both intended and improvised function. When considering that urban green infrastructure [UGI] is both a designed system which helps regulate the physical environment and a critical space for public enjoyment and interaction, this study posits that applying an ergonomics approach to UGI planning can add a critical social element and thereby strengthen system sustainability and longevity. This approach will require

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[1] Dunn 2010, Ahern 2007, Goulder et al. 1997

[2] International Ergonomics Association [IEA] 2014

developing a comprehensive understanding of the multiple, inter-related social and environmental functions of UGI networks. More broadly, understanding these functions is key to the development of a sustainable approach to environmental planning. Accordingly, in this report I draw on both soft and hard science methods to better visualize and understand how social and environmental systems inter-relate within UGI.

I base my analysis of ergonomics as a green infrastructure planning tool on a case study of Dresden, the largest city in the German state of Saxonia with a population of roughly 529,781 inhabitants in 2012[1]. Dresden's UGI system is a recognized product of Germany's centralized planning system, where strong vertical alignment between federal, state and regional policy gives rise to a heavily regulated land use planning framework at the city level. Accordingly, Dresden's extensive network of open spaces, cycle paths and pedestrian-oriented streets make it worthy of study as a site of innovative green infrastructure planning, as well as an ideal location to analyze social and environmental functions of UGI.

Five adjacent administrative districts – commonly referred to as *Neustadt* – were selected as a study area within Dresden. Neustadt was primarily selected because it contains a typologically diverse network of green infrastructure (*figure 2*). Accordingly, social uses represented are both formal and informal, in that there are significant areas of open spaces (e.g. sections of the Elbe River floodplain) which lack official classifications as park or recreational areas, but are nonetheless used as such. Additionally, this infrastructure is spatially distributed throughout the study area, which ensured that a range of settings, accessibility and urban surroundings were captured in study results. Furthermore, Neustadt is both inhabited by, and

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[1] UN Statistics 2013

attracts, a demographically diverse population. It is located far enough away from major universities to prevent a student culture bias, and it contains a range of housing options and prices. In respect to types of land use in Neustadt, there is also a variety of residential, commercial and industrial uses represented [*figure 3*].

Another factor which makes Neustadt a particularly suitable study area is that all five administrative districts are projected to grow in the next 15 years (*figure 1*), which in turn will necessitate new construction and lead to significant land use transitions. As of July 2014, multiple new housing and commercial development projects were already underway—a factor which has caused some residents to fear gentrification and/or unwanted changes in community character. From an environmental planning perspective, these transitions could result in additional strain on green infrastructure, continue to increase land development pressure, and ultimately catalyze the need for creative and socially-informed decision-making.

Correspondingly, the relevancy of this study extends beyond understanding UGI multifunctionality, to considering how ergonomics could help guide more socially-informed decision-making processes. To exemplify this point, recent years have already seen specific examples of heated debate surrounding major urban development decisions in Dresden, as decisions supporting hard engineered infrastructure have taken precedence over green infrastructure. This controversial development has, and is continuing to, fuel tensions between citizens and local authority. The best example is the recent construction of the *Waldschloesschen Bridge*, a project intended to decrease traffic congestion by providing another river crossing in the urban core. Not only was this project adamantly protested because of its environmental and visual impacts to the Elbe Valley and corresponding recreational areas, but it also led to the removal of the Elbe Valley as a UNESCO World Heritage site in 2009. Currently, discourse in Dresden surrounding privatization of select stretches of the Elbe floodplain is inciting considerable grassroots protests and widespread backlash (*illustration 1*).

Drawing on principles of ergonomics, I approached this study by gathering various data on select UGI cases in Neustadt to understand the social and environmental functions of UGI in the Neustadt before I used GIS to analyze the value and spatial clustering of these functions. Specifically, I collected surface type and coverage data to analyze environmental function, and observed various types of UGI use to determine social function. This analysis, in turn, allowed me to consider the implications for environmental planning of such a spatial, GIS-based approach to evaluating both environmental and social contributions of UGI networks. Although UGI is often characterized as an asset because it simultaneously serves critical social and environmental functions, few planning tools or research approaches exist where multiple functions are integrated into a systematic spatial analysis. Thus, an ergonomics-based approach allows us to use mixed methods and to draw

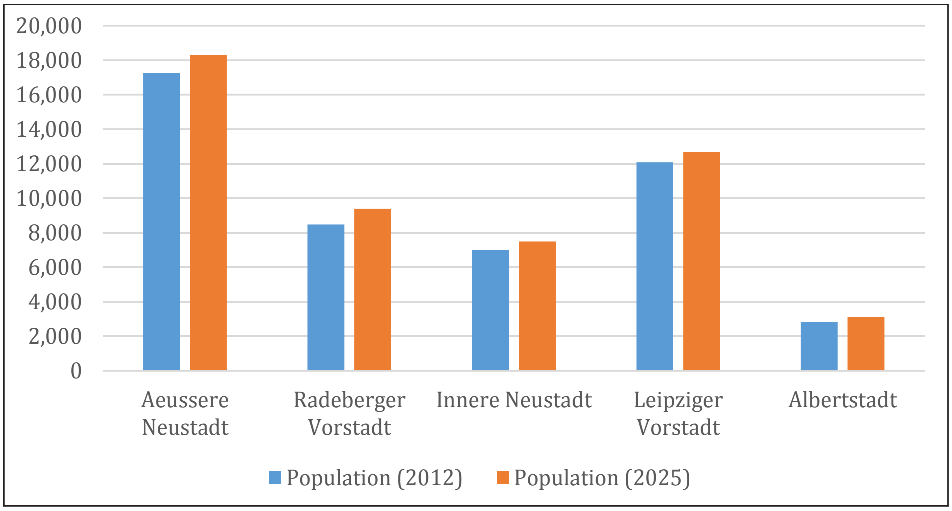

Figure 1: Population Growth in the Dresden Neustadt

on both the environmental and social sciences to offer more comprehensive and realistic insight into the multiple, and spatialized, contributions of UGI systems.

Results from this study suggest that the ways in which the multiple functions of UGI are understood change drastically depending on whether environmental or social functions are considered. Accordingly, using ergonomics to combine the hard and soft sciences opens up the potential to develop a better, and more holistic, understanding of how UGI contributes to both social and environmental sustainability. In order to better understand the implications of delineating various diverse UGI functions, three target phenomena – based on empirical assumptions from pre-existing socio-ecological research[1] were analyzed, namely: *Emergence*, the co-location of high environmental and social function; *Environmental Hotspots*, high functioning environmental areas with low social function; and *Social Hotspots*, high functioning social areas with low environmental function. The occurrence of any of these phenomena point to considerable planning, design and managerial

Illustration 1: (Eng) "Elbe Valley Remains Public Space!" Signs protesting privatization of the Elbe Floodplain

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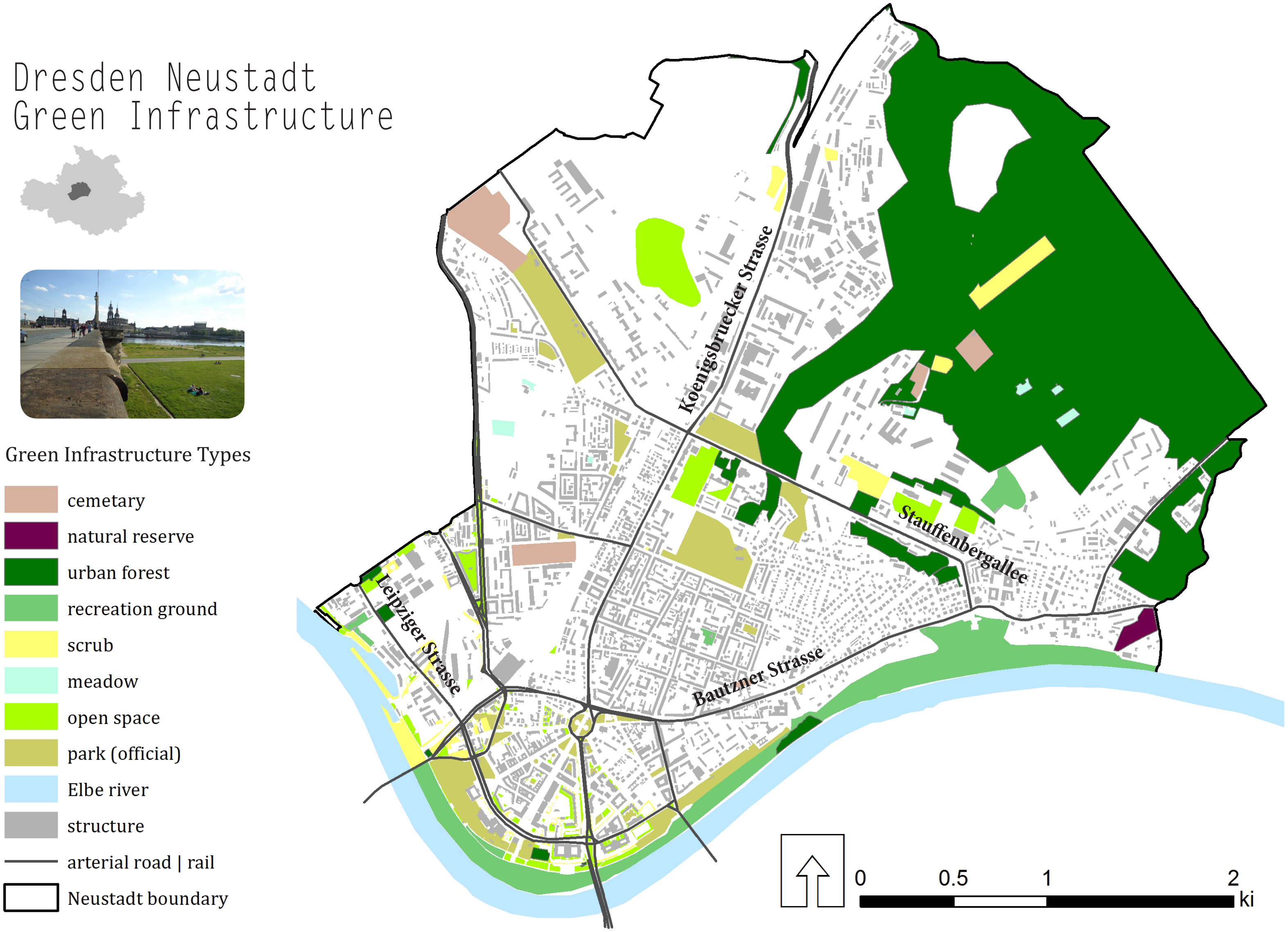
[1] Alessa, et al. 2008

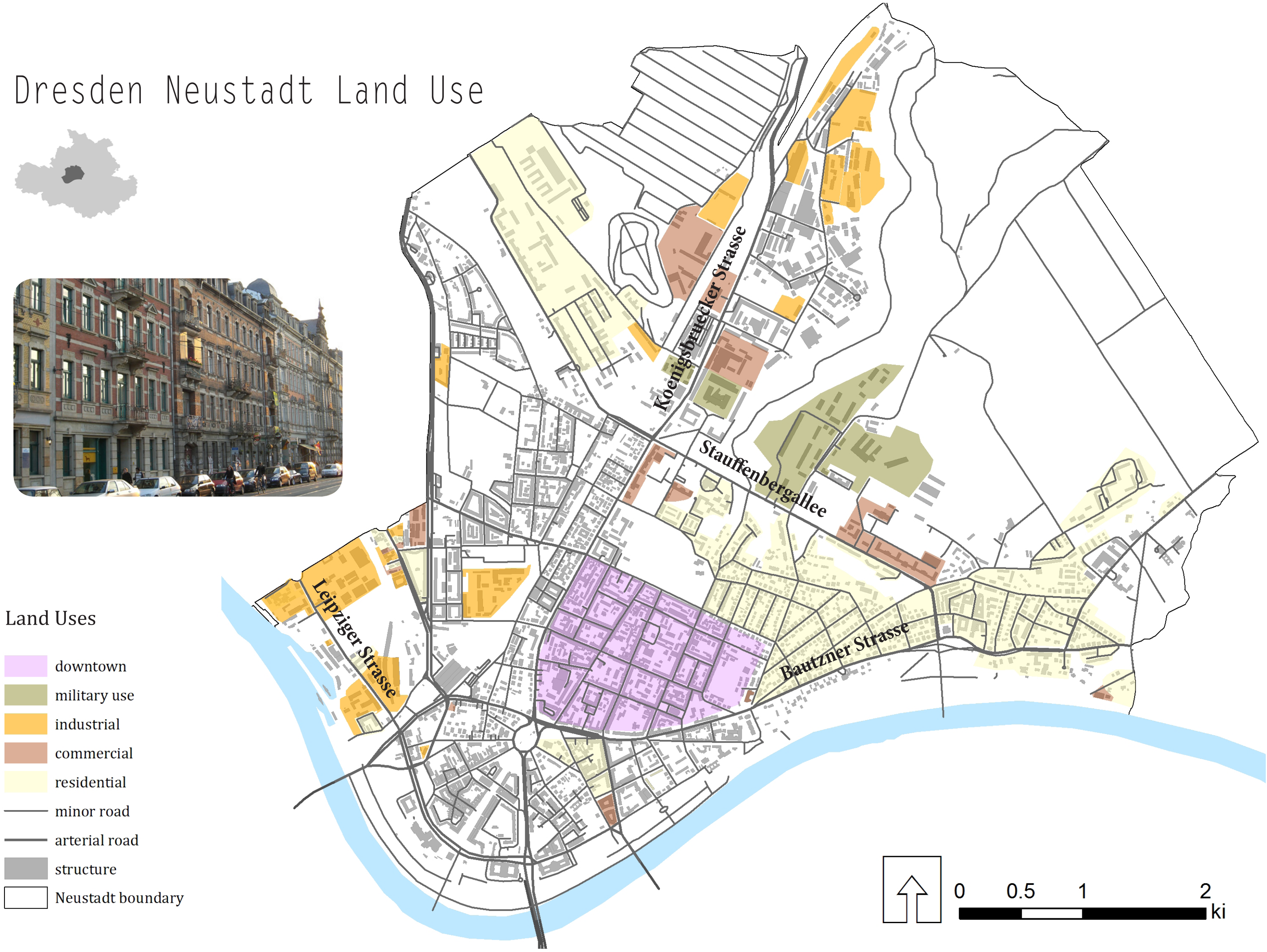
implications, as well as new perceptions regarding how public spaces are understood. Of all cases analyzed, 61% exhibited sufficiently high-value social and/or environmental functions to be considered as one of these phenomena, with emergence the most common at 28%, but social and environmental hotspots also relatively frequent at 17% and 16%, respectively.

This study derives its conceptual foundation from a literature review including social and environmental functions of green infrastructure systems, ergonomics, spatial analysis and socio-ecological systems theory. Following the literature review, research design and methods are outlined in detail to describe the analytical approach I implemented in response to the research questions. In the subsequent chapter section, I present and analyze the findings from my research in Dresden. Finally, I discuss the broader implications of this research in the concluding chapter.



Datum: GCS Deutsches Hauptdreiecksnetz, Projection: Gauss Krueger Zone 3 | Created 5/2014

Figure 2: Green Infrastructure Overview and Distribution



Datum: GCS Deutsches Hauptdreiecksnetz, Projection: Gauss Krueger Zone 3 | Created 5/2014

Figure 3: Land Use Overview and Distribution

Chapter 1:

Social-Ecological Systems and Green Infrastructure: The Challenge of Measuring Multi-Functionality

Theories of Socio-Ecological Systems

In considering spatial integration of social and environmental variables and ergonomic applications in green infrastructural planning, it helps to explore current theories which look at humans as part of environmental systems. A relevant body of literature for this study considers cities as socio-ecological systems, forming a fast-growing interdisciplinary field which has been characterized as bearing "high relevance" to solving some of the most pressing problems of our time[1]. The premise of socio-ecological systems theory is that human beings should never be seen as extraneous to environmental systems, since they, just as other biological entities, live in, live from, and shape these systems. Accordingly, socio-ecological systems theory has informed the analysis of the widespread degradation of global ecosystems[2] resulting from rapid urbanization, which could result in the conversion of an additional 1.2 million km² of green space to urban areas by 2030[3]. Ultimately, scholars working in this field attempt to generate a better understanding of human-ecological interaction in urban systems for enhanced sustainability[4].

Socio-ecological systems theory most directly applies to planning in advocating that the study of urban environmental systems must always be informed by social context. In this regard, gaining a more holistic understanding of local ecology must consider forms of meaning and value significance. For example, the Millennium

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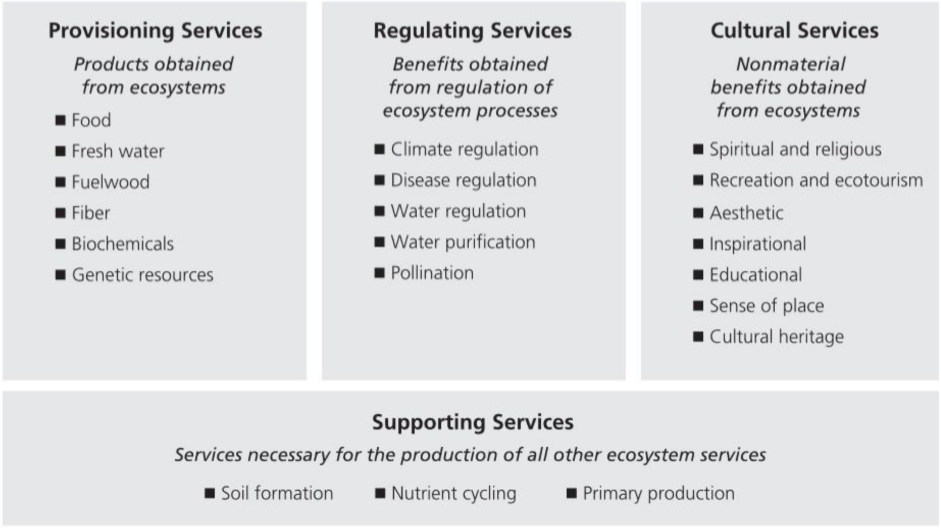
[1] Cummings 2012

[2] Millenium Ecosystem Assessment [MEA] 2006

[3] Yale School of Forestry and Environmental Studies 2012

[4] Pickett, et al. 2001, Stockholm Resilience Center [SRC] 2007, Ostrom 2009



Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting Services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

Figure 4: The Millenium Ecosystem Services Valuation Framework

Ecosystem Assessment[1] [MEA] provides a useful foundation for articulating both the tangible and intangible services that humans derive from ecosystems [*figure 4*]. In a cultural sense, MEA links nonmaterial benefit such as inspiration, heritage and spirituality to ecosystem value, suggesting that such intangible factors should be included in any baseline evaluative framework. The MEA framework, then, suggests that paradigms for understanding ecosystems (on the macro scale) are not only concerned with life-support systems, but also with value-networks which fuel social and cultural development. In fact, consideration of humans as "integral parts of ecosystems" seems to be the dominant viewpoint in many major environmental organizations [UNEP, National Park Service, and Ecological Society of America].

However, despite evidence that socio-ecological systems are acknowledged, there are few examples of methodologies or tools which affectively combine social and environmental variables for better decision-making. Pincetl's research on biogenic infrastructure and tree planting initiatives in Los Angeles provides a good

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[1] Millennium Ecosystem Assessment [MEA] 2006

example of this dichotomy in concluding that urban sustainability initiatives often lack "engagement with the impacts on local populations"[1], which might stem from the realities of a planning system where city departments are not used to looking at planning holistically but are rather focused on their own distinct goals and objectives[2].

Building off of Pincetl's point, it is important to consider some of the challenges associated with generating a more holistic planning framework. From a theoretical perspective, socio-ecological systems are generally considered to be complex systems[3] whose analysis necessitates the combination of scientific disciplines. Accordingly, in order to simultaneously analyze both social and environmental functions, such planning tools would need to incorporate both the natural and social sciences and their associated methodologies. However, barriers to this integration have been articulated by various researchers. Ostrom, for example, has noted that the social and environmental sciences have "developed independently [...], created their own sub-cultures, [...], and do not combine easily,"[4]. Furthermore, Fuerst[5] and Jahn et al.[6] have claimed that any scientific exploration requires establishing a "boundary prior to inquiry based on either socio-cultural or environmental parameters," a factor which ultimately creates a subjective research aim.

