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Urban green infrastructure in Leipzig: Ecosystem services, user's visions and the influence of green, spatial and grey characteristics. Implications for a resilient development.

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Summary

With regard to increasing inhabitant numbers in cities, urban green infrastructure (UGI) becomes a key solution for designing resilient and sustainable cities. Urban development concepts such as the compact green city aim at densification rather than urban sprawl in which high-quality UGI play an important role by providing essential ecosystem services (ES) and benefits that are essential for human well-being and contribute to climate change adaptation. The flow of these ES is influenced by different sets of values within societies, personal characteristics, beliefs, and preferences as well as the design of UGI itself. Besides benefits, UGI can co-create disservices/disturbances or trade-offs between ES that depend on different personal perceptions of a diverse urban population. Hence, assessing place-specific ES and disservices flows of urban residents should be a basic approach of UGI planning to evaluate shortcomings and demands to local urban ecosystems. Providing this knowledge and integrating the citizens' perspective into planning, can contribute to the design and management of resilient UGI meeting multiple demands and guaranteeing equal access for all. This dissertation project therefore aims to highlight ES flow or use, benefit, and disservice perception of UGI visitors, and how this is influenced by specific UGI characteristics. I further emphasize major conflicts, ideas, and topics that are important to residents of Leipzig regarding the future development of the city's UGI in order to reveal shortcomings in planning and to find solutions to meet major conflicts in UGI. The aim of the dissertation is to formulate concrete design principles of resilient UGI facilitating ES provision, reducing use conflicts, and that is able to buffer consequences from climate change or other risks such as the COVID-19 pandemic.

In chapter three, I present results from a spatially explicit study with randomly selected park and brownfield users in Leipzig, Germany. Respondents of different age groups were asked for their primarily used ES and further perceived benefits as well as disservices/disturbances. Results underline the function of manicured formal public parks as well as informal brownfields for providing multiple ES and benefits. Age specific perception of benefits and disservices/disturbances could be highlighted underscoring heterogeneous UGI demands. Physical interactions and biking were the most frequently used ES group, followed by dog walking and experiential & aesthetical ES. Littering and conflicting uses such as barbequing and dog walking were revealed as main disservices/disturbances in UGI. Findings show that brownfields are primarily used as physical space for dog walking underscoring the potential of informal UGI to decrease disservices/disturbances that arise from conflicting uses in public parks. The fourth chapter links the used ES and perceived benefits to specific green, spatial, and grey UGI characteristics. I was able to show that tree cover is a predictor for physical interactions (walking, doing sports) and for perceived benefits relating to regulating ES and social & cultural interactions in urban parks. Brownfields with low or medium tree cover were used more frequently than brownfields with high levels of tree cover. In addition, I found inhabitant density in 300m and available sport facilities as the main spatial and grey characteristics that influence ES use and benefit

perception. While urban parks in densely populated neighbourhoods provide space for social & cultural interactions and physical interactions, public parks that are located in less dense districts supply more regulating or experiential & aesthetical ES. Results underline, that the diversity of tree cover and adequate facilities all contribute to multifunctional ES provision and should be important aspects in UGI planning and management. Chapter five complements the previous chapters by adding the citizen's perspective regarding the future development and improvement of UGI that was assessed in an online survey that was set up and kindly provided by the city's Office of Green Space and Water. This perspective is linked to guiding themes of the local planning strategy, Master Plan Green. Three major problem dimensions were derived, quality & usability, users & activities, and safety & security. I was able to allocate specific suggestions from citizens addressing these problems. Most ideas and visions can be arranged into the five leading themes that are guiding the Master Plan green: biodiversity, climate change adaptation, environmental justice, health, and sustainable mobility. However, there are other topics that are important to citizens mainly referring to the quantity and socio-cultural & economic aspects of UGI that should gain more attention in planning strategies.

Based on central findings from the previous chapters, implications for UGI planning are formulated in order to contribute to resilience and integrate the citizens' perspective. First, the integration of diverse UGI such as small-scale greening, informal UGI like brownfields, façade and rooftop greening and strengthening the access to sub-urban green spaces offer opportunities to promote the quantity of urban green and to buffer conflicts. More trees in the cityscape and integrating diverse levels of tree cover within UGI, can furthermore facilitate ES provision. Second, my results provide evidence, that enhancing biodiversity levels, urban wilderness, and near-natural maintenance of UGI can be planning measures that contribute to climate change adaption and are well accepted by citizens. Next, the provision with adequate and sufficient grey infrastructure should further be a central approach in planning in order to establish fair access and usability for residents of different ages. Finally, to assess shortcomings, conflicts, and expectations of local residents, the participation of citizens and neighbourhood initiatives could be a valuable tool in UGI planning offering the opportunity to, for example, tackle the littering problem. With regard to local socio-economic, environmental, and political circumstances, the findings of this dissertation provide UGI design implications that can be relevant for planners in Leipzig and also other cities. Implications refer to topics and principles that are important to residents and guide the current debate about UGI design in Europe.