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[1] Pincetl 2010 (p.43)
[2] Pincetl 2010 (p. 48)
[3] Folk 2004, Zurlini 2006, Ostrom 2009
[4] Ostrom 2009
[5] Fuerst 2011
[6] Jahn et al. 2009

Green Infrastructural Systems

Defined as a network of interconnected green spaces, green infrastructure can be conceptualized as a framework for understanding the provision of ecosystem services which is critical within both natural and anthropogenic systems[1], and in an applied sense, how these services can be distributed and maintained. Green infrastructure exists at multiple scales[2]: as regional networks of park systems, natural preserves and wildlife corridors; as urban green spaces which provide both aesthetic value and recreational opportunity, while improving air quality, managing storm water and reducing urban heat canopies; and even as design elements integrated into a built structure, such as a green rooftop, which helps to lower building energy output.

New conceptual understandings of green infrastructure are currently evolving. For example, Jack Ahern's research on green infrastructure has placed new emphasis on the spatial dimensions of these systems, ultimately concluding that green infrastructure is characterized by so-called "pattern-process relationships.[3]" Pattern-process relationships define green infrastructure function as something which is part of a greater ecological system where living elements interact. This emergent perspective is significantly different from previous understandings. Neuman & Smith, for example, have noted that historical views of green infrastructure have focused on an ability to sanitize, cleanse and regulate urban systems[4], neglecting to consider the interworking of systemic elements across spatial scales. Strang further exemplifies this point in claiming that the planning

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[1] Benedict & McMahon 2006

[2] Amerian Society of Landscape Architecture [ALSA] 2014

[3] Ahern 2017

[4] Neuman & Smith 2010

of most contemporary American cities have largely ignored local hydrology[1]—a fact which has ultimately generated infrastructural systems which work against natural systems. Taken together, many researchers are starting to consider green infrastructure as part of its own "articulated discipline"[2].

Although linked to a wider network, this study looks specifically at urban green infrastructure [UGI], i.e. green spaces and their functions at the city and neighborhood scale. Manifested in land use types such as parks, urban forests, community gardens, greenways and biogenic infrastructure such as street trees, UGI has been not only characterized as a multifunctional[3] system, but one which is stochastic[4]. Stochastic in this sense is referring to a type of 'living' infrastructure whose functional capacity and output is dynamic—in essence, that it is constantly evolving in response to its surroundings as does any natural system. Accordingly, researchers are focusing increasing attention on how UGI could have superior capacity to adapt and respond to changing conditions, as opposed to traditional gray infrastructure which is generally created for a singular purpose[5]. Because a system's resilience is manifest through the ability to withstand and recover quickly outside disturbance[6], the multifunctional nature of green and hybrid infrastructural systems is being increasingly seen as something which could contribute to resilience in the built environment[7].

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[1] Strang 2009

[2] Mell 2012

[3] Bennett 2009

[4] Benedict & McMahon

[5] Strang 1996

[6] Blockley et al. 2012

[7] Environmental Protection Agency [EPA] 2014

Environmental Function(s)

If properly integrated into a built system, UGI not only provides local environmental benefits, but also enhances the operational potential of engineered systems. For example, researchers have shown how low impact design solutions and hybrid gray-green systems can be used to manage and purify runoff[1]; how green rooftops can lower building energy demands and reduce the urban heat island effect[2]; and how urban forests can improve air quality and recycle environmental pollutants through carbon sequestration[3]. Furthermore, well-planned and maintained UGI systems can support groundwater recharge, reduce flooding, and mitigate erosion from surface runoff. Particularly when combined with engineered systems, green infrastructure functions can even take on entirely new meanings which challenge conventional structural objectives, such as the potential for buildings to serve as wildlife habitat and support biodiversity[4].

The multiple functions of green infrastructure and hybrid designs are often categorized as "ecosystem services." Ecosystem services have been defined as "the benefits that human populations derive, directly or indirectly, from ecosystem functions,"[5] which at their most basic level, comprise the natural life support systems upon which all humans rely[6]. Various studies have examined the environmental benefits of green infrastructure from an ecosystem services perspective[7]. Additionally, as theoretical and applied urban research is focusing more attention on adapting to a changing global climate, the resilience-building

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[1] Zimmerman 2010
[2] Oberndorfer et al. 2007
[3] Escobedo et al. 2009
[4] Eakein 2012
[5] Costanza et al. 1997
[6] Benedict & McMahon 2006
[7] Nowak 2009, Escobedo 2009, Barten 2008, Harris et al. 2006

potential of ecosystem services in urban areas is generating more attention. A prime example is the potential of UGI to provide cooling microclimates and reduce the urban heat islands effectuated by hard, engineered surfaces such as asphalt and concrete. After the European heat wave claimed over 52,000 lives in the summer of 2003[1], researchers began to take a critical look at biophysical features which generate altered energy exchanges in urban areas[2], as well as cooling which can be generated by urban green spaces[3]. This is just one example of how ecosystem services and urban resilience can go hand-in-hand.

Since the premise of ecosystem services is that landscapes perform functions essential for human well-being[4], the capacity of landscapes to provide these services could be a basis for quantifying green infrastructural function. Attempts at quantifying these ecosystem services and green infrastructural function has taken on many forms. For example, Pataki, et al. quantifies function by considering distinct performance objectives, and linking these to specific biogeochemical processes[5]. Conversely, Kremen proposes a more holistic approach to measuring ecosystem services in green infrastructure by considering the value of "habitat units" and ecological community structure as a whole[6]. Taken together, the fact that many methods exist to measure ecosystem services leads to inevitable differences in perception of UGI functions and valuation—a factor which is rarely given due consideration by city planners. Pataki, et al. exemplifies this in noting that comprehensive methods to assess and represent green infrastructure system

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[1] Larsen 2006
[2] Gil et al. 2006
[3] Stupelpnagel et al. 1990
[4] Pataki 20011, Sahely 2009
[5] Pataki 2011
[6] Kremen 2005

value are often disparate, unclear or centered on only one specific outcome[1]. Some attribute this to "entanglement in social and political processes" associated with city planning[2], as the financing of green infrastructure projects is often a power play between bureaucrats, businesses and interest groups[3].

In addition to green infrastructure being subject to various socio-political priorities, other local factors – such as local climate and economic interests – also influence the way the environmental contributions of these systems are understood. For example, a case study of forest valuation in eight Mediterranean countries yielded very different outcomes as benefits were ultimately quantified differently based on distinct local needs, different threat perceptions associated with aridity, and/or the presence of agricultural markets[4]. Similarly, at the city-scale, ecosystem valuation is contingent upon specific demographic contexts and built environments which reflect what residents see as critical. In this sense, a city prone to flash flooding or operating on a combined sewer overflow system might attach more value to the infiltrative function of vegetative cover, whereas a city with a hot annual climate might consider cooling potential (evapotranspiration and shading) as more functionally beneficial. In sum, while distinct UGI functions and benefits will rightfully be dependent upon their environmental and climatic context, it is important to detangle the representation of these functions from agendas and interest groups which may seek to overshadow stacked benefits, i.e. the idea that structures and open spaces can simultaneously serve multiple and diverse functions.

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[1] Pataki 2011
[2] Ernstson 2012
[3] Pincetl 2010
[4] Pagiola et al. 2004

Social Function(s), Ergonomics and Spatial Analysis

A great challenge in modern city planning is how to understand, design, and manage UGI networks for an elaborate and multi-faceted social context. Although conventional methods of generating public feedback – if made accessible and transparent – are valuable for beginning to understand societal values, these approaches are usually oriented towards the 'active citizen'[1]; essentially, those who are predisposed to engage in participatory processes. Because of this, the traditional framework of environmental planning runs the risk of generating social discordance and forging UGI designs which do not speak to dominant use patterns and human need. On a global level, as urbanization escalates and planners are tasked with confronting unprecedented issues of environmental justice and resource constraints, UGI as a design concept will become ensconced in an increasingly complex social atmosphere. Because the primary function of the built environment is to accommodate and facilitate human inhabitance, the potential of UGI to become a sustainable solution rests upon its social applicability.

Just as UGI's environmental function is dependent on local context[2], social values of UGI will derive meaning from local culture and customs. However, in looking at conventional methods used to generate public feedback, even thoughtfully facilitated participatory processes are seen as having certain shortcomings. For example, McDowell claims that there is a tendency to assume that community groups represent a "coherent whole"[3]—a factor which can lead planners to think that the opinion of one member of a specific neighborhood or demographic speaks for all. In addition, participatory processes can also tend to fixate on racial identity

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[1] Beebeejaun 2006

[2] Picket, et al. 2001

[3] McDowell 1999

or income as identifiers of "otherness"[1], and neglect to see more complex "value-laden" and heterogeneous ties which may exist within various social groups[2], a factor which is increasingly characteristic of modern communities[3]. Ultimately, because of the complex social functions and values manifest in public spaces, ergonomics holds the potential to strengthen traditional participatory processes which inform UGI planning by considering observed behavior in conjunction with voiced input. In the next chapter, I present the principles of ergonomics and show how this informed my research design and research questions.

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[1] Beebeejaun 2006

[2] Miraftab 2004

[3] Forrest et al. 2001, Sayer et al. 1997

Chapter 2:

Research Design, Research Questions and Field Data Collection

Using Ergonomics with GIS for UGI Analysis

Commonly applied in architecture or engineering, ergonomics describes the process of incorporating human need and well-being into design[1]. The application of ergonomics is particularly evident in the design of green buildings, which rely on both occupant perception and social indicators to assess ideal structural forms and use of space. For example, one study of green building design in South Africa looked at physical employee well-being and behavioral patterns (productivity, absenteeism) in order to develop design parameters and sculpt socially-appropriate spaces[2].

Although ergonomic methods are well established in architecture and engineering, they are rarely applied to UGI system design. The most likely reason for this is logistical challenges involved with observing/studying UGI social uses at the city-scale. Whereas architects are concerned with a spatially delineated structure and a more predictable user-group, UGI systems are comprised of open public spaces and green biogenic features with less spatial specificity. User groups are the general public and use patterns and needs will be more diverse.

Given these challenges, one tool which could make the collection and interpretation of ergonomic data in UGI networks feasible is Geographic Information Systems [GIS]. GIS is a software program which is used to create, manipulate, analyze and manage various types of geographic data. Due to the potential that GIS holds to conduct complex analyses across various disciplines and "blur distinctions"

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[1] International Ergonomics Association [IEA] 2014

[2] Thatcher 2014

between them, it has been described as an integrating technology[1]. In this sense, social-environmental mapping methods could help uncover relationships and establish correlations between the natural environment and anthropogenic trends.

Although not specifically linked to ergonomics, many social researchers perceive spatial analysis as a pathway to achieve a greater understanding of how human values are shaped by, and impact, the physical environment. For example, Janelle and Goodchild have advocated that GIS can help to "understand the coupling of social and physical processes (on the landscape)" which can uncover "physical patterns of contemporary public spaces, activity patterns (passive versus active engagement) and socio-environmental cohesion"[2]. Furthermore, Jorgensen's research on social mapping methodologies has posited that defining a place from a resident-driven perspective will require developing an understanding of behaviors in a given space, in essence, that behavioral types should be looked at in their spatial or physical context[3]. In reference to green infrastructure specifically, there has also been speculation by various researchers that GIS holds great potential to inform socially-appropriate design. Wickham et al., for example, has described spatial analysis as holding potential to integrate natural systems into community well-being[4]. Others still have considered GIS as a tool which can help understand community accessibility[5], and prevent land use conflicts[6], as well as spatially organize ecological and social functions[7] [Ahern 2007].

Given the value of GIS as an integrating technology, some researchers are

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[1] Goodchild 2000
[2] Janelle & Goodchild 2004
[3] Jorgensen 2009
[4] Wickham et al. 2010
[5] Fabos 2004
[6] Carr & Zwick 2005
[7] Ahern 2007

starting to explore how spatial analysis can be used to better understand the intersection of social and environmental systems. One such example is a GIS-based study conducted in Kenai, Alaska which sought to understand the dynamics of emergence in resource management and open space planning. Emergence has been defined as a space where "multiple and diverse, human values are co-located with a [productive] biophysical resource"[1]. The objective of this study was to explore tools which could help harmonize resource planning with diverse human needs. In this study, Alessa, Kliskey and Brown combined "human-perceived and physically measured ecological values" in GIS to understand where these values overlap[1]. This study draws on Brown's idea of "landscape value"[2], a concept which describes the cognitive bridge between the geography of place and the psychology of place. In short, spatially explicit landscape values represented in this study describe how people interact with, live in or attach meaning to a place[1].

Another example of social-environmental mapping comes from the City of Stockholm, Sweden. Often considered at the forefront of progressive city planning, the Stockholm City Planning Administration [SCPA] devised a method for understanding the social significance of urban open spaces by measuring and representing "social use values" into a so-called Sociotope Map. Sociotope maps are generated by field observation of public social spaces, and input of various use types into GIS. This tool has been justified by the SCPA as a response to a "[need] for more efficient connections between the systematic world of planners and the life-world of citizens" which "starts from the users' space and perspective, not the planners"[3]. Sociotope mapping considers distinct uses and forms of social life

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[1] Alessa, et al. 2008

[2] Brown 2005

[3] Stockholm City Planning Administration [SCPA]

which manifests within green spaces; ultimately showing that people can share use values, and simultaneously, that every space has its own unique set of values[1]. Sociotope maps are used in Sweden as a tool to engage in more socially-informed environmental planning as they are usually overlaid with environmental data (the "Biotope Map"). This overlay method has already been applied in numerous UGI planning projects, including a densification project in 2003 where the map was used to help understand how citizens of different ages use open space in order to "save the most popular spaces from exploitation" and improve existing spaces[1].

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1 Stahle 2006

Research Goals, Questions and Data Collection Methods

The goal of my study was to develop a deeper understanding of the multiple functions of UGI in the study area, and, secondly, suggest how the integration of ergonomics with GIS can help inform environmental planning.

The following research questions guided my data collection and analysis:

1. What types of social and environmental functions do UGI cases in the study area serve?
2. To what degree are emergence, social hotspots, and environmental hotspots present?
3. What are the implications of these phenomena, and how can this ergonomics methodology inform environmental planning?

In order to select my UGI cases, I used an ArcGIS shapefile of Dresden's land use types, and isolated green spaces and open areas. I then overlaid this shapefile with Google Earth imagery to make sure that all major UGI was represented, looking for areas where UGI was missing or no longer present due to new construction or demolition. Afterwards, I made corresponding changes to the shapefile through digitization and/or feature deletion. Using this shapefile as a baseline, I made a field survey map to use as a guide in selecting UGI cases,

I then began my social and environmental field data collection with an initial field survey, spending two days walking around the study area and taking pictures of various types of UGI on the field survey map. I also made note of the key environmental features of each UGI case. After all UGI had been photographed and observed, I analyzed dominant features and differentiations in each UGI case and used this to determine seven different types of UGI typologies [*figure 5*]. I then used these typologies as baseline criteria for selecting diverse UGI cases, ensuring that

Urban Pocket Park	**Park: Normal**	**Park: Historic**	**Floodplain**
Park on Bischofsplatz	Alaunpark	Martin Luther Church Park	Elbe Floodplain West
Park on Ottostrasse	Hechtpark	St. Pauli Park	Elbe Floodplain East
Park on Albertplatz	Park on Koenigsplatz	Palaisgarten	Elbe Floodplain Central
	Olbrichtplatz	Staudengarten	
		Rosengarten	

Urban Forest	**Cemetary**	**Street Park**
Dresdener Heide	Inner Neustadt Cemetary	Hauptstrasse

Urban Pocket Park	Small public green spaces which offer amenities such as benches, platforms or public art; natural features are generally not the dominant feature
Park: Normal	Large public green space; natural features are the dominant feature
Park: Historic	Public green space oriented around a historical monument
Street Park	Pedestrian-only street where biogenic infrastructure is a dominant feature
Floodplain	Open floodplain or meadow
Urban Forest	Large forested area with public trails and access points
Cemetary	Cemetary with public access

Figure 5: Typologies of UGI in Neustadt

each typology was represented at least once. I also took care to ensure that UGI cases were spatially distributed throughout the study area and not concentrated in only one district. Accordingly, I selected 18 cases to serve as proxies for the greater UGI network in the Neustadt study area [*figure 6, Figures 7.1-7.18*].

After selecting my UGI cases, I documented the surface type for each UGI case and determined corresponding coverage ratios. Surface types included ten different vegetated and non-vegetated surfaces which are characteristic in Dresden. I then applied a framework developed by the researchers at the Leibniz Institute in Dresden[1] which assigns performance coefficients to each surface

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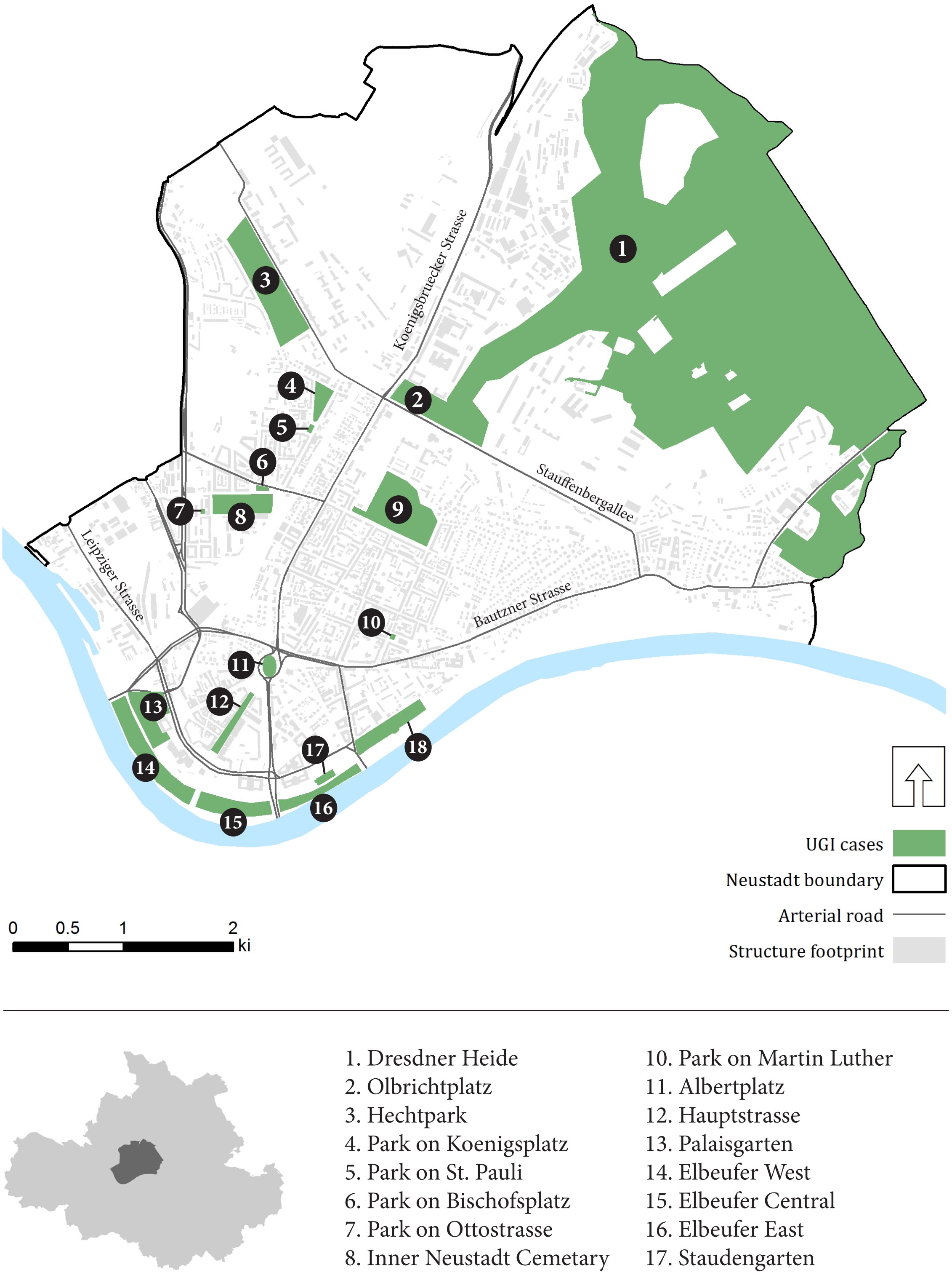
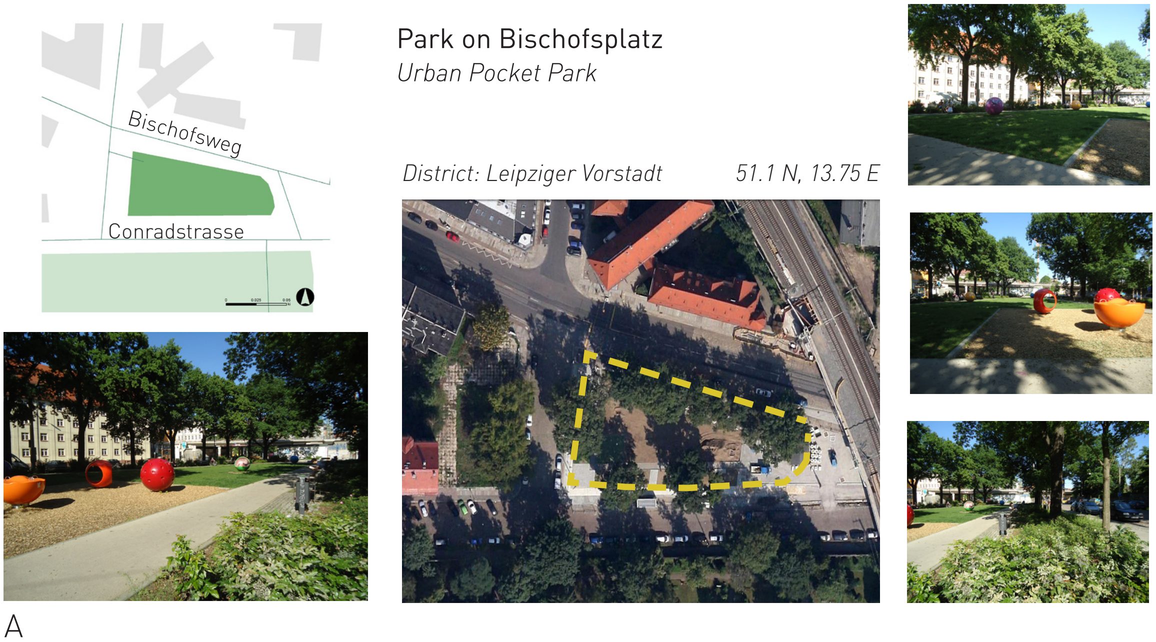
[1] Arlt, et al. 2005



1. Dresdner Heide
2. Olbrichtplatz
3. Hechtpark
4. Park on Koenigsplatz
5. Park on St. Pauli
6. Park on Bischofsplatz
7. Park on Ottostrasse
8. Inner Neustadt Cemetary
9. Alaunpark
10. Park on Martin Luther
11. Albertplatz
12. Hauptstrasse
13. Palaisgarten
14. Elbeufer West
15. Elbeufer Central
16. Elbeufer East
17. Staudengarten
18. Rosengarten

Figure 6: UGI Case Selection Overview



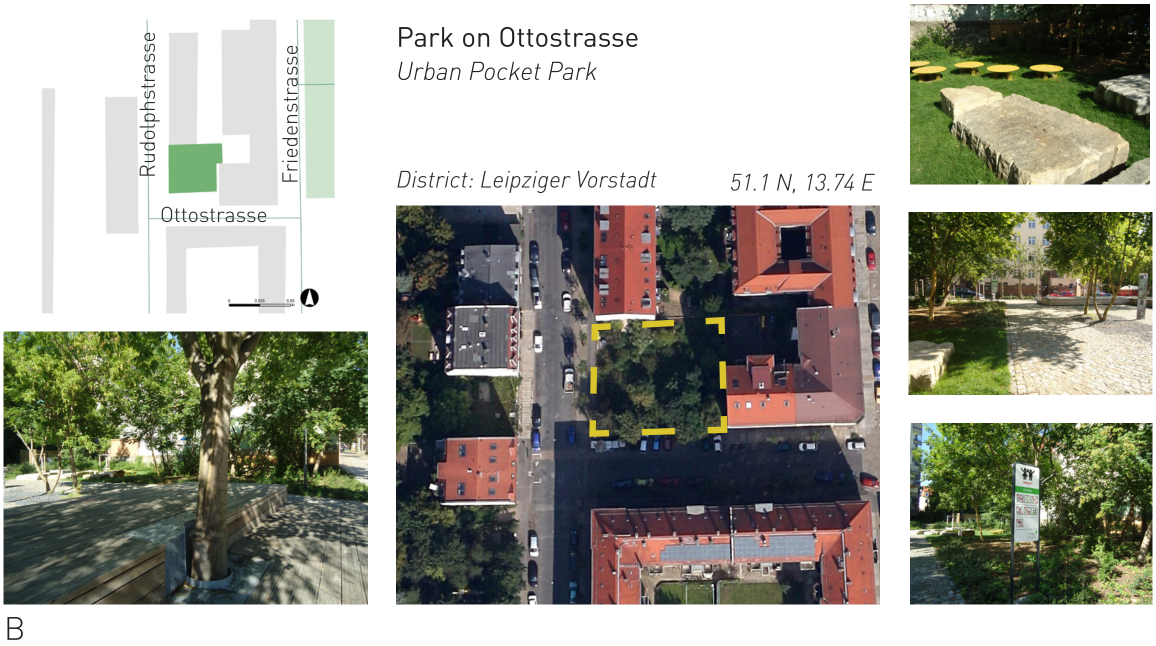
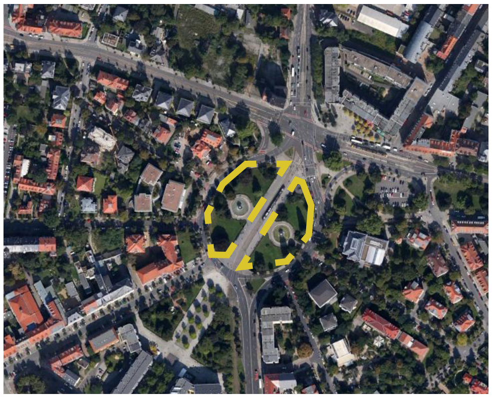


Figure 7: UGI Case Selections

Park on Albertplatz

Park: Normal

District: Innere Neustadt *51.06 N, 13.75 E*



C

Hechtpark

Park: Normal

District: Leipziger Vorstadt *51.09 N, 13.74 E*

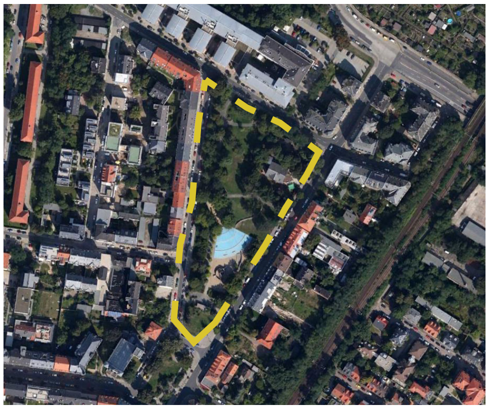
D

Figure 7, cont.

Park on Koenigsplatz

Park: Normal

District: Innere Neustadt *51.08 N, 13.75 E*



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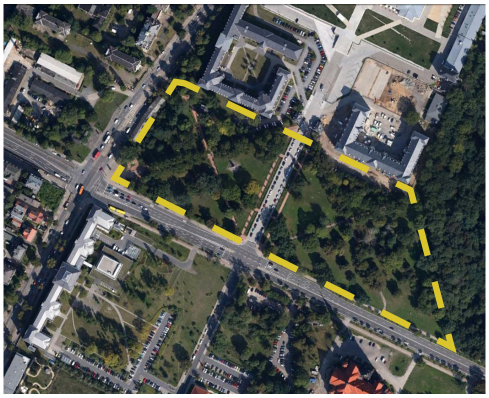
Olbrichtplatz

Park: Normal

District: Albertstadt *51.08 N, 13.76 E*



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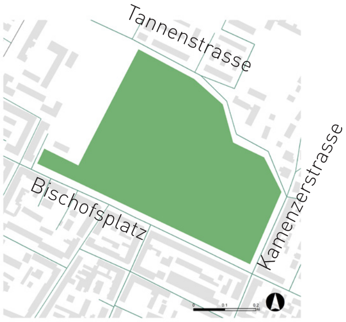

Alaunpark

Park: Normal

District: Auessere Neustadt *51.07 N, 13.76 E*

G

St Pauli Park

Park: Historic

District: Leipziger Vorstadt *51.07 N, 13.75 E*

H

Figure 7, cont.

Palaisgarten

Park: Historic

District: Innere Neustadt *51.06 N, 13.74 E*

I

Staudengarten

Park: Historic

District: Innere Neustadt *51.06 N, 13.75 E*

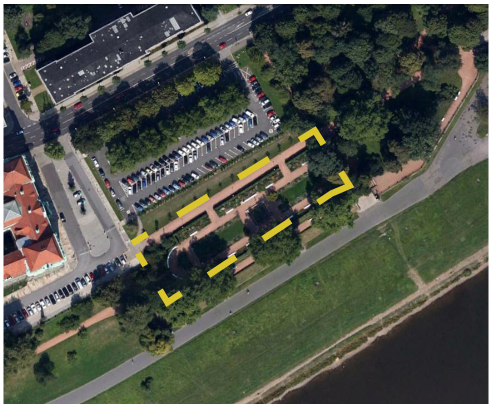

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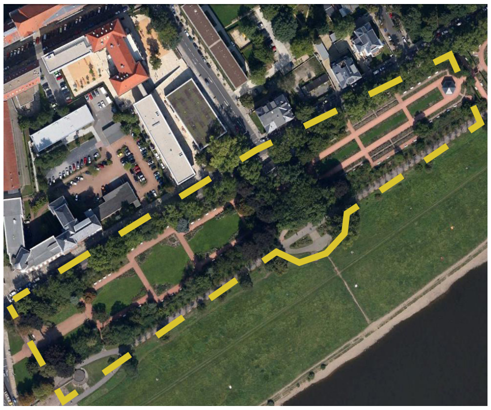
Figure 7, cont.

Rosengarten

Park: Historic

District: Innere Neustadt *51.06 N, 13.76 E*



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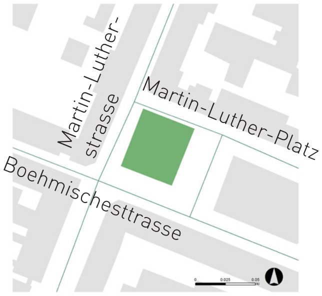

Martin Luther Church Park

Park: Historic

District: Auessere Neustadt *51.06 N, 13.75 E*

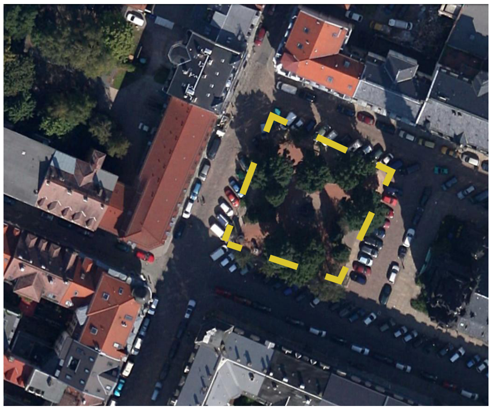

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Figure 7, cont.

Elbewiese West

Floodplain

District: Innere Neustadt *51.06 N, 13.74 E*

M

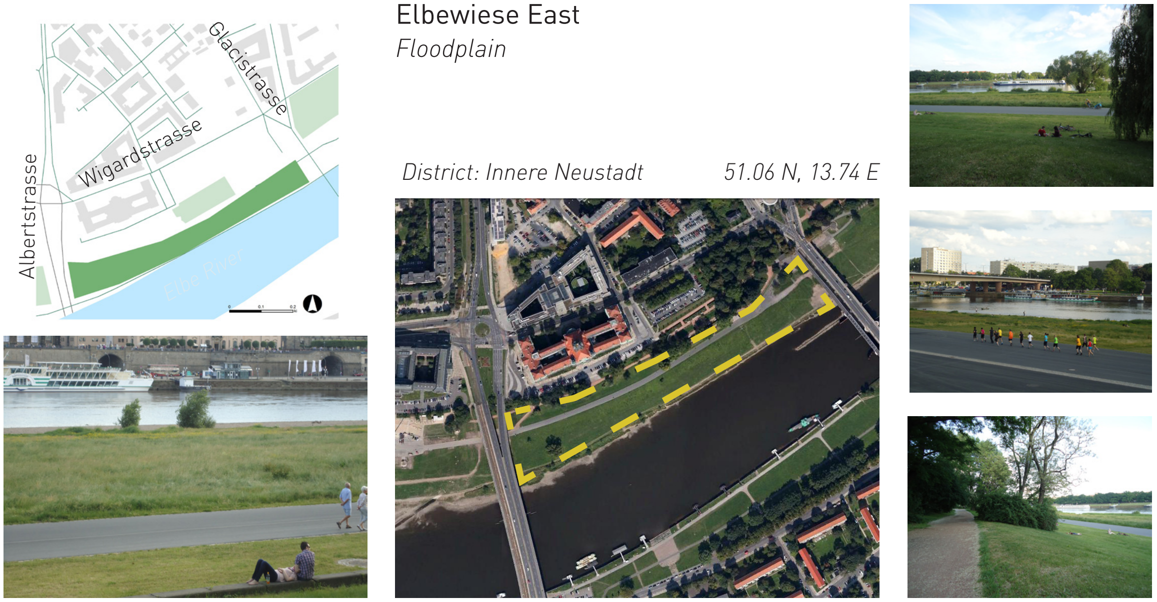
Elbewiese Central

Floodplain

District: Innere Neustadt *51.05 N, 13.74 E*

N

Figure 7, cont.



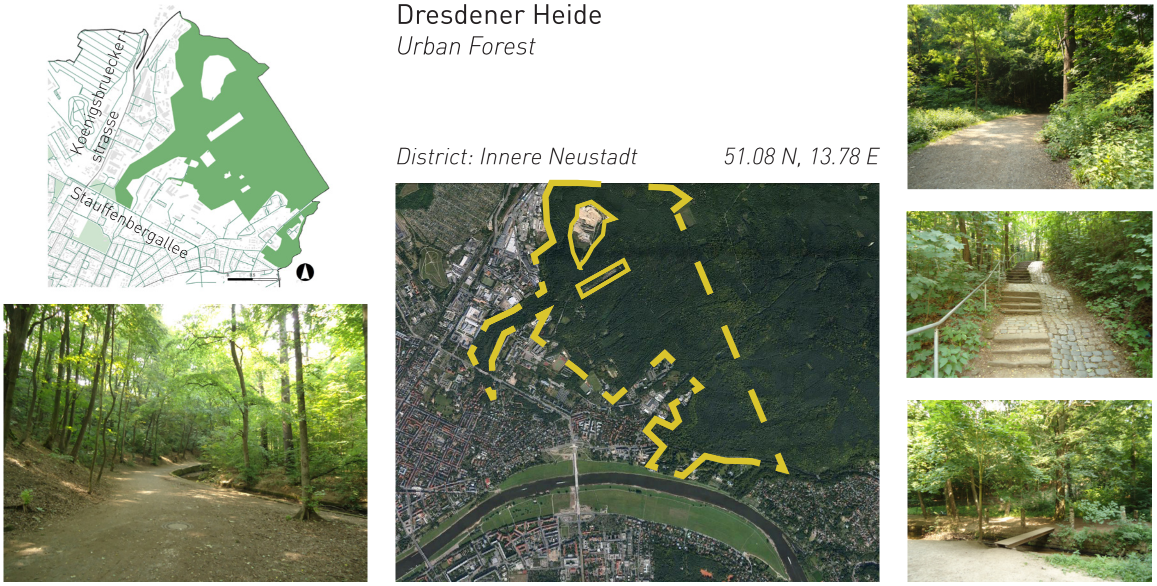
Elbewiese East

Floodplain

District: Innere Neustadt

51.06 N, 13.74 E

O



Dresdener Heide

Urban Forest

District: Innere Neustadt

51.08 N, 13.78 E

P

Figure 7, cont.

Inner Neustadt Cemetary
Cemetary

District:Leipziger Vorstadt *51.07 N, 13.74 E*

Q

Hauptstrasse
Living Street

District: Innere Neustadt *51.06 N, 13.75 E*

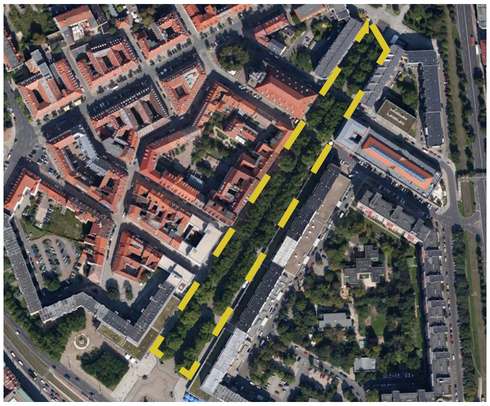


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Figure 7, cont.

type, and uses coverage ratios to determine environmental function. Performance coefficients are ranged in value from 0-1, indicating the capacity of certain types of surfaces to provide certain ecosystem services, e.g. to regulate water cycles or air quality. These performance coefficients were developed by Leibnitz researchers in a series of studies on surfaces in Dresden and have since been used as a baseline to measure the environmental functions of various types of development in Saxonia. These environmental functions describe different types of urban ecosystem services which Leibnitz researchers determined to be of primary importance. The seven environmental functions articulated by Leibnitz and measured in this study include: (a) climate regulation; (b) dust-binding capacity, (c) rainwater infiltration, (d) groundwater recharge, (e) biotope-generation capacity, (f) permeability and porosity, and (g) pollution retention and removal.

In order to collect social data, I observed the behavior of park users at each UGI case and documented various use types at peak and non-peak times. I used behavioral observation guidelines established by the Project for Public Spaces [PPS]. PPS is a NYC-based organization which has researched over 1,000 public spaces around the world to investigate placemaking and determine how residents interact in various urban settings. Accordingly, PPS has established a useful framework for public observation including a combination of behavioral and trace observation. Whereas behavioral observation includes making notes on all visible types of social activity, trace observation consists in documenting 'signs of use', such as litter or bike tracks. In conjunction with this data collection method, I then determined social functions of UGI cases by using the sociotope mapping framework established by Stahle[1] which consists of deriving social use values from field observation. In

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[1] Stahle 2006

this framework, observation data was analyzed to determine the different types of unique uses and qualities which attract users. These can include characteristics which encourage a certain type of interaction, such as wilderness or shade, or use types such as quiet activity or recreation. Once these use values were refined by combining similar activities and characteristics, they are called social functions. Accordingly, 12 different social functions were measured in this study by observing which UGI cases exhibited these characteristics, or showed signs of these uses on any occasion.