Deutsche Zusammenfassung

Im Hinblick auf steigende Einwohnerzahlen in Städten ist urbane grüne Infrastruktur (UGI) von zentraler Wichtigkeit für die Gestaltung resilienter und nachhaltiger Städte. Stadtentwicklungskonzepte wie die kompakte grüne Stadt zielen auf Verdichtung statt auf Zersiedelung ab, wobei hochwertige UGI eine wichtige Rolle spielen, indem sie wichtige Ökosystemleistungen (ÖSL) bereitstellen, die für das menschliche Wohlbefinden und die Anpassung an den Klimawandel unerlässlich sind. Die tatsächliche Nutzung dieser ÖSL wird durch unterschiedliche Wertesysteme, persönliche Eigenschaften, Überzeugungen und Präferenzen sowie durch das Design der UGI selbst beeinflusst. Darüber hinaus kann UGI negative Effekte (disservices) oder Konflikte zwischen ÖSL bewirken, die ebenfalls von persönlichen Präferenzen einer vielfältigen städtischen Bevölkerung abhängig sind. Daher sollte die Erfassung der Nutzung bzw. Wahrnehmung von ÖSL und disservices ein grundlegender Ansatz lokaler UGI-Planung sein, um lokal spezifische Anforderungen und Defizite in städtischen Ökosystemen zu bewerten. Derartige Erkenntnisse und die Integration der Bürger*innenperspektive in die Planung kann dabei helfen, resiliente UGI zu entwerfen, die den vielfältigen Anforderungen gerecht werden kann und einen gleichberechtigten Zugang für alle garantiert. Diese Dissertation erfasst daher die Nutzung und Wahrnehmung von ÖSL und disservices in der Stadt Leipzig, Deutschland, und wie diese durch persönliche und durch UGI-Merkmale beeinflusst sein können. Darüber hinaus analysiere ich wesentliche Konflikte, Ideen und Themen, die den Leipziger*innen in Bezug auf die zukünftige Entwicklung der UGI der Stadt wichtig sind, um Defizite in der Planung aufzuzeigen und Lösungen für häufige Konflikte in UGI zu finden. Das Ziel der Dissertation ist es, konkrete Gestaltungsprinzipien für UGI zu formulieren, die die Bereitstellung von ÖSL fördern, Nutzungskonflikte reduzieren und Folgen des Klimawandels oder andere Risiken wie die COVID-19-Pandemie abpuffern können.

In Kapitel drei beschreibe ich Ergebnisse einer Studie in ausgewählten Parks und Brachflächen in Leipzig. Die Befragten verschiedener Altersgruppen wurden nach ihren tatsächlich genutzten und weiterer wahrgenommener ÖSL und disservices befragt. Die Ergebnisse betonen die Funktion von gepflegten öffentlichen Parks sowie informellen Brachflächen für die Bereitstellung vielfältiger ÖSL. Altersspezifische Präferenzen von ÖSL und Wahrnehmung von disservices unterstreichen die heterogenen Anforderungen an UGI. Physische Nutzungen und Radfahren waren die am häufigsten genutzte ÖSL-Gruppe, gefolgt von Hund ausführen und erlebnisorientierten & ästhetischen Nutzungen. Müll und störende Nutzungen wie Grillen und Hund ausführen wurden als häufigste disservices genannt. Brachflächen werden häufig zum Hund ausführen genutzt, was ihr Potenzial, Nutzungskonflikte in öffentlichen Parks zu verringern, unterstreicht. Das vierte Kapitel verknüpft die genutzten und wahrgenommenen ÖSL mit ausgewählten grünen, räumlichen und grauen UGI-Merkmalen. Ich konnte zeigen, dass die Baumbedeckung ein Prädiktor für physische Nutzungen, regulierende ÖSL und für soziale & kulturelle Interaktionen in städtischen Parks ist. Brachflächen mit