Once both social and environmental functions had been determined for each UGI case, I entered and summed all functional outcomes in Excel. Functional outcomes indicate how many total functions each UGI case serves. I then entered this data into GIS in order to determine whether the different UGI cases met the criteria to be considered one of three different types of spatial phenomena: emergence, social hotspots, and environmental hotspots. Emergence describes a UGI case with a high number of both social and environmental functions. Social hotspot describes a UGI case with a high number of social functions and a low number of environmental functions, while environmental hotspot describes a UGI case with a high number of environmental functions and a low number of social functions. In order to analyze these there phenomena in GIS, I established thresholds to determine what is considered to be a 'high' or 'low' number of functions. These were determined by looking at the average number of functions for both social and environmental data and determining which UGI cases were above and below average values. Accordingly, I then analyzed high and low functioning UGI in GIS using the overlay function to determine emergence, social and environmental hotspots. In the following chapter, I present the methods I used to conduct this analysis in greater detail.

Chapter 3:

Quantifying and Analyzing Environmental and Social Functions

Quantifying Environmental Function

My first step was to determine what environmental functions each UGI case performed. Using the Leibnitz Framework[1] which uses surface types and coverage ratios to determine performance measures for various environmental functions, the following was measured for each UGI case:

1. Climate regulation
2. Dust-binding capacity
3. Pollution removal and retention
4. Permeability and porosity
5. Groundwater recharge
6. Rainwater infiltration
7. Biotope-generation capacity

There are two procedural steps involved with applying the Leibnitz Framework: (a) determining ratio percentages of various surface types for each UGI case, and (b) applying functional coefficients and a mathematical formula to quantify outcome. The ten different surface types used in this analysis are depicted in figure 8, as are the associated coefficients and equation in figure 9.

In order to determine coverage ratios, I used two different methods depending on the context of each specific UGI case. One method used aerial control points and the other a visual assessment. The aerial control point method was applied in each case when possible. Visual assessments were only used in instances when a UGI case did not have aerially discernable surface cover transitions, rendering control points infeasible. In order to ensure that both methods were of comparable

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[1] Arlt, et al. 2005

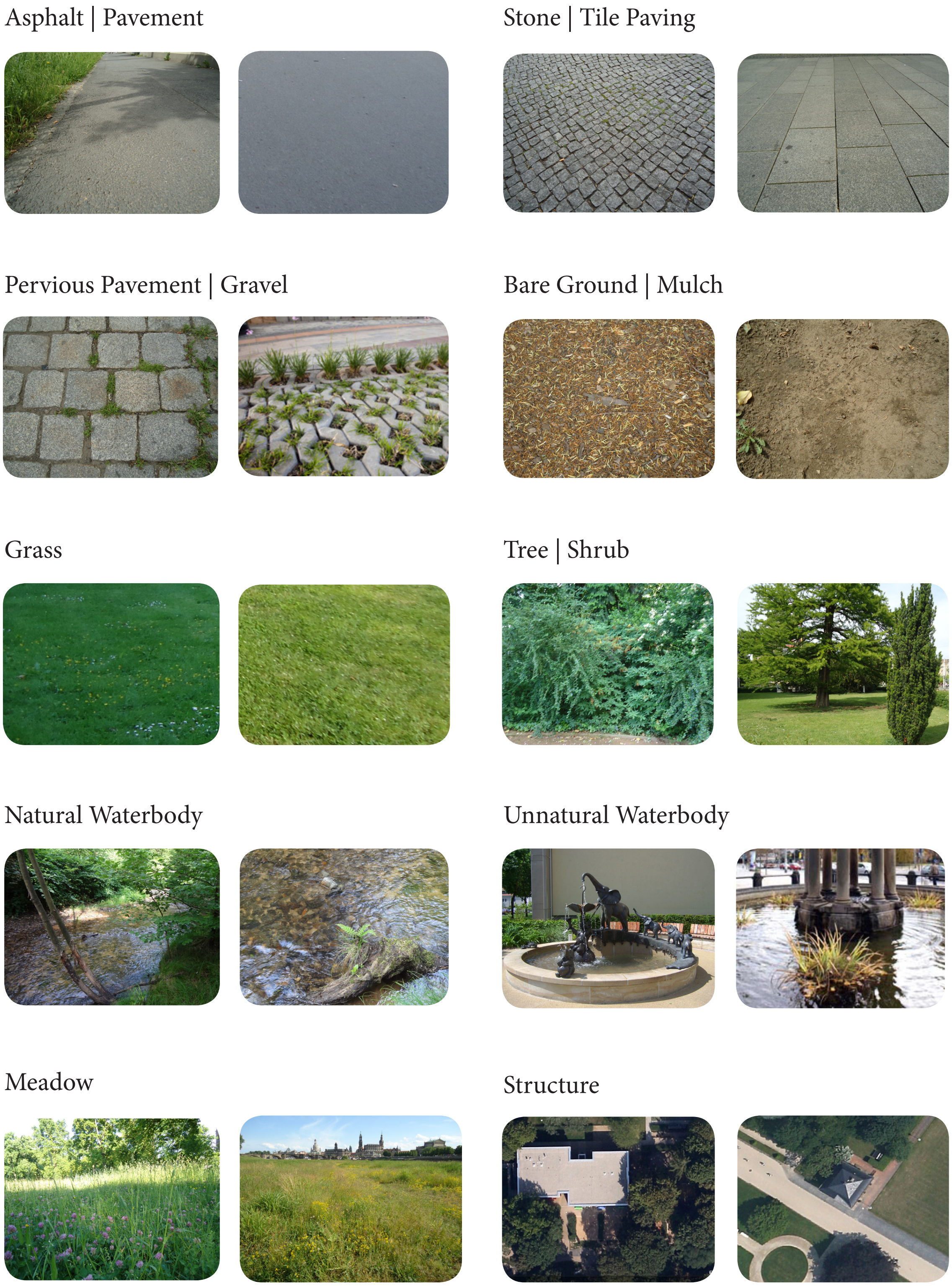

Figure 8: Dresden Surface Types

$$ESP_n = \sum_{j=1}^{12} SP_{\text{Cover Type}_j} * RP_{\text{Cover Type}_j}$$

$$\text{Avg. ESP} = \frac{\sum_{n=1}^{7} ESP_n}{7}$$

ESP = Ecological Surface Performance
SP = Surface Performance
RP = Ratio Percentage

Performance Coefficients

	SEALED		PARTIALLY SEALED			UNSEALED				
	Built Structure	Unnatural Water	Asphalt or Pavement	Stone or tile paving*	Pervious Pavement or Gravel*	Bare Ground	Grass	Tree or Shrub	Meadow	Natural Water Source
Climate Regulation	0	1	0	0.15	0.3	0.3	1	0.8	1	1
Dust-Binding Capacity	0	1	0	0.05	0.1	0.1	0.2	0.8	0.4	1
Pollution Removal or Retention	0	0	0	0.25	0.4	0.5	0.8	0.8	0.8	X
Permea-ability and Porosity	0	0	0.1	0.3	0.6	1	0.8	1	1	1
Ground-water Recharge	0	0	0	0.4	0.8	1	0.5	0.5	0.5	1
Rainwater Infiltration	0	0	0.1	0.45	0.5	1	0.8	0.9	1	1
Habitat Potential	0.1	0	0.1	0.25	0.4	0.5	0.6	0.9	1	1

Figure 9: Leibnitz Framework for Quantifying Environmental Function based on Surface Cover

accuracy, I reviewed a number of studies which compared methodologies for determining vegetation coverage ratios. Sufficient evidence was found to prove that – if carefully conducted – most statistical differentiations in control points and visual assessment methods are insignificant[1]. Accordingly, this study assumes that either method selected will produce outcomes of similar accuracy.

Both methods first required making field survey sketches of each UGI case. To do this, I printed out large aerial images of each UGI case and drew on these images on-site, making note of various surface types. In cases where aerial control points were infeasible, for example in heavily canopied UGI, I used the sketches and notes from the field survey were to estimate coverage ratios. Whenever possible, I subsequently applied aerial control points.

Using aerial control points to determine coverage ratios consists of assigning random points to an aerial image and noting down which surface type the point reflects. These points are then used as indicators of coverage ratios based on occurrence frequency. In this study, I used i-Tree Canopy software to randomly generate control points within the project area. I imported an ESRI polygon Shapefile depicting boundaries of the selected UGI cases into i-Tree Canopy; which are then automatically overlaid with Google Earth images. The ten surface types of the Leibnitz Framework were then entered into the system for reference [*figure 8*]. For each subsequent coverage ratio assessment, 100 - 300 control points were used, depending on the size of the UGI case [*figure 10]*. The field survey sketches were used to aid in identifying surface cover types at each aerial point, in instances when this was difficult to determine (ex: bare ground and gravel).

Once I determined the surface types and coverage ratios for each UGI

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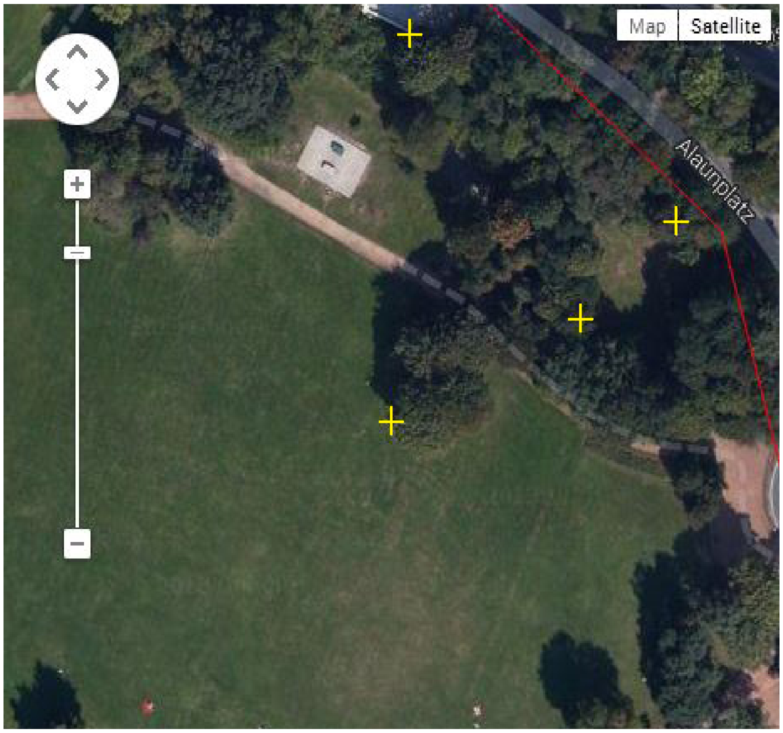
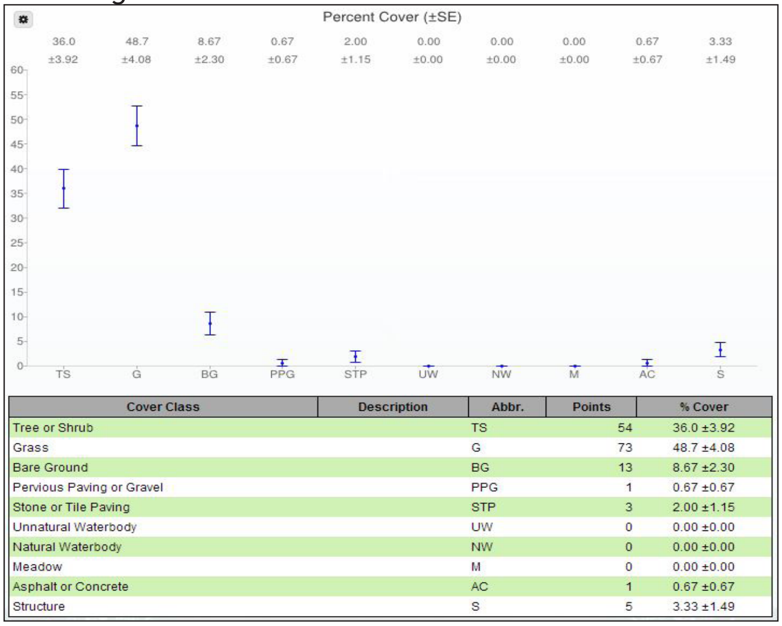
[1] Dethier et al. 1993, Meese et al. 1992

Control Points



Coverage Ratio Results



Cover Class	Description	Abbr.	Points	% Cover
Tree or Shrub		TS	54	36.0 ±3.92
Grass		G	73	48.7 ±4.08
Bare Ground		BG	13	8.67 ±2.30
Pervious Paving or Gravel		PPG	1	0.67 ±0.67
Stone or Tile Paving		STP	3	2.00 ±1.15
Unnatural Waterbody		UW	0	0.00 ±0.00
Natural Waterbody		NW	0	0.00 ±0.00
Meadow		M	0	0.00 ±0.00
Asphalt or Concrete		AC	1	0.67 ±0.67
Structure		S	5	3.33 ±1.49

Figure 10: Determining Coverage Ratios through the Control Point Method

case, I applied the mathematical formula from the Leibnitz Framework [*figure 8*] in order to assess performance capacity for each of the seven environmental functions listed above. In order to do this, I entered the coverage ratio percentages for each surface type [*table 1*] into Excel where they could easily be multiplied by their performance coefficients and summed. Outcomes ranged from 0-1, with 0 indicating 'no performance', and 1 indicating 'maximum performance' [*table 2*]. Given the range of outcomes between 0 and 1, it was necessary to establish a threshold to determine which numerical values were significant (i.e. the numerical outcome was high enough to assume that the UGI serves a given function) or insignificant (i.e. the numerical outcome was too low to assume that UGI serves a given function). To do this, I averaged all outcomes for each environmental function and used these average values as basis to determine which UGI cases serve a given function—in essence, if the outcome for a UGI case was over the average value, it was determined to serve that function [*figure 13*].

CASE	Built Structure	Unnatural Water	Asphalt	Stone Paving	Pervious Paver or Gravel	Bare Ground	Grass	Tree or Shrub	Meadow	Natural Water Source
Park on Bischofsplatz	0	0	0.07	0.05	0.12	0	0.42	0.34	0	0
Park on Albertplatz	0	0.0891	0.0198	0.198	0	0	0.337	0.365	0	0
Alaunpark	0.0333	0	0.0067	0.02	0.0067	0.0867	0.487	0.36	0	0
Hechtpark	0	0	0	0.01	0.01	0.1	0.14	0.74	0	0
Park on Koenigsplatz	0	0	0	0	0.28	0	0.227	0.493	0	0
Park on Ottostrasse	0.08	0	0	0	0.2	0	0.3	0.42	0	0
Elbewiese West	0	0	0.02	0	0.01	0.03	0.1	0.05	0.79	0
Elbewiese Central	0.01	0	0.04	0	0.03	0.02	0.15	0.03	0.72	0
Elbewiese East	0	0	0.04	0	0.02	0.01	0.05	0.1	0.78	0
Dresdner Heide	0	0	0	0	0.01	0.01	0.1	0.85	0.01	0.02
Inner Neustadt Cemetary	0	0	0	0.03	0.02	0.08	0.57	0.3	0	0
Olbrichtplatz	0.01	0	0	0	0.01	0.09	0.24	0.65	0	0
Martin Luther Church Park	0	0.01	0	0.1	0.2	0	0.4	0.29	0	0
St. Pauli Park	0.01	0	0	0.01	0.1	0	0.71	0.17	0	0
Palaisgarten	0	0	0.01	0.03	0.07	0.01	0.55	0.33	0	0
Staidengarten	0.01	0.01	0.01	0.02	0.15	0	0.55	0.25	0	0
Rosengarten	0.02	0	0.03	0.03	0.3	0.02	0.31	0.29	0	0
Hauptstrasse	0	0.02	0	0.2	0.2	0	0.3	0.28	0	0

Table 1: Coverage Ratio Outcomes

Value Ranking

CASE	Climate Regulation	Dust-binding Capacity	Pollution Removal or Retention	Permeability and Porosity	Groundwater Recharge	Rainwater Infiltration	Biotope Generation Capacity	**Aggregated Functions**
Park on Bischofsplatz	0.05	0.05	0.04	0.07	0.03	0.07	0.06	0
Park on Albertplatz	0.04	0.04	0.10	0.14	0.09	0.11	0.10	1
Alaunpark	0.02	0.02	0.02	0.01	0.00	0.01	0.01	5
Hechtpark	0.02	0.21	0.05	0.12	0.03	0.09	0.13	6
Park on Koenigsplatz	0.08	0.05	0.02	0.00	0.06	0.04	0.43	3
Park on Ottostrasse	0.09	0.00	0.05	0.06	0.00	0.08	0.03	0
Elbewiese West	0.15	0.04	0.06	0.12	0.02	0.15	0.24	5
Elbewiese Central	0.12	0.07	0.03	0.07	0.03	0.11	0.18	5
Elbewiese East	0.13	0.01	0.05	0.11	0.03	0.13	0.24	5
Dresdner Heide	0.03	0.31	0.07	0.14	0.01	0.09	0.18	6
Inner Neustadt Cemetary	0.06	0.05	0.04	0.02	0.02	0.03	0.01	5
Olbrichtplatz	0.00	0.16	0.05	0.10	0.02	0.07	0.10	6
Martin Luther Church Park	0.07	0.07	0.05	0.08	0.02	0.07	0.07	1
St. Pauli Park	0.09	0.13	0.04	0.04	0.00	0.03	0.06	3
Palaisgarten	0.05	0.04	0.04	0.01	0.01	0.00	0.01	2
Staudengarten	0.02	0.08	0.00	0.05	0.00	0.05	0.06	2
Rosengarten	0.15	0.09	0.09	0.09	0.05	0.11	0.09	1
Hauptstrasse	0.15	0.09	0.11	0.14	0.01	0.12	0.12	1
AVERAGE	0.789	0.420	0.708	0.840	0.523	0.801	0.681	

🟨 Above average value

Table 2: Environmental Function Outcomes

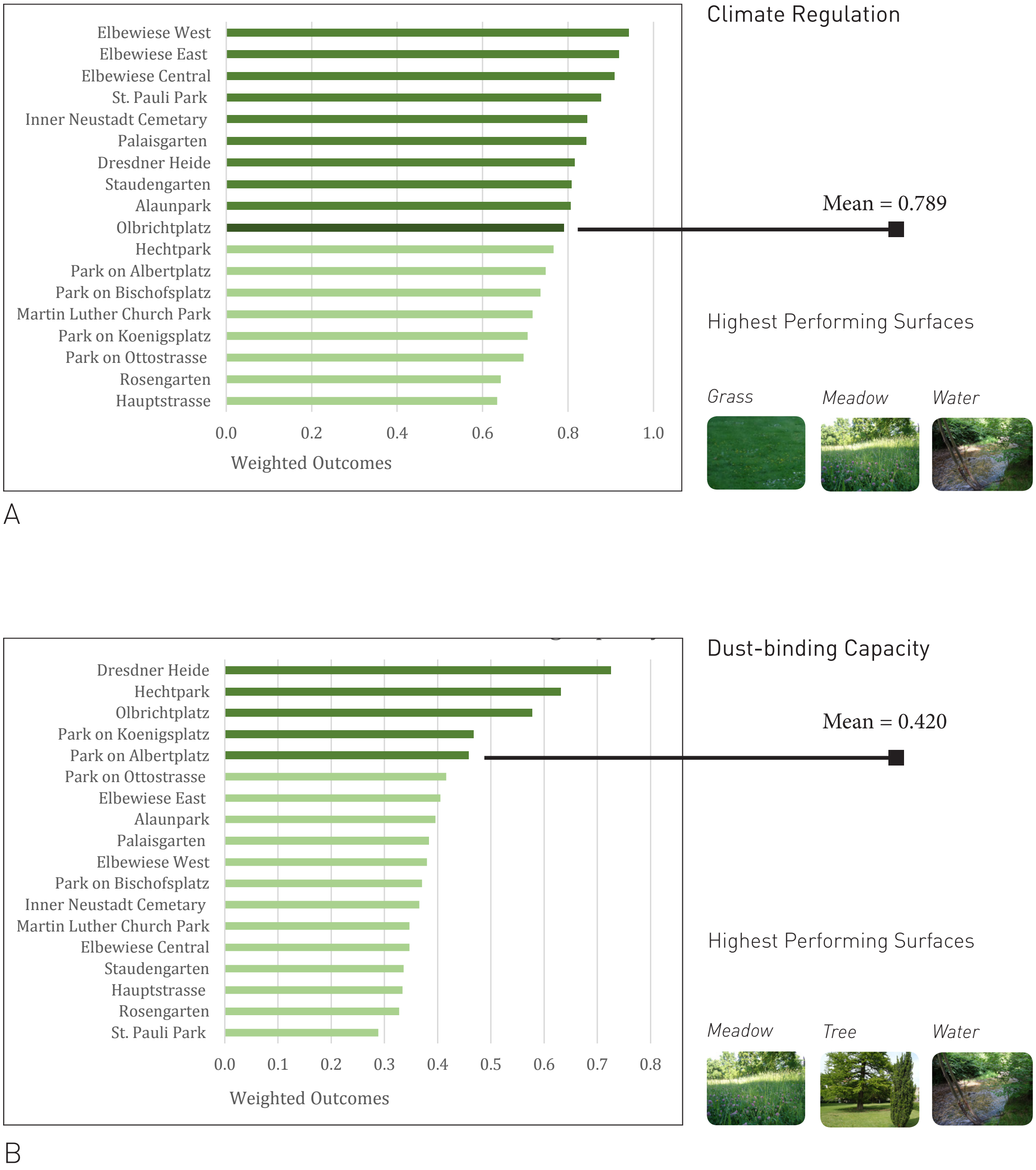
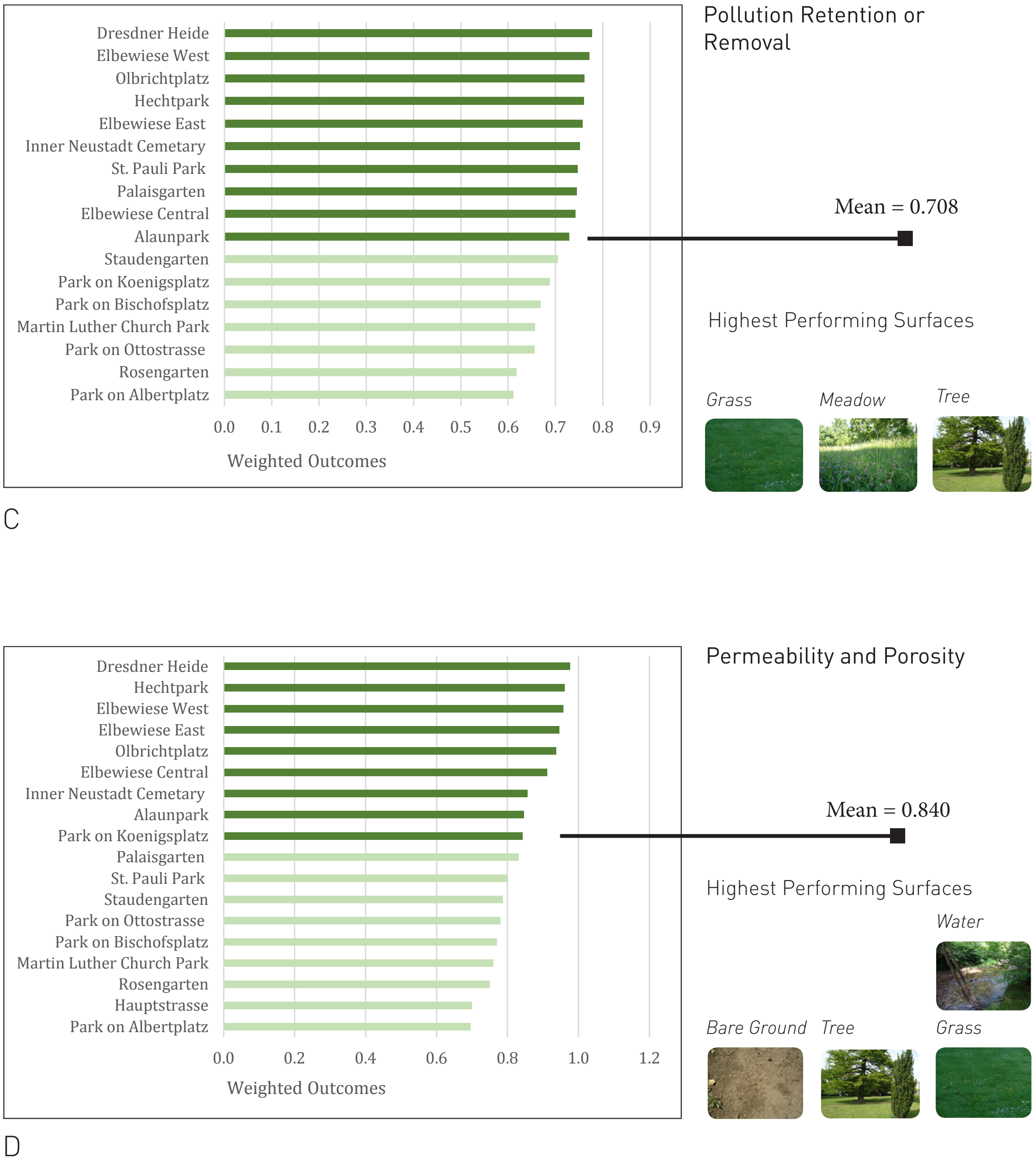


Figure 11: Ranking Environmental Function Significance



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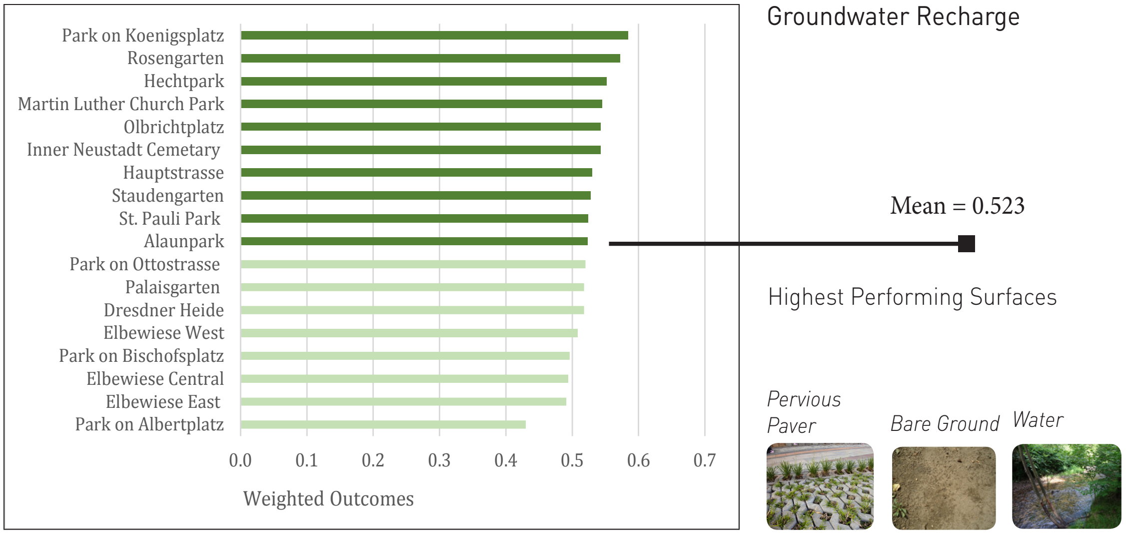

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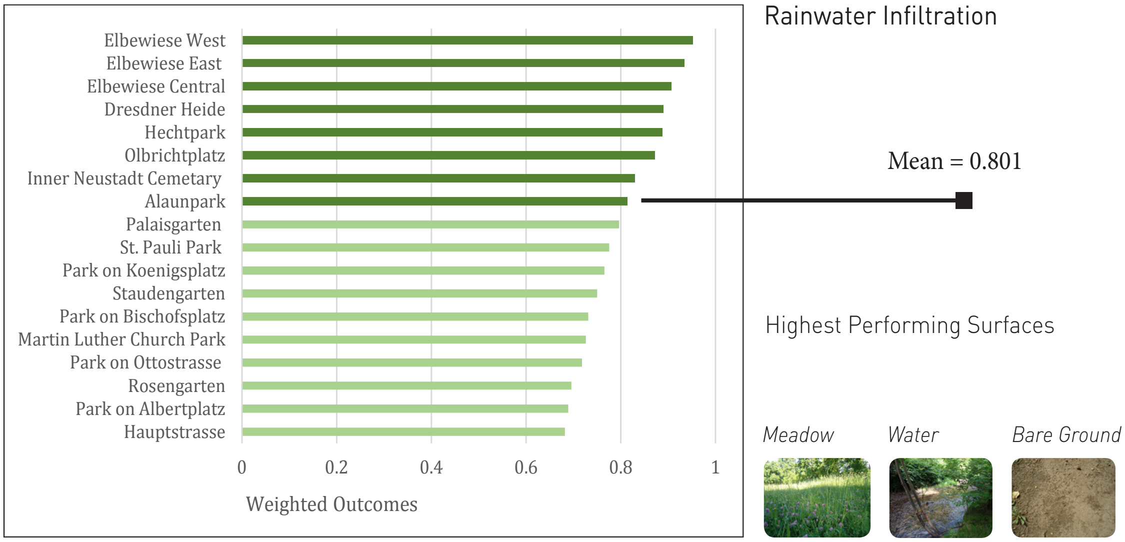

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Figure 11, cont.

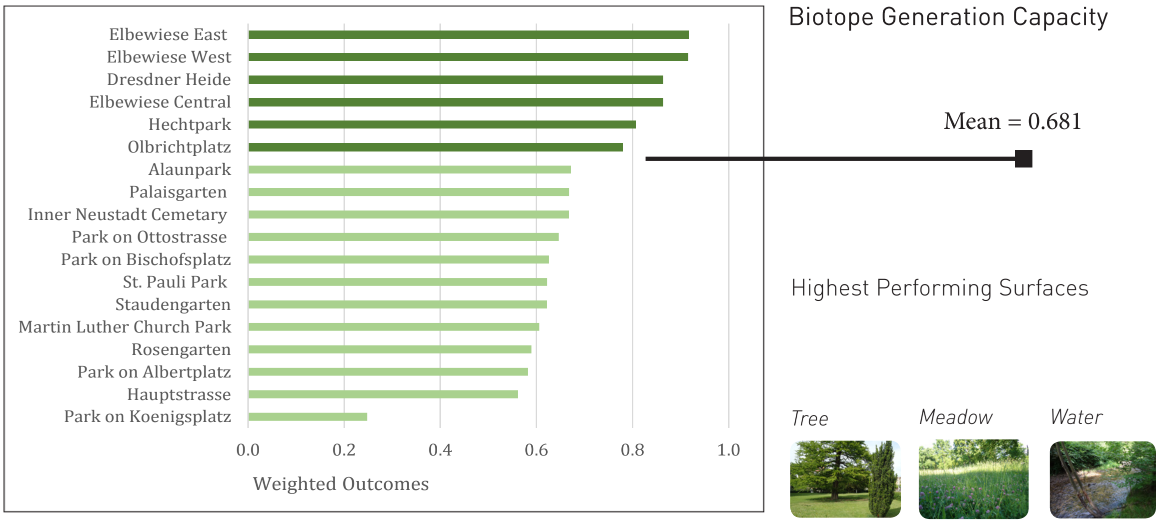

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Figure 11, cont.

Quantifying Social Function

In order to determine social function, I applied the Sociotope Mapping Methodology developed by Stahle[1] in my data collection and analysis. The first step in this framework is to get a general idea of how UGI is being used by conducting an initial field survey. The purpose of this initial field survey is to determine which social functions UGI serves in the study area—not to begin seeing which spaces fulfill these functions. Unlike the environmental functions which were already articulated by Leibnitz, social functions have to first be determined before they can then be measured.

To conduct the initial field survey, I observed each UGI case for 10-20 minutes each, and made note of all different uses and behaviors observed. I also approached at least three UGI users at each site to obtain insight on how they use and value these spaces. All of these comments were added to my notes. Once all this information was collected, I analyzed my data for similar activities and site characteristics and compiled a list of 17 social functions. I then cross-checked this list by conducting five semi-structured interviews with Neustadt residents whom I approached on the street (one resident in each of the five districts). With the help of these residents, I further condensed the list into 12 different social functions which are important for Neustadt UGI users [*table 3*].

After establishing categories of social functions, I then observed each UGI case a minimum of three times. Using the social function categories as a checklist, I made note of each social function I observed in all UGI cases. In accordance with observation guidelines drawn from the Project for Public Spaces, I observed all cases on at least three occasions, at different times of the day, and under various weather

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[1] Stahle 2006

Social Function	**Description**
Play	-Group recreation or organized activity such as bocce or soccer -Playing with pets
Exercise	Individual fitness activity such as jogging, skating, biking or yoga
Quiet Activity	Reading, working, people watching
Picnic or Grilling	Meal-oriented social activity
Crowds	Socializing in pairs or groups
Wilderness	-Interaction with nature by observing plants or natural features -School groups of students engaged in natural education activities -Wildcrafting
Inspiration	Drawing, painting, playing instruments
Street Diversion	A space that, although not a destination, offers a welcome detour from city streets
Rest	Sleeping. Reclining, Sunbathing
Forum	A place which attracts public events such as meetings, concerts or protests
Water-cooling	Wading, swimming, being sprayed with water
Shade-cooling	Seeking out shade

Table 3: Categories of Social Functions

conditions ("peak and non-peak times")[1]. All use types were noted through both direct observation as well as trace observation. For example, charcoal remnants and the remains of a single-use grill along the Elbe floodplain (*illustration 2*) would merit the classification of a 'Picnic or Grilling' social function, although this activity was not observed directly.

After data collection was completed, all observed social functions for each field survey were aggregated for each UGI case to determine the total number of social functions that each space serves [figure. Considering the range of outcomes and the number of social functions considered, high socially functioning UGI was determined to be areas which served six or more social functions.

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[1] Project for Public Spaces [PPS] 2000

CASE	Play	Exercise	Quiet Activity	Picnic or Grilling	Crowds	Water -cooling	Shade -cooling	Wilder-ness	Inspira-tion	Street Diversion	Rest	Forum
Park on Bischofsplatz	1	0	1	0	0	0	1	0	0	1	0	0
Park on Albertplatz	0	0	1	0	1	1	1	0	0	0	0	0
Alaunpark	1	1	1	1	1	0	1	0	1	1	1	1
Hechtpark	0	1	1	0	0	0	1	1	0	1	0	0
Park on Koenigsplatz	1	1	1	0	1	0	1	0	0	1	1	0
Park on Ottostrasse	0	0	1	1	0	0	1	0	1	0	0	0
Elbewiese West	1	1	1	1	1	1	0	0	1	1	1	1
Elbewiese Central	1	1	1	1	0	1	1	0	0	1	1	1
Elbewiese East	0	1	1	1	0	1	1	1	1	1	1	1
Dresdner Heide	0	1	1	0	0	1	1	1	1	1	0	0
Inner Neustadt Cemetary	0	0	1	0	0	0	1	0	0	1	0	0
Olbrichtplatz	0	0	0	0	0	0	1	0	0	1	1	0
Martin Luther Church Park	0	0	1	1	1	1	1	0	1	0	0	1
St. Pauli Park	0	0	1	0	0	0	1	0	1	0	1	0
Palaisgarten	0	0	1	0	0	0	1	0	1	0	0	0
Staudengarten	0	0	1	1	0	0	0	0	1	0	0	0
Rosengarten	0	1	1	0	0	0	1	0	1	0	0	0
Hauptstrasse	0	0	1	0	1	1	1	0	0	1	0	1

1 = Observed on **any** occassion
0 = Never observed

Table 4: Social Outcomes

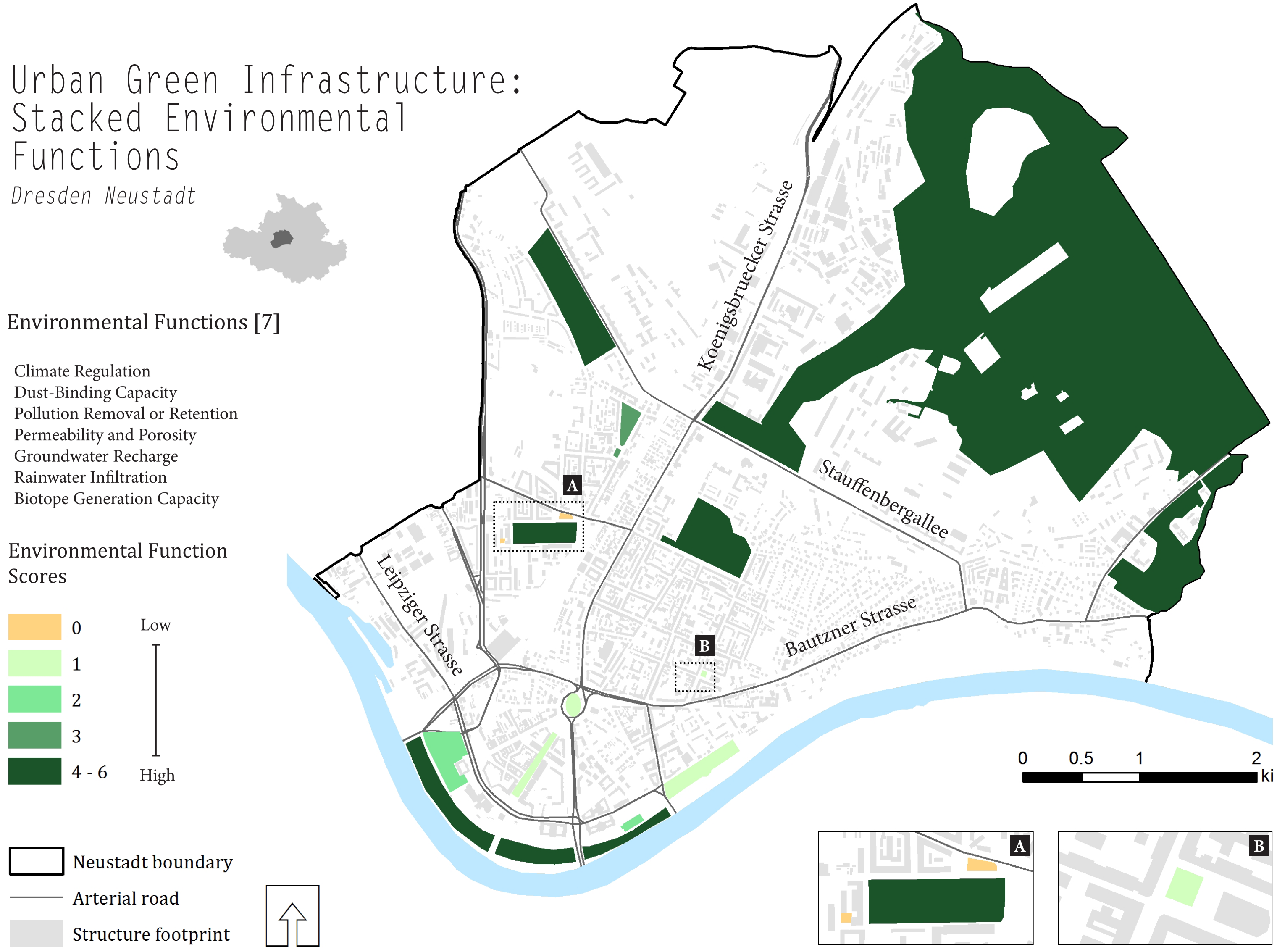
Illustration 2: Remnants of a of a disposable grill commonly used in Dresden

Combining Functions

After the environmental and social functions for each UGI case had been determined, I entered all functional outcomes into GIS for analysis. Using the thresholds discussed previously, high functioning environmental UGI was determined to be cases which served 5 or more environmental functions. Correspondingly, high functioning social UGI was determined to be cases which served 6 or more social functions. Using the 'select by attribute' function in GIS, I then isolated UGI cases of high environmental and social function, and made maps to show their spatial distribution [*figure 12, figure 13*]. Finally, I added together the values of social and environmental functions of each site [*figure 14*] and used a basic query in GIS to determine whether one of three distinct phenomena was present at each site:

1. *Emergence*: The co-location of high environmental and social functions
2. *Social Hotspots*: Areas of high social function, but low environmental function
3. *Environmental Hotspots*: Areas of high environmental function, but low social function

Once I had determined which UGI sites could be characterized as either sites of emergence, social hotspots or environmental hotspots, I then made a map to illustrate the spatial distribution of these sites and illustrate their frequency relative to all other case studies [*table 4*]. I finally used a field calculator in GIS to determine the occurrence percentages for each phenomena within the study area.