niedriger bis mittlerer Baumbedeckung wurden zudem häufiger genutzt als Brachflächen mit hoher Baumbedeckung. Darüber hinaus beeinflussen die Einwohnerdichte im Umkreis von 300 m und verfügbare Sportanlagen (räumliche und graue Merkmale) die ÖSL-Nutzung und Wahrnehmung. Während Stadtparks in dicht besiedelten Stadtteilen Raum für soziale & kulturelle Interaktionen und physische Nutzungen bieten, stellen Parks in weniger dichten Stadtteilen, mehr regulierende oder erlebnisorientierte & ästhetische ÖSL bereit. Die Ergebnisse verdeutlichen, dass eine vielfältige Baumbedeckung und eine qualitative Infrastruktur wichtige Aspekte bei der Planung und dem Management von multifunktionalen UGI sein sollten. Kapitel fünf ergänzt die vorangegangenen Kapitel, indem es die Perspektive der Bürger*innen hinsichtlich der zukünftigen Entwicklung und Verbesserung von UGI analysiert, die in einer Online-Umfrage vom Amt für Stadtgrün und Gewässer Leipzig erfasst wurde. Diese Bürger*innenperspektive wurde den Leitthemen der lokalen Planungsstrategie, dem Masterplan Grün, zugeordnet. Daraus wurden drei Problemdimensionen abgeleitet, nämlich Probleme hinsichtlich Qualität & Nutzbarkeit, Nutzer*innen & Aktivitäten und Sicherheit in UGI. Konkrete Vorschläge, Ideen und Themen der Bürger*innen konnten den Problemen als Lösungsansätze zugeordnet werden und lassen sich in die fünf Leitthemen des Masterplan Grüns einordnen: Biodiversität, Anpassung an den Klimawandel, Umweltgerechtigkeit, Gesundheit und nachhaltige Mobilität. Es gibt jedoch auch weitere Themen, die den Bürger*innen wichtig sind, vor allem die Quantität und soziokulturelle & wirtschaftliche Aspekte von UGI, die in Planungsstrategien integriert werden sollten.

Auf Grundlage der zentralen Erkenntnisse der vorangegangenen Kapitel wurden konkrete Vorschläge für die UGI-Planung formuliert, die zur UGI-Resilienz beitragen und die Perspektive der Bürger*innen integrieren. Erstens, bieten diverse UGI, z.B. kleinräumige Begrünungen, informelle UGI, Fassaden- und Dachbegrünung, und eine bessere Verbindung zu suburbanen Grünflächen die Möglichkeit, die Quantität des städtischen Grüns zu erhöhen und Konflikte abzumildern. Mehr Stadtbäume und die Integration diverser Baumbedeckungsgrade innerhalb der UGI können die Bereitstellung vielfältiger ÖSL weiter fördern. Zweitens, konnte ich zeigen, dass die Förderung von urbaner Biodiversität, städtischer Wildnis und naturnaher Pflege von UGI häufig gewünschte Planungsmaßnahmen sind und zur Klimaanpassung beitragen können. Weiterhin sollte die Bereitstellung von qualitativer und ausreichender grauer Infrastruktur ein zentraler Ansatz in der Planung sein, um einen fairen Zugang und Nutzbarkeit für alle Nutzer*innen unterschiedlichen Alters zu ermöglichen. Zu guter Letzt kann die Beteiligung von Bürger*innen und Nachbarschaftsinitiativen ein nützliches Instrument in der UGI-Planung sein, um Konflikte, wie z.B. das häufig genannte Müllproblem, und Erwartungen der Anwohnenden zu erfassen und zu beheben. Im Hinblick auf die lokalen sozioökonomischen, ökologischen und politischen Gegebenheiten liefern die Ergebnisse dieser Dissertation konkrete Gestaltungs- und Planungsvorschläge, die für UGI-Planende in Leipzig und anderen Städten relevant sein können. Die Design- und Planungsansätze beziehen sich dabei auf Themen und Prinzipien, die für die Bewohner*innen wichtig sind und die aktuelle Debatte über UGI-Design in Europa bestimmen.

List of publications and author contributions

The dissertation contains content of the following two articles, which have been published in peer-reviewed journals before thesis submission. The publications are cited in chapters, sections or paragraphs of this dissertation, wherever content of the paper was used. In the following, I constitute the authors' contributions to the two manuscripts[1]:

Palliwoda, J., E. Banzhaf, and J. A. Priess. 2020. How do the green components of Urban Green Infrastructure influence the use of Ecosystem Services? Examples from Leipzig, Germany. Landscape Ecology 35:1127–1142. DOI: 10.1007/s10980-020-01004-w.