Datum: GCS Deutsches Hauptdreiecksnetz, Projection: Gauss Krueger Zone 3 | Created 5/2014

Figure 12: Spatial Distribution of UGI Environmental Function

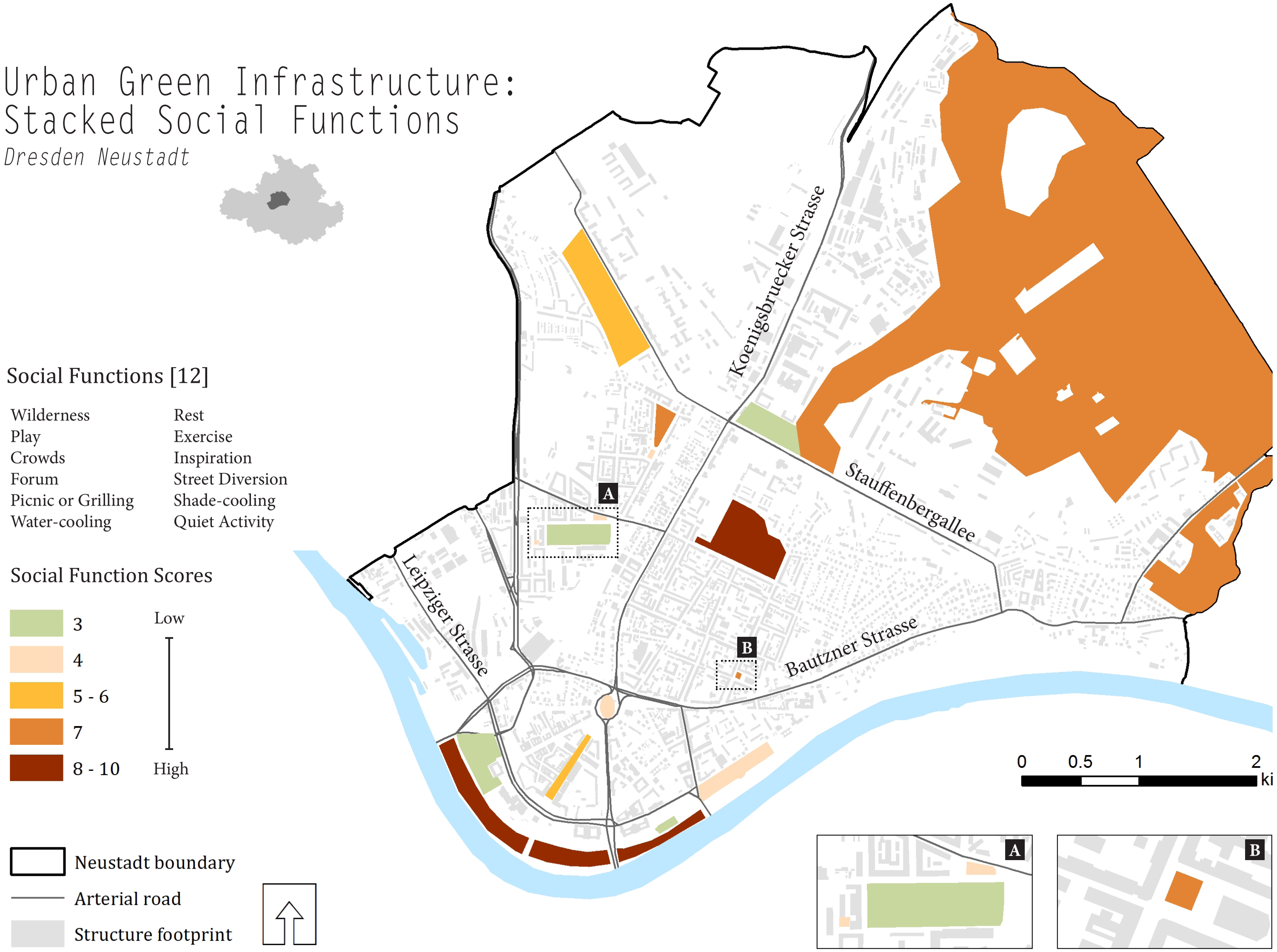


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Figure 13: Spatial Distribution of UGI Social Function

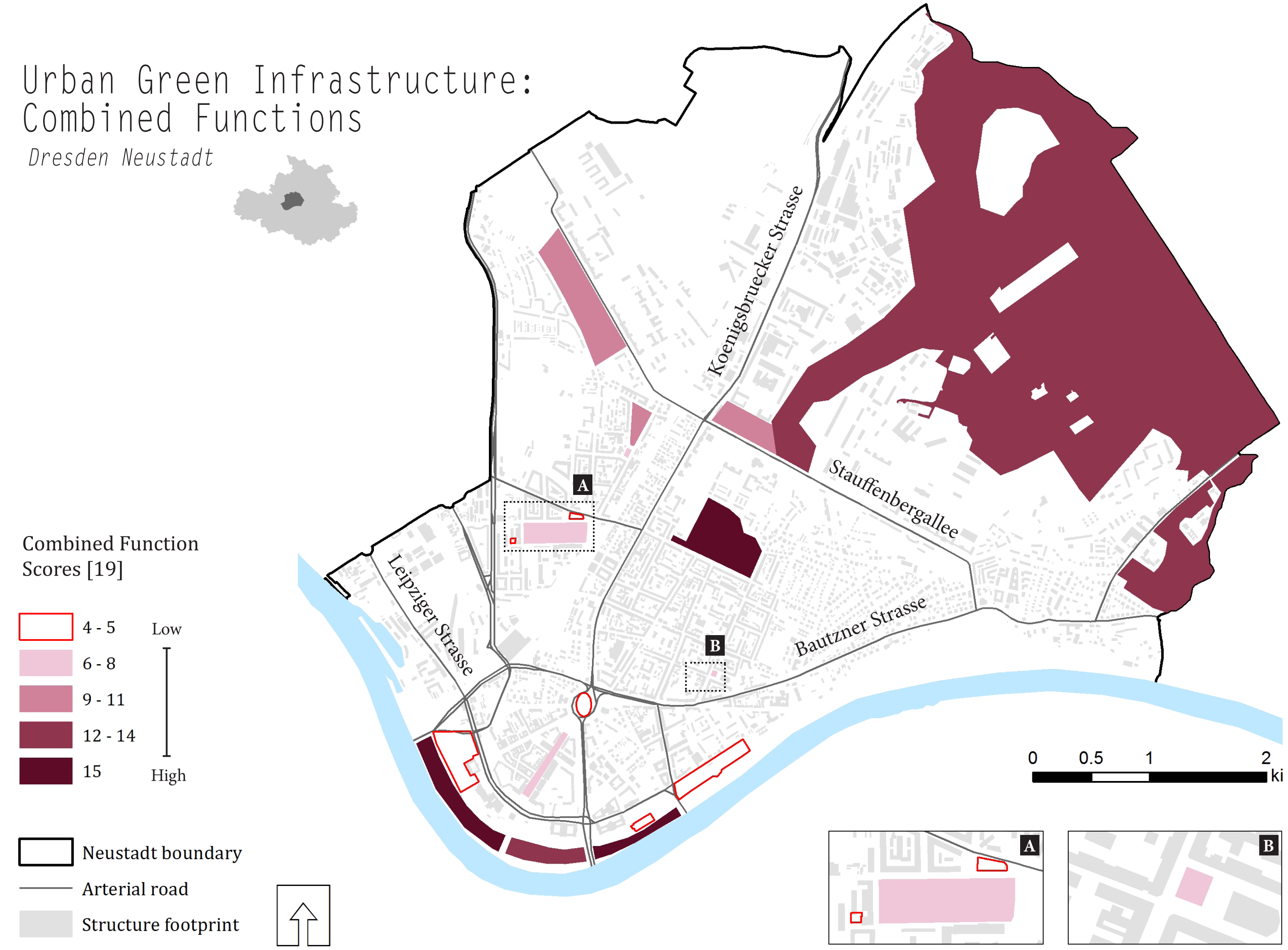

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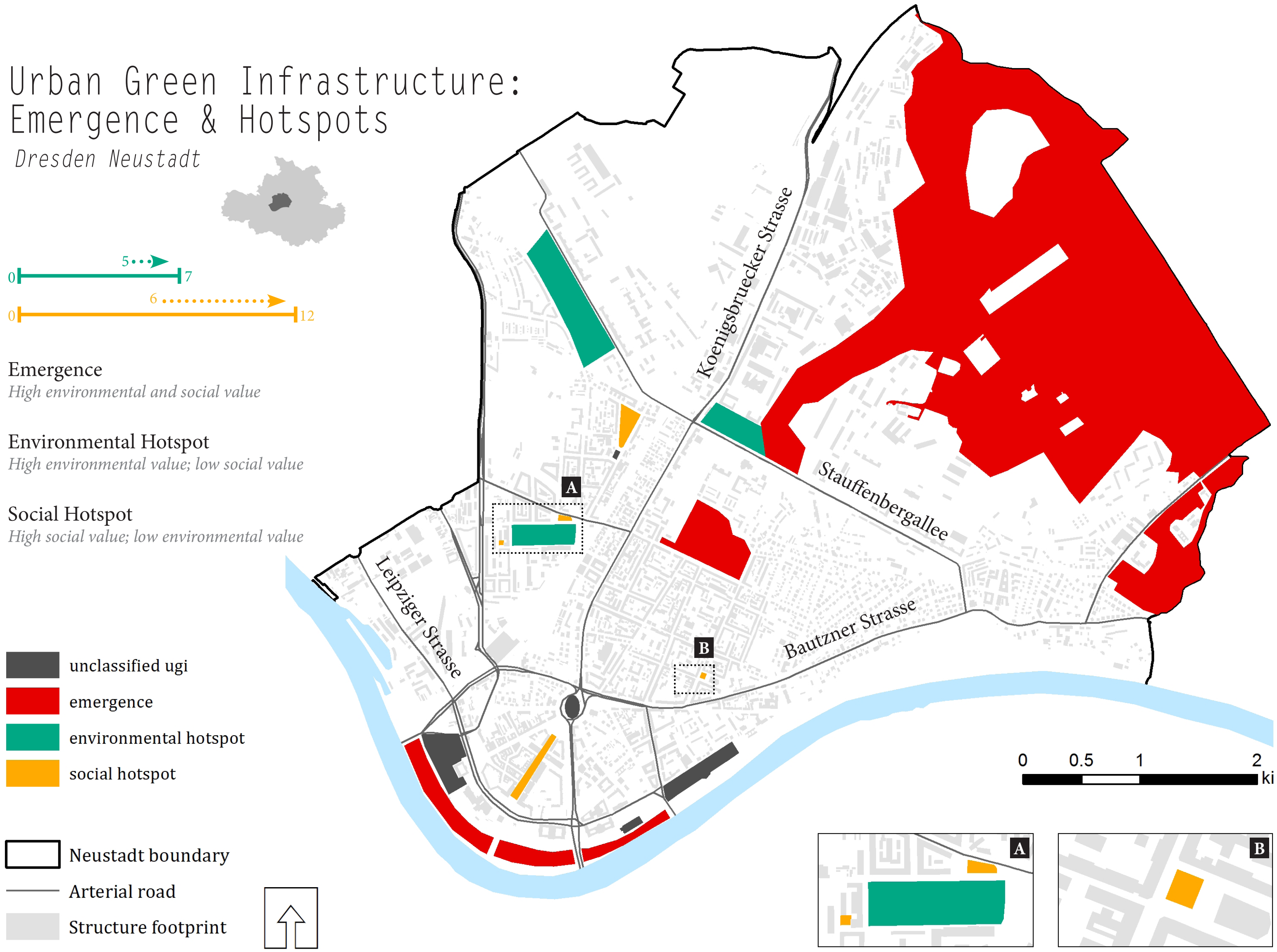
Figure 14: Spatial Distribution of UGI Combined Function



Datum: GCS Deutsches Hauptdreiecksnetz, Projection: Gauss Krueger Zone 3 | Created 5/2014

Figure 15: Spatial Distribution of UGI Emergence, Environmental Hotspots and Social Hotspots

Challenges and Limitations

I faced a number of challenges while conducting this study. Regarding environmental function, it is recognized that UGI size, connectivity and conditions are also essential to performance capacity. However, because this study seeks to look at all UGI as of potentially equal value, these factors were not considered in gauging environmental function. Another reason for this is that more and more cities are starting to engage in Low Impact Design strategies to engender positive environmental externalities [ex: New York City, Seattle, Portland]. Low Impact Design is generally implemented at the site level in many different city locations to achieve positive environmental outcomes at both the neighborhood and greater city scale. Accordingly, this study is meant to begin to explore how even seemingly small or "insignificant" spaces are valued, used and understood. Therefore, all UGI cases were judged based upon the same standardized criteria and looked at only through the lens of their surface types and coverage ratios.

Another significant limitation of this study was the number of cases used. Ideally, a larger sample would have been more effective in conducting a multivariate analysis; however, this was not possible because of time and funding limitations. Also, UGI cases were observed over a period of 2-3 weeks in early summer. It could be that social use values change, increase or diminish at other times of the year. In this regard, vegetative coverage and environmental performance also changes with the seasons. However, this study could not take that into account. Ideally, observation would take place multiple times throughout the year.

Regarding the assessment and combination of social and environmental functions, all functions are considered of equal value. This impacts study outcomes in that functions which are considered to be the most critical are not given more weight than other functions. However, because this study is looking at multifunctionality, variable weighting would have complicated - and potentially deviated - from original study objectives. If appropriate for a given urban context, functional weighting may be appropriate following the standard methods outlined in this study.

In quantifying social function, it should also be taken into consideration that not all UGI uses are easily determined or identified and even uses that were observed were subject to various assumptions. For example, identifying whether or not residents were using a UGI space for interaction with the natural environment, exercise or solitude was not always easy to determine, and certain signals had to be used as assumptions—such as the type of clothes worn (exercise clothes or running shoes), whether the person was seen picking up and examining vegetation or where they chose to sit in relation to other people.

Another limitation to social observation is considering the potential for hidden uses of UGI spaces. Although UGI was observed at both peak and non-peak times, certain uses (e.g. those that occur in the middle of the night) would have been harder to observe, or they were missed entirely. Also, illicit, unwanted or illegal uses were not considered in this study. Because the inclusion of these use types would generate other sets of implications, this is recommended to include in future research.

Chapter 4:
Findings

Results of the data collection and analysis discussed above shows that UGI sites in the Dresden Neustadt perform distinct environmental and social functions. Although 61% of UGI cases could be characterized as sites of emergence, social hotspots or environmental hotspots, some sites with high environmental function serve limited social functions, and vice versa. This study suggests that the presumed significance of UGI sites depends greatly on the value given to different social and environmental functions, which has important implications for priority-setting in UGI planning.

Environmental Outcomes

Regarding environmental function, UGI cases in the Neustadt varied drastically in relation to their vegetative assemblages and/or coverage ratios, showing that the Neustadt contains a considerable range of landscape diversity. For example, tree/shrub coverage ratios ranged from 10% - 15% on the open meadowland of the Elbewiese cases, in comparison to an overwhelming 85% in the Dresdner Heide. This diversity in surface types and coverage ratios is what ultimately resulted in great outcome variability, as ratios are directly correlated to their respective surface performance coefficients. Accordingly, the seven measured environmental functions exhibited distinct spatial distributions and performance contributions throughout the study area [FIGURE X].

Although all seven environmental functions had considerable outcome variability, some variables had considerably more range than others. Biotope generation and dust-binding capacity are two prime examples of where outcomes encompassed a broader numerical spectrum relative to other environmental functions, meaning that high-functioning UGI for these specific functions were more rarely occurring. This variation in outcome range dictates that certain surfaces types in Dresden are more 'critical' for producing specific environmental functions, as compared to other environmental functions which are supported by a variety of surface types. In the case of biotope generation capacity for example, only three surface types in Dresden make considerable contributions to this environmental outcome, namely; (i) natural water source, (ii) tree or shrub, and (iii) meadow. This indicates that only UGI with high percentages of canopy cover, natural water sources and/or meadow are capable of making greater contributions to sustaining biotopes in the ecological context of Dresden. The same is true for dust-binding capacity. High-functioning surfaces are limited to water [natural or unnatural] and tree or shrubs. Accordingly, UGI cases such as Park on Koenigsplatz, with relatively high percentages of pervious pavement and grass, had very low outcomes for this environmental function, as compared to the Dresdner Heide which had abundant canopy cover and natural water sources.

Because this study derives environmental function from a comparative framework, environmental outcomes for UGI cases in Neustadt are all quantified relative to the outcomes of other cases in the respective study area. Given this methodological approach, the three highest performing environmental UGI cases were determined to be Olbrichtsplatz, the Dresdner Heide and Hechtpark, with six significant function values quantified at each site. Secondarily, Alaunpark, the three Elbewiese cases, and the Inner Neustadt Cemetery were also deemed to be UGI cases of high environmental function, with each site serving five functions. Conversely, many of the urban pocket parks – with generally higher percentages of pervious pavement or asphalt – were determined to be the lowest functioning UGI cases [*Figure 16*].

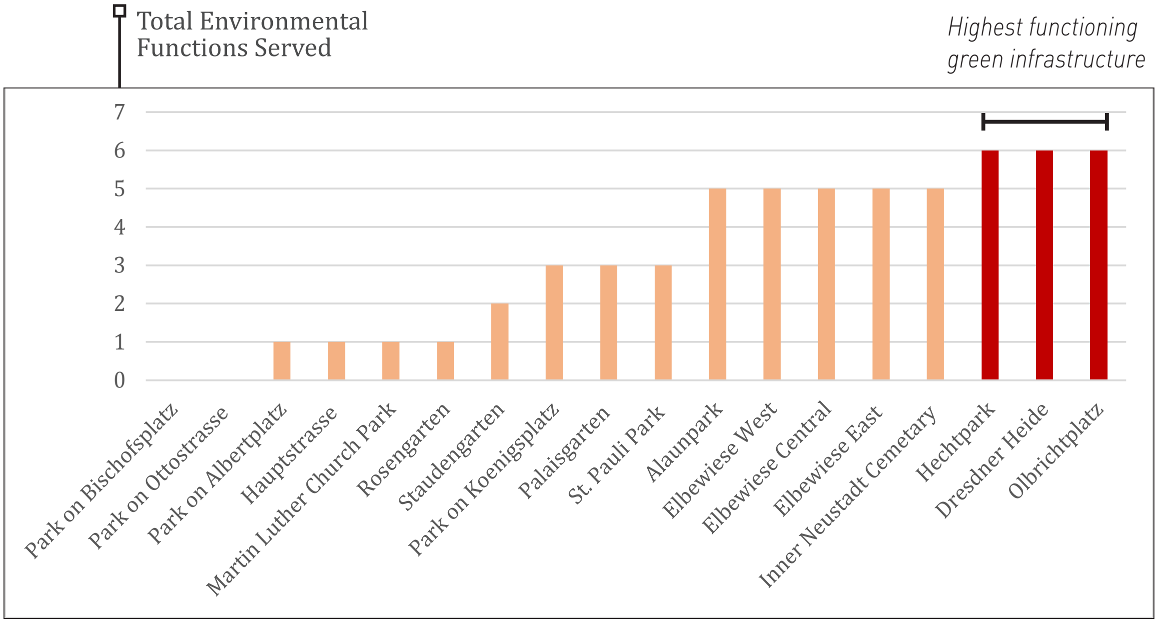


Figure 16: Environmental Outcome Ranking

Social Outcomes

Quantifying social function in the Neustadt study area also produced a range of outcomes and a variable distribution. Out of a possible 12 social use values, outcomes ranged from 3-10 social functions observed at each UGI case [*Figure 17*]. Interestingly enough, some of the highest environmentally-functioning UGI in Neustadt ultimately had the lowest social scores. For example, Olbrichtsplatz, a UGI case which serves 6 environmental functions, was among the lowest ranked UGI for social functions with only 3 different activity types observed. This was also the case with Hechtpark, another high environmentally-functioning UGI case, which ultimately only served 5 social functions—a score that is also relatively low compared to other cases.

In addition to considering diversity in social function outcomes, it is also worth mentioning that certain social functions in the study area were more common than others [*Figure 18*], a finding which lends insight into the types and patterns of activity that can be considered typical of Neustadt public life. For example, every single

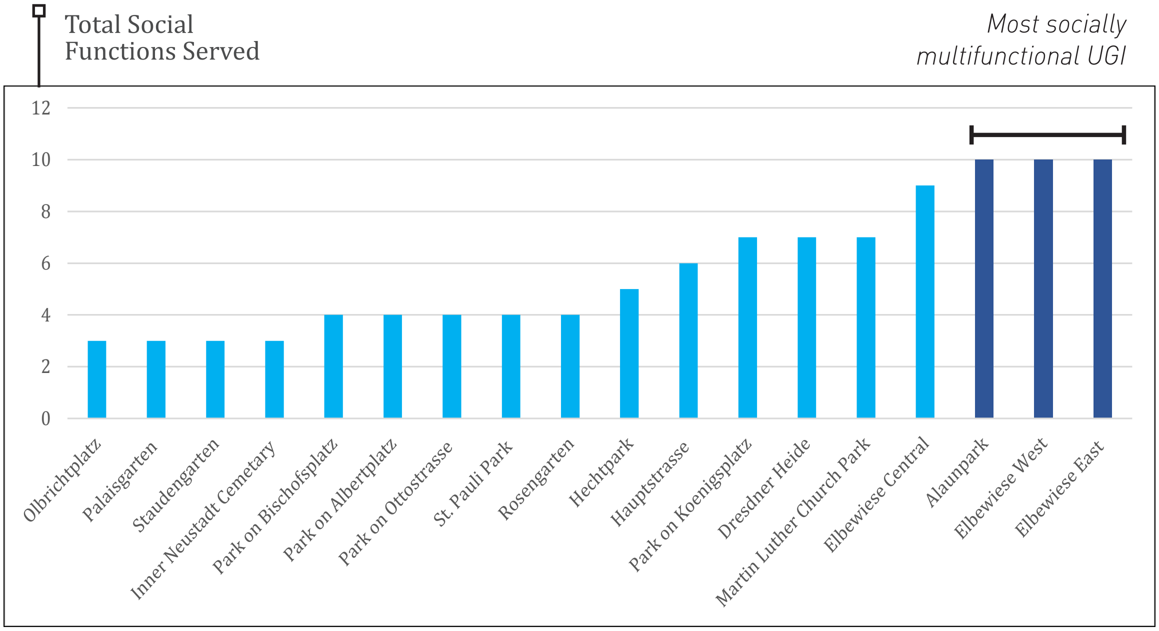
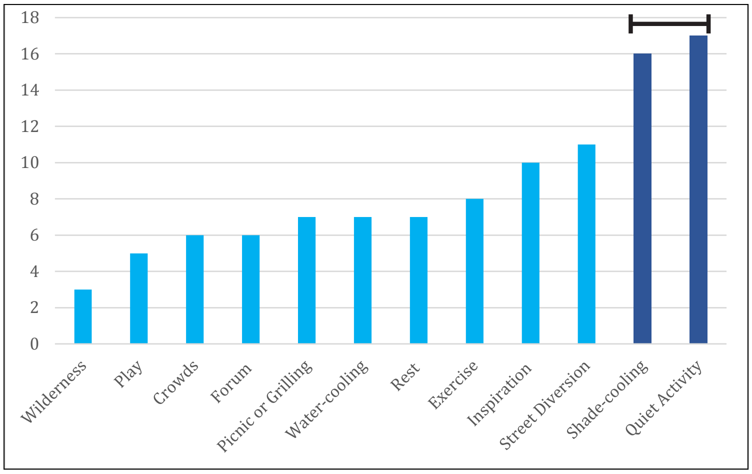


Figure 17: Social Outcome Ranking

UGI case observed [18 total] had residents engaged in 'quiet activities,' including reading, working or people watching. These activities were commonly observed even in the most heavily used parks such as Alaunpark. Shade-cooling was also a frequent social use function, observed in 16 out of 18 sites. In nearly every UGI case, with the exception of Elbewiese west, residents were intentionally seeking out shaded areas to sit and spend time. Other frequently observed social use values included street diversion in 65% of cases, inspiration [drawing, painting, playing instruments] in 59% of cases, and exercise in 47% of cases. Interestingly, the most commonly observed activities were all 'solitary,' in the sense that they were engaged in by individuals and not social groups. In this regard, it is evident that spaces for individual use are highly important and widely used in the social context of Neustadt.

The highest functioning social UGI cases in Neustadt were Alaunpark, Elbewiese West and Elbewiese East, which each served ten social functions [*Figure 17*]. Elbewiese Central was also ranked very high at nine social functions observed. Furthermore, these UGI cases in general, whether due to location, atmosphere or design, were observed as having a high degree of social versatility with activities ranging from quiet rest to crowds and play. Although this could be due to the fact that these spaces are larger than other UGI cases, there is some evidence to the contrary. By far the largest UGI case, the Dresdner Heide, served significantly fewer social functions than other UGI cases, including some located in close proximity. This is most likely due to the fact that certain UGI cases have developed unique micro-cultures and are sought out by users who desire to be in the midst of a distinct atmosphere. For example, although Alaunpark is generally quite loud and full of active groups, individuals can almost always be observed engaged in quiet activities on the fringe these crowds.

Direct Use Value	Frequency
Wilderness	3
Play	5
Crowds	6
Forum	6
Picnic or Grilling	7
Water-cooling	7
Rest	7
Exercise	8
Inspiration	10
Street Diversion	11
Shade-cooling	16
Quiet Activity	17



Most commonly observed social functions

Figure 18: Frequency of Social Functions

Combined Function Outcomes

Given the range of variables observed in the study area, it was interesting to note that none of the highest functioning environmental UGI cases received the highest social scores [*Figure 19*]. Also worthy of mention is that perceptions and distribution of overall function change considerably once environmental and social variables are combined. This is demonstrated by the fact that one third of all UGI cases in the Neustadt study area were determined to be either social or environmental hotspots, at 16% and 17%, respectively. Correspondingly, emergence was the most commonly observed phenomena—occurring in 28% of cases. Because each of these phenomena hold specific sets of implications, it is important to note that this phenomenon was evident in 61% of all cases, meaning that these implications should be given the utmost consideration [*Figure 20*]. These are discussed in the following section.

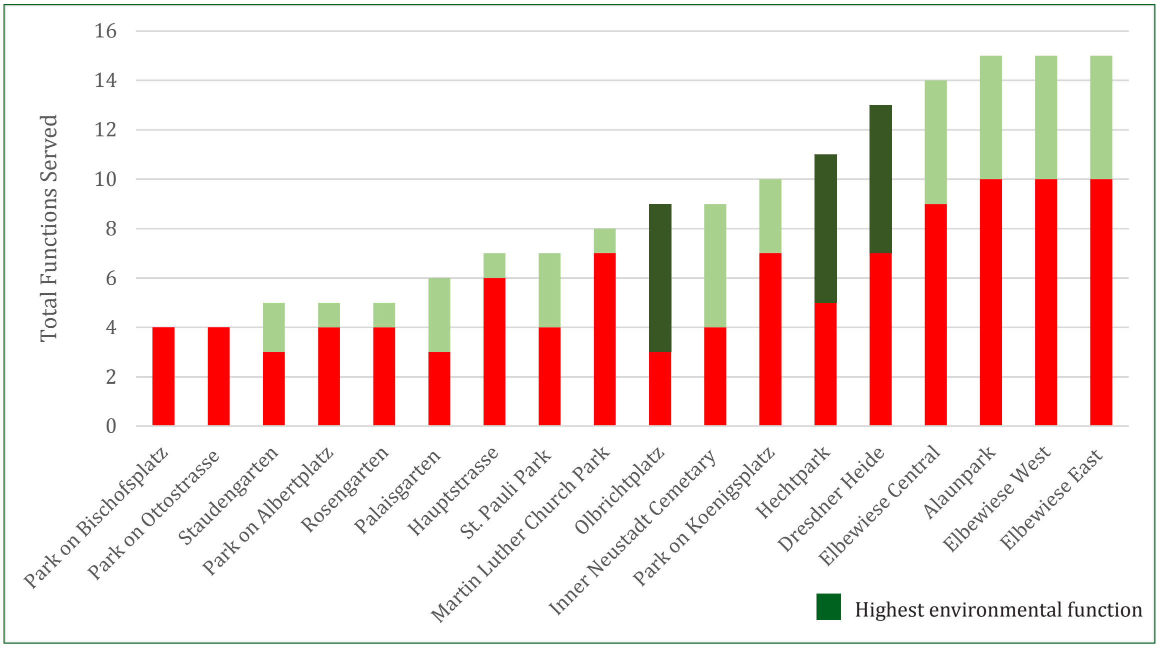


Figure 19: Combined Function Ranking

Chapter 5:

Discussion and Recommendations

As discussed in the literature review, current conceptualizations of UGI view multifunctional capacity as something of paramount importance[1], while simultaneously recognizing that the combined value of social and environmental functions in UGI is poorly understood[2]. This study has suggested that the integration of ergonomics into environmental planning frameworks could provide such a methodological framework for analysis of multifuctionality in UGI, and inform sustainable design and maintenance of urban spaces more broadly.

This study has shown that aggregating local social and environmental variables in a UGI network can significantly inform the way individual UGI sites are perceived and valued (*Figure 19, Figure 21*). As discussed in the Findings chapter, above, virtually all of the highest environmentally functioning UGI cases lost considerable ranking when social variables were integrated into the analysis.

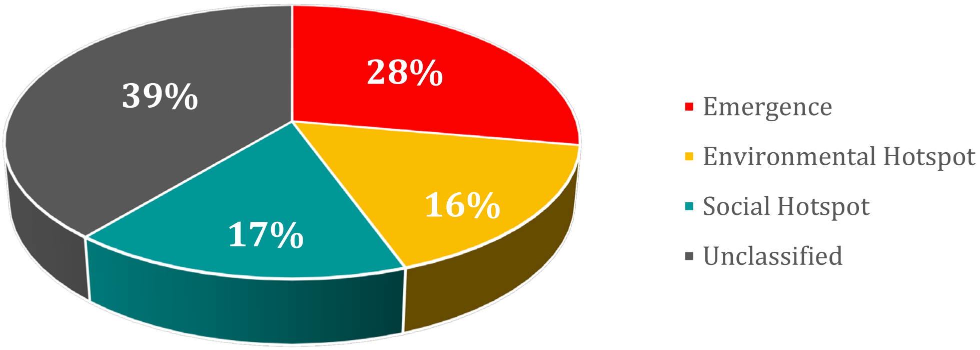


Figure 20: Percentages of UGI Phenomena from Spatial Clustering

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[1] Bennett 2009, Ahern 2007

[2] Wolf 2003, Stockholm Resilience Center [SRC] 2007

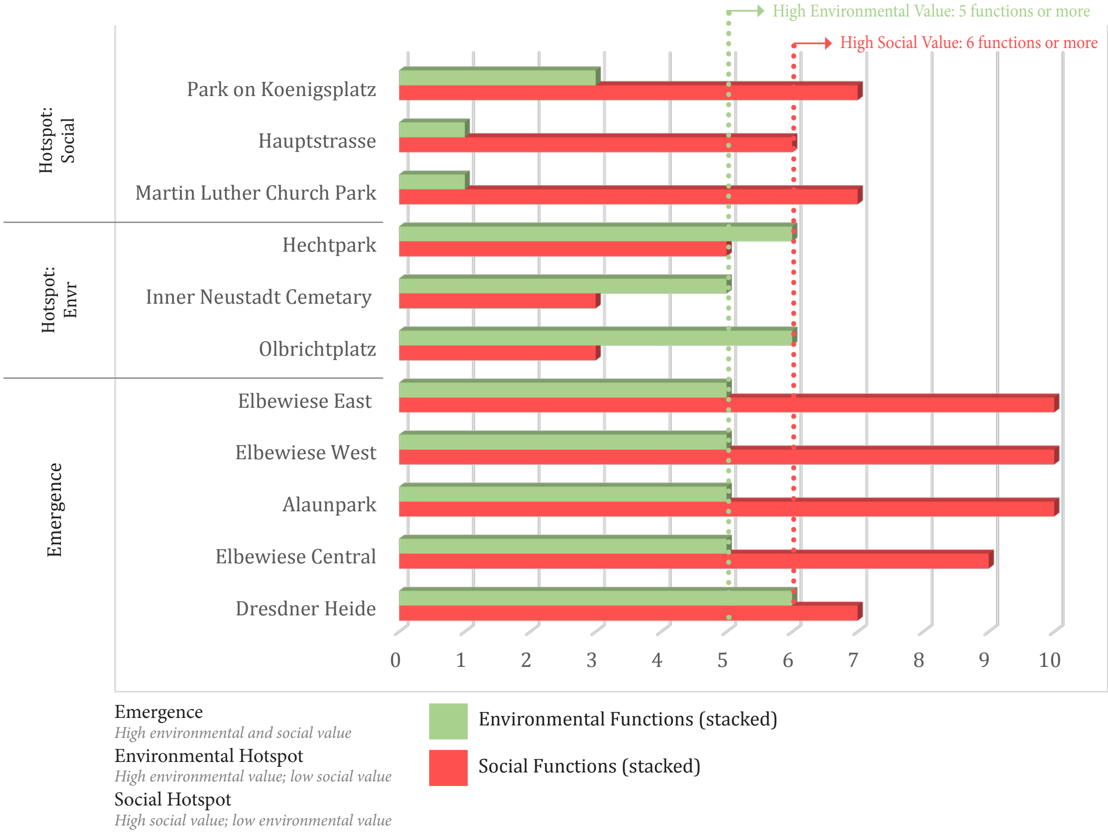

Figure 21: Determinations of UGI Phenomena

Olbrichtsplatz, a historic park located in the northern part of the Neustadt study area, provides a prime example of the implications of different social and environmental outcomes of an ergonomics analysis. Whereas Olbrichtplatz would rank very high in a UGI assessment that considered only environmental function, or very low in an assessment of social function, an analysis considering a combined range of functions would put Olbrichtsplatz somewhere in the middle. Hechtpark, a shaded knoll located in the heart of a bustling mixed use district, is a similar case. Although Hechtpark's heavily canopied design makes it among the highest ranked cases for biotope-generation capacity, permeability/porosity and climate regulation, it is not a popular gathering point in respect to other parks in the area.

Building upon this point, it is helpful to consider whether the combined value of social-environmental function of different UGI cases allow us to characterize these as sites of emergence, as environmental hotspots, or as social hotspots [*Figure 21*], In the case of the Neustadt, my research found that an overwhelming 61% of all UGI cases fall within one of these three categories.

Emergence and its Implications

In this study, emergence was the most common of all three phenomena, occurring in over a quarter of cases at 28%. Although this concept has been analyzed through the lens of resource management and conservation initiatives at the regional level, very little literature exists which explores implications of emergence in urban neighborhoods.

Emergence implies high environmentally-functioning UGI which also serves a range of social functions. From a conceptual perspective, emergence could be seen as UGI in its ideal form: as the more functions infrastructure serves, the more direct and regulatory benefits it generates[1]. From a social perspective, a site of emergence is functionally versatile, supporting a variety of uses and inspiring human interaction and recreational purposes, as well as providing a space for relaxation and solitude. This indicates that these spaces hold the potential to make significant contributions to resident physical and psychological health, while simultaneously providing vital ecosystem services. Because sites of emergence provide the broadest spectrum of benefits, documentation and analysis of UGI emergence could be used as a baseline for developing desirable UGI designs.

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[1] Environmental Protection Agency [EPA] 2014, European Commission [EC] 2013

Illustration 3: Alaunpark, early Sunday morning before the crowds hit

In addition to informing UGI design, identifying sites of emergence could also provide a wider range of perspectives to inform land use decision making. Although land development and privatization can provide valuable revenue or venues for economic development, the value of UGI to both residents and the urban system should be considered before development is approved. Within Dresden for example, all three sections of the Elbe Floodplain were determined to be sites of emergence due to their social use versatility and environmental function. Not only are these areas sites of emergence, but the western and eastern floodplains of Neustadt are among the highest cumulatively ranked UGI sites, suggesting that these spaces are among the most socially and environmentally valuable spaces in the Neustadt. In this regard, current considerations to develop or privatize the Elbe floodplain reflect administrative negligence or a lack of understanding of the importance of these multifunctional spaces. Removing these spaces from public use would undermine broader goals of social sustainability and run counter to residents' needs. Particularly considering the highly controversial development of the Waldschloesschen Bridge [*see Introduction*] and the protests the project incited, identifying emergence could be seen as a tool to better anticipate areas of potential land use conflict and as a way to respect highly-valued sites.

Identifying emergence can also offer valuable insight into types and frequency of UGI maintenance that are necessary to ensure that UGI assets persist. Alaunpark [*Illustration 3*], another site of UGI emergence in Dresden, is a prime example of potential maintenance issues. Alaunpark's popularity and versatility of uses could damage park vegetation if not carefully tended. Traces of heavy use are particularly evident on Monday morning after heavy weekend use. Because keeping the park in top condition is in the best interest of residents and environmental planners, ensuring that adequate waste disposal facilities are provided and vegetation is maintained should be of the utmost priority. Therefore, emergence could offer clues as to where maintenance efforts might be increased or additional amenities (e.g. trash receptacles and signage) could be added.

Illustration 4: Social Functions of Martin Luther Church Park

Social Hotspots and Implications

Social Hotspots indicate UGI cases where high social function accompanies (comparatively) low environmental function. In Dresden, 17% of all UGI cases were determined to be social hotspots [figure 28].

Implications regarding social hotspots include adding value and legitimacy to sites which may be considered environmentally underperforming, as well as generating a deeper understanding of patterns of spontaneous social congregation. In Neustadt, for example, a small park outside of the Martin Luther Church inspires a wide variety of social uses, despite its limited green spaces and higher ratios of 'gray' surfaces. Located in a square which is set back from busy downtown streets, local residents often bring blankets and baskets full of food to this park to have Sunday brunch, or even drag pillows and street furniture into the park for evenings full of wine and lounging [*illustration 4*]. This UGI case manifests a very distinct social life which appears to be of great value to residents who live around or in close proximity to this space. Furthermore, this space is heavily frequented by students and lower-income families, perhaps because it offers an opportunity to enjoy the atmosphere of downtown without having to spend money in increasingly expensive Neustadt cafes. In order for city planners to generate and support public spaces which are based on the day-to-day reality and needs of urban residents, it is critical that social hotspots are recognized and given due legitimacy.

In addition to recognizing valuable public space, tracking social hotspots in UGI could also yield insight into broader urban trends. Within the context of Neustadt, for example, the majority of social hotspots are found in urban pocket parks [e.g. Park on Ottostrasse, Park on Koenigsplatz and Park on Bischofsplaz]. In every case, these pocket parks are also located adjacent or in close proximity to small discount stores where food and drinks can be purchased at very low prices. Given that trends of gentrification in Neustadt are relatively new and highly controversial[1], the lively social life of these pocket parks could be seen as a form of resident's resilience or adaptation to the rising cost of living; in effect, that they provide an affordable alternative for a range of social uses. Although this is the case in Neustadt, tracking social hotspots could provide valuable insight in other urban environments on relevant local issues.