- J. Palliwoda: Conceptualisation (developing research goals and the Methodology), Investigation and data assessment/ collection, Formal data analysis, Data visualisation and curation, Writing of original version of the manuscript, Review and editing
- E. Banzhaf: Review and editing
- J.A. Priess: Review and editing, Supervision, Funding acquisition and project administration of the Leipzig case study of UrbanGaia

Palliwoda, J., and J. A. Priess. 2021. What do people value in urban green? Linking characteristics of urban green spaces to users' perceptions of nature benefits, disturbances, and disservices. Ecology and Society 26 (1): 28. DOI: 10.5751/ES-12204-260128

- J. Palliwoda: Conceptualisation (developing research goals and the Methodology), Investigation and data assessment/ collection, Formal data analysis, Data visualisation and curation, Writing of original version of the manuscript, Review and editing
- J.A. Priess: Review and editing, Supervision, Funding acquisition and project administration of the Leipzig case study of UrbanGaia

[1] Based on CRediT (Contributor Roles Taxonomy): https://www.elsevier.com/authors/policies-and-guidelines/credit-author-statement

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1. General Introduction

1.1. Urbanisation and major challenges

We are living in the "Urban century" – the share of people living in urban areas is continuously increasing and almost 70% of the world's population is projected to live in cities by 2050 (McDonald et al. 2018, United Nations 2019). In Europe, this share is already at about 75% (United Nations 2019). Clearly, cities are hotspots for economic growth, research, innovation and better education opportunities and thus attracting especially young people (McDonald et al. 2018, Eurostat 2020). Yet due to the expansion of urban areas and the need for energy and resources, natural habitats are lost or being fragmented and increasing inhabitant numbers cause pressure on remaining open spaces in cities for social, economic as well as environmental needs (European Environment Agency 2015). The dynamic urbanization process leads to a variety of challenges depending on the city's local political, economic and socio-demographic context (European Commission 2011). The majority of global and European cities are facing similar challenges and problems: land use change and soil sealing, biodiversity loss caused by the decline of natural areas, environmental problems such as air quality caused by increased motorized traffic and social injustice and segregation (de Oliveira et al. 2011, European Commission 2011). Climate change furthermore leads to increasing environmental extreme events like heatwaves, droughts and heavy rainfalls that are especially affecting urban areas (European Environment Agency 2016a, Chapman et al. 2017).

1.2. Urban green infrastructure and ecosystem services

Policy and planning aim at the development of resilient urban areas that are able to meet these environmental and socio-economic challenges. Urban resilience refers to the ability of urban areas to buffer environmental hazards, economic risks or other threats to human health such as natural disasters or a pandemic (Parker and Simpson 2020). City development concepts meeting these challenges range from "sustainable cities" and "compact green cities" to "low carbon cities" (de Jong et al. 2015). Along with social, health, digital, cultural and economic issues, all of them refer to the importance of urban green spaces providing multiple benefits to which I refer as urban green infrastructure (UGI) in this dissertation. UGI describes the network of all kinds of green and blue spaces and features ranging from planned and managed natural and semi-natural landscapes such as urban parks or forests, canals, ponds, allotment gardens, green façades to unmanaged informal sites like vacant lots and green brownfields (Lovell and Taylor 2013, European Environment Agency 2014). UGI can include technical solutions with ecological components as well as entirely nature-based solutions. In this dissertation, the UGI term will mainly refer to green spaces as these were the focus of this study. All different types of UGI, unlike their "grey counterparts", provide multiple ecosystem services (ES) and functions including ecological, economic and social benefits underlining the multi-

functionality as a core element of UGI (Gómez-Baggethun and Barton 2013, European Environment Agency 2014, Hansen and Pauleit 2014).

The ES concept has gained increasing interest in research during the last few decades and with the Millennium Ecosystem Assessment (MEA) in 2005 at latest, the ES concept found its way into policy and decision making (Millennium Ecosystem Assessment 2005, Fisher et al. 2009). The CICES classification system, for example, differentiates three main categories of final ES: provisioning, regulating and cultural ES (Haines-Young and Potschin 2013). They are considered to directly or indirectly influence various components of human well-being. These components refer to security (e.g. personal safety, security from disasters), basic material for good life (access to food and goods), health (feeling well, access to clean air and water) and good social relations (social cohesion, mutual respect) and can be provided by UGI to a greater or lesser extent (MEA, 2005). A fourth group of ES, supporting services like habitat provision, nutrient cycling or soil formation, forms the basis of final ES and are not used directly by people (MEA, 2005).

While urban food supply as a provisioning service plays a minor role in cities (yet, studies underline its potential for global food security as in Eigenbrod and Gruda (2014), Russo et al. (2017)), important regulating services are, for example, urban climate regulation, air filtration (Elmqvist et al. 2015, Daniels et al. 2018) and noise reduction (Chaparro and Terradas 2009). With climate change we are expecting changes in temperatures, precipitation, evapotranspiration, and wind speed leading to increasing heat stress, especially in dense urban areas with high surface sealing (IPCC 2014, Chapman et al. 2017). Higher vegetation cover and UGI can contribute to reduce urban heat stress and extreme temperatures in cities (Chapman et al. 2017). Elements of UGI such as urban parks or forests, furthermore provide cultural services in terms of space for recreation and nature experiences (Breuste et al. 2013, Andersson et al. 2015, Bertram and Rehdanz 2015), support social cohesion (Maas et al. 