Social hotspots could also be a useful starting point to begin to understand socially-appropriate greening initiatives in a given city district. For example, small scale UGI in Martin Luther Church Park provide an example of green designs residents are most likely to respond to, which in turn increases the likelihood that UGI projects are supported by the public. Because the integration of (green-gray) hybrid systems is becoming more common as a best practice[2], social hotspots hold the potential to shape these strategies into designs which represent and serve the local community.

Environmental Hotspots and Implications

Environmental Hotspots are the reverse of social hotspots, i.e. UGI cases which are of high environmental and low social function. Environmental hotspots benefit the urban environment by contributing various regulatory functions such as biotope generation capacity, urban heat island reduction, air quality improvement and storm water control. In this study, 16% of UGI cases were determined to be environmental hotspots.

Identifying environmental hotspots in a UGI network is an important starting point for urban biodiversity planning. Biodiversity is increasingly recognized as an

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[1] Glatter 2006

[2] New York City Comprehensive Plan [PlaNYC], Stockholm Planning Commission SCA

essential component to ensuring the survival of life and earth's resources[1]. Because urban infrastructural expansion encroaches and/or fragments essential habitat, considering optimal spatial configurations which connect and conserve habitat for a variety of plants and wildlife could help to preserve and support natural ecosystem functions within urban environments. Given that environmental hotspots are less frequented by urban residents, these areas could be targeted for their habitat preservation and generation capacity, and expanded or maintained accordingly.

As discussed in the literature review, UGI is increasingly characterized by pattern-process relationships[2] which must be understood in order to support healthy landscape function. Understanding these processes implies looking at ecological processes and spatial configurations at multiple scales[3].

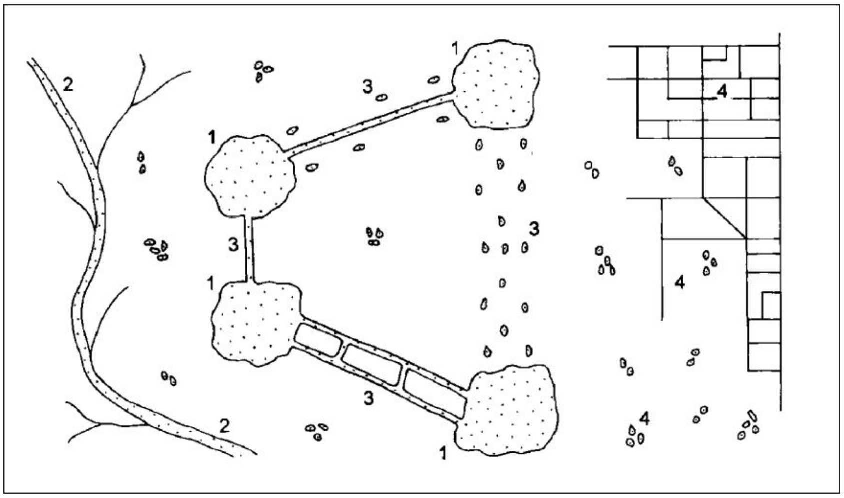

Figure 22: Forman's "Indispensable" Spatial Configuration for green infrastructure networks. (1) Large patches of natural vegetation [hubs] (2) Stream / river corridor (3) Connectivity between patches and stepping stones (4) Small "bits of nature" [Forman 1995: p. 492]

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[1] United Nations Environmental Programme [UNEP] 2014
[2] Ahern 2007
[3] Ndubisi 2002

Environmental hotspots, in this regard, may be great areas to target for developing and expanding natural "hubs, corridors or stepping stones"[1]. Hubs, corridors and stepping stones are part of a spatial framework developed by Foreman[1] to classify various landscape elements and discusses optimal configurations for maintaining healthy green infrastructure networks [*figure 22*]. These pieces of infrastructure, ideally, are planned for optimal connectivity in and around urban spaces to allow for plant and animal movement.

In summary, this study presents an ergonomics framework for beginning to understand how UGI multifunctionality can be documented, measured, and analyzed for applications in city planning. Implications corresponding to the three documented phenomena are just a starting point, and deeper explorations into the implications of social-environmental systems mapping for UGI sustainability is warranted. Accordingly, future research should consider more comprehensive and innovative methods of analyzing UGI systems, as well as mechanisms for combining the natural and social sciences to understand urban systems.

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[1] Foreman 1995

References

Ahern, J. (2007) "Green Infrastructure for Cities: the spatial dimension," In: Cities of the Future towards Integrated Sustainable Water and Landscape Management [Novontny, V. & Brown, P.] London: IWA Publishing.

Alessa, L.N., Kliskey, A. A. & Brown, G. (2007) "Socio-ecological hotspots mapping: A spatial approach for identifying coupled socio-ecological space," Landscape and Urban Planning, 65; 27-39.

American Society of Landscape Architects (2014) Green Infrastructure Definition. URL available: http://www.asla.org/, accessed on 6/7/14.

Arlt, G. Hennersdorf, J., Lehmann, I. & Thinh, N.X. (2003) In: Arlt, G. & Lehmann, I. (2005) "Oekologische Flaechenleistungen – Methodische Grundlagen; Analyse und Bewertung teilstaedtischer Gebiete in Dresden," Projekt 150: Potenziale staedtischer Freiraeme und Wohnungsbestaende fuer den Oekologischen Umbau ausgewaehlter Gross- und Mittelstaedte. Dresden: Leibniz-Institut fuer oekologische Raumenentwicklung e.V.

Rall, E.L. & Haase, D. (2011) "Creative Intervention in a Dynamic City: A sustainability assessment of an interim use strategy for brownfields in Leipzig, Germany," Landscape and Urban Planning, 100(3); 189-201.

Barten, J. et al. (2008) "Can urban tree roots improve infiltration through compacted soils for stormwater management?" Journal of Environmental Quality, 37; 2048–2057.

Beebeejaun, Y. (2006) "The Participation Trap: Limitations of Participation for Ethnic and Racial Groups," International Planning Studies, 11(1): 3-18.

Benedict, M.A. & McMahon, E. T. Green Infrastructure: Linking Landscapes and Communities, Washington, D.C., Island Press.

Blockley D. et al. (2012) "Infrastructural Resilience for high-impact, low-chance risks," Civil Engineering, 165(6): 13.

Bolund, P. & Hunhammar, S. (1999) "Ecosystem services in urban areas," Ecological Economies, 29(2): 293-301.

Buehler, R., Jungjohann, A., Keeley, M. & Mehling, M. (2011) "How Germany Became Europe's Green Leader: A Look at Four Decades of Sustainable Policymaking," The Solutions Journal (online), 2(5); URL available: http://www.thesolutionsjournal.com/node/981, accessed on 2/13/14.

Brown, G. (2001) "Mapping Spatial Attributes in Survey Research for Natural Resource Management: Methods and Applications," Society and Natural Resources, 18; 1-23

Brown, G. (2005) "Mapping spatial attributes in survey research for natural resource management: methods and applications," Society and Natural Resources, 18; 1-23.

Bryson, J.M. (2013) "Designing Public Participation Processes," Public Administration Review, 73(1): 23-34.

Carr, M.H. & Zwick, P. (2005) "Using GIS suitability analysis to identify potential future land use conflicts in North Central Florida," Journal of Conservation Planning, 1: 58-73

Child, M.F. (2009) "The Thoreau ideal as unifying thread in the conservation moment," Conservation Biology, 23: 441-243.

Costanza et al. (1997) "The value of the world's ecosystem services and natural capital," Nature, 387 (15): 253–260

Cummings, G.S. (2011) Spatial Resilience in Social-Ecological Systems. Springer Science and Business Media B.V.

Dempsey et al. (2009) "The social dimension of sustainable development: Defining urban social sustainability," Sustainable Development, 19(5): 289-30.

Dethier, M.N. (1993) "Visual versus random-point percent cover estimations: 'objective' is not always better," Marine Ecology Progress Series, 96; 93-100.

Eisenhauer, B. W., Krannich, R. S. & Blahna, D. J. (2000) "Attachments to special places on public lands: an analysis of activities, reason for attachments, and community connections," Society and Natural Resources 13(5):421–441.

Environmental Protection Agency [EPA] (2014). "Why Green Infrastructure?" Official Website. URL available: http://water.epa.gov/infrastructure/greeninfrastructure/gi_why.cfm, accessed on 6/13/14.

Ernstson, H. (2012) "The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes," Landscape and Urban Planning, 2283.

Escobedo, F. and Nowak, D. (2009) "Spatial heterogeneity and air pollution removal by an urban forest," Landscape Urban Planning, 90; 102–10.

European Commission (2007) Towards a Green Infrastructure for Europe: Developing new concepts for integration of Natura 2000 network into a broader countryside. URL available: http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_integration.pdf, accessed on 4/20/2014.

European Commission (2013) Building a Green Infrastructure for Europe. URL available: http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_broc.pdf, accessed on 78/2014.

Fabos, J.G. (2004) "Greenway planning in the United States: its origins and recent case studies," Landscape and Urban Planning 27, 7-17.

Federal Ministry for the Environment, Natural Conservation, Building and Nuclear Safety [2008] "German Strategy for Adaptation to Climate Change," Official Federal Website: URL Available, http://www.bmub.bund.de/en/topics/climate-energy/climate/adaptation-to-climate-change/, accessed on 2/27/14.

Fisher, B., Turner, K.R. & Morling, P. (2006) "Defining and classifying ecosystem services for decision making," Ecological Economies, 68: 643-653.

Flaechennutzungsplan [FNP] (2009) City of Dresden Official Website, URL Available (German): http://www.dresden.de/de/08/01/stadtplanung/fnp/fnp_neu/c_003.php, accessed on 2/13/14.

Folk, C. (2004) "Traditional knowledge in social–ecological systems," Ecology and Society, 9(3); 7.

Forman, R.T.T. (1995) "Land Mosaics," Cambridge University Press: Cambridge.

Forrest, R. & Kearns, A. (2001) "Social cohesion, social capital and the neighbourhood," Urban Studies, 38(12): 2125–43

Glaeser, M. (2011) "A Management Perspective on Social Ecological Systems: A generic system model and its application to a case study from Peru," Human Ecology Review, 18(1); 1-18.

Glock, B. (2009) "Coping with shrinking cities is a major public policy issue in Eastern Germany," European Urban Knowledge Network Interview, URL available: http://www.eukn.org/Interviews/2009/%E2%80%9CCoping_with_shrinking_cities_is_the_major_public_policy_issue_in_Eastern_Germany_%E2%80%9C, accessed on 2/13/14

Gruehn, D. (2013) "Regional and Urban Planning in Germany." Dortmond University of Technology, URL available: http://www.lote.ut.ee/orb.aw/class=file/action=preview/id=1186614/Gruehn+Tartu+29+05+2013+Regional+and+Urban+Planning+in+Germany.pdf, accessed on 2/4/13

Harris, J., Hobbs, R., Higgs, E., and Aronson, J (2006) "Ecological restoration and global climate change," Restoration Ecology 14(2); 170-176

International Ergonomics Association [IEA] (2014) Official Website, URL available: http://www.iea.cc/whats/, accessed on 6/4/2014.

Janelle, D.G. & Goodchild, M.F. (2004) “Spatially Integrated Social Science,” Oxford [England]: Oxford University Press

Jiqun, W. (2010) “The spatial-temporal changes of the ecosystem service value by land use and land coer change in Circum-Taihu Lake Region,” Geoinformatics: 18th International Conference. URL available: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=5567957&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D5567957, accessed on 3/20/14

Jorgensen, B.S. (2009) “Subjective Mapping Methodologies for Incorporating Spatial Variation in Research on Social Capital and Sense of Place,” Journal of Economic and Social Geography, 101(5); 554-567.

Kreibich, H. & Thieken A.H. (2009) “Coping with floods in the City of Dresden, Germany,” Natural Hazards, 51; 423-436.

Kremen, C. (2005) “Managing Ecosystem Services: what do we need to know about their ecology?” Ecology Letters, 8; 468-479.

Landesamt fuer Umwelt, Landwirtschaft und Geologie (2013) „Arten und Lebensraumtypen des NATURA 200-Netzes in Sachsen,“ Official Website. URL available: http://www.umwelt.sachsen.de/umwelt/natur/19273.htm, accessed on 2/14/14 (in German)

Larsen, J. (2006) „Setting The Record Straight: More than 52,000 Europeans died from heat in the summer of 2003,“ Earth Policy Institute, Official Website. URL available: http://www.earth-policy.org/plan_b_updates/2006/update56, accessed on 3/20/14

Leipold, H. (2000) „Die kulturelle Einbettung der Staatsordnung. Buergergesellschaft vs. Sozialstaatsgesellschaft,“ In: Wirtschaftlicher Systemvergleich Deutschland USA (eds: B. Wentzel & D. Wentzel), Stuttgart: Lucius & Lucius

Maher, C. & Thackway, R. (2007) “Approaches for measuring and accounting for ecosystem services provided by vegetation in Australia,” Bureau of Rural Sciences (Australia).

Margaret, C. (1948); Chase, J. (1953); & Kaliski, J. (2008) Everyday Urbanism. New York: Monacelli Press.

McClanahan, T.R., Castilla, J.C., White, A.T. & Defeo, O. (2009) "Healing small-scale fisheries by facilitating a complex socio-ecological systems," Reviews in Fish Biology and Fisheries, 19(1); 33-47.

Meese, R.J. & Tomich, P.A. (1992). "Dots on the rocks: a comparison of percent cover estimation methods," Journal of Marine Biology and Ecology, 165; 59-73.

Mell, I.C (2012) "Green Infrastructure Planning: a contemporary approach for innovative interventions in landscape urban management," Journal of Biourbanism, issue 1.

Millennium Ecosystem Assessment (2006) "Ecosystems and Human Well-being: a report of the Millennium Ecosystem Assessment." URL available: http://www.maweb.org/documents/document.356.aspx.pdf, accessed on 2/11/14.

Miraftab, F. (2004) "Making neo-liberal governance: The disempowering work of empowerment," International Planning Studies, 9(4): 239– 59.

Ndubisi, F. (2002) "Ecological Planning: A Historical and Comparative Synthesis," Johns Hopkins University Press: Baltimore.

Neuman, P. & Smith, S. (2010) "City Planning and Infrastructure: Once and Future Partners," Journal of Planning History 9(1): 21-42.

Newman, P. & Thornley, A. (1996) "Urban Planning in Europe: International Competition, National Systems and Planning Projects," London and New York: Routledge.

Nuissl, H. & Rink, D. (2005) "The 'production' of urban sprawl in eastern Germany as a phenomenon of post-socialist transformation," Cities 22(2); 123-134.

Ostrom, E. (2009) "A General Framework for Analyzing Sustainability of Socio-Ecological Systems," Science, 325; 419-422.

Outen, D.C. (2010) “Quicknotes: Green Infrastructure,” the American Planning Association.

Pagiola, S. et al. (2004) “Assessing the Economic Value of Ecosystem Conservation,” the World Bank Environment Department, Environmental Department Paper No. 101.

Pickett, S. T. A. et al. (2001) “Urban Ecological Systems: Linking Terrestrial, Ecological, Physical and Socioeconomic Components of Metropolitan Areas,” Annual Review, Ecological Systems, 32; 127-157.

Pincetl, S. (2010). From the sanitary city to the sustainable city: challenges to institutionalizing biogenic (nature’s services) infrastructure. Local Environment 15(1):43-58.

PlaNYC (2011) “NYC Green Infrastructure Plan,” NYC Department of Environmental Protection.

Project for Public Spaces (2000) “How to turn a place around: a handbook for creating successful public spaces,” New York: Project for Public Spaces.

Rall, E.L. & Haase, D. (2011) “Creative Intervention in a Dynamic City: A sustainability assessment of an interim use strategy for brownfields in Leipzig, Germany,” Landscape and Urban Planning, 100(3); 189-201.

Rees, W. & Wackernagel, M. (1996) “Urban Ecological Footprings: Why cities cannot be sustainable – and why they are a key to sustainability,” Environmental Impact Assessment Review, 16: 223-248

Regional Development Plan for the Stockholm Region (2001) Regionplane- och trafikkontoret (Office of Regional Planning and Urban Transportation), Stockholm.

Sahely, H. et al. (2005). Developing sustainability criteria for urban infrastructure systems. Canadian Journal of Civil Engineering 32:72-85.

Sayer, A. & Storper, M. (1997) "Guest editorial essay, ethics unbound: For a normative turn in social theory," Environment and Planning, 15(1): 1– 17.

Schmidt, S. & Buehler, R. (2007) "The Planning Process in the US and Germany: a Comparative Analysis," International Planning Studies, 12(1); 55-75.

Schwedler, H-U. (1999) "Berlin – eine zweimalige Stadt: Stadtplanung im Spannungsfeld vieler Interessen," In: Urban Planning and Cultural Inclusion, Lessons from Berlin and Belfast (eds. Neil, W.JV. & Schwedler, H-U) London: Macmillan. (in German)

Stahle, A. (2006) Sociotope Mapping – exploring public open space and its multiple use values in urban and landscape planning practice," Nordic Journal of Architectural Research, 19(4); 13.

Stedman, R.C. [2003] "Is it Really Just a Social Construction? The Contribution of the Physical Environment to Sense of Place," Society and Natural Resources, 16; 671-685.

Stilgenbauer J. & McBride, J.R. (2010) "Reconstruction of Urban Forests in Hamburg and Dresden after World War II," Landscape Journal, 29(2); 144-160.

Stockholm Resilience Center [SRC] (2007) "Socio-Ecological Systems," Official Website URL: http://www.stockholmresilience.org/21/research/what-is-resilience/research-background/research-framework/social-ecological-systems.htm, accessed on 2/8/14.

Strang, G.L. (1996) "Infrastructure as Landscape, Landscape as Infrastructure," Places, 10(3); 10-15.

Von Stuepnagel, A. Horbert, M. & Sukopp, H. (1990) "The importance of vegetation for the urban climate," In Urban Ecology (ed. Sukopp, H.)

UNEP (2013) Green Economy in a Blue World, Synthesis Report. URL available: http://www.unep.org/pdf/green_economy_blue.pdf, accessed on 7/8/2014.

UNESCO World Heritage Centre (2014) "Dresden Elbe Valley," Official Website. URL Available: http://whc.unesco.org/en/list/1156, accessed on 2/14/14.

UN Statistics Division (2013) Demographic Statistics Database (online): http://data.un.org/Data.aspx?d=POP&f=tableCode%3A240

Von Petz, U. (2010) "News from the Field: City Planning exhibitions in Germany, 1910-2010," Planning Perspectives, 25(3); 375-382

Wagner, H. (2000) "Foreword," In: The Revival of Dresden (Eds: Jaeger, W. & Brebbia, C.A.) Southampton, UK: WIT Press.

Wiechmann, T. (2007) "Conversion Strategies under Uncertainty in Post-Socialist Shrinking Cities: The Example of Dresden in Eastern Germany," In: The Future of Shrinking Cities – Problems, Patterns and Strategies of Urban Transformation in a Global Context. Berkley: Faculty Publications of the Center for Global Metropolitan Studies, 1-16.

Wolf, K. L. (2003). "Ergonomics of the City: Green Infrastructure and Social Benefits," In C. Kollin (ed.), Engineering Green: Proceedings of the 11th National Urban Forest Conference. Washington D.C.: American Forests Management," Journal of Forestry, 96(5); 18–23.

Wolfel, R. (2012) "What is Old is New Again: The Reintegration of Dresden's Landscape into the Modern German State," The Geographical Bulletin, 53; 93-109.

Yale School of Forestry and Environmental Studies (2011) "Rapid Urban Expansion Threatens Biodiversity". Official website, URL Available: https://environment.yale.edu/news/article/rapid-urban-expansion-threatens-biodiversity/, accessed on 3/21/14

Zimmerman, M. et al. (2010). Effects of low-impact-development (LID) practices on streamflow, runoff quantity, and runoff quality in the Ipswitch River basin, Massachusetts: A summary of field and modeling studies. US Department of the Interior and the US Geological Survey.

Zurlini, G. et al. (2006) "Disturbance Patterns in Socio-ecological system at multiple scales," Ecological Complexity, 3, 119-128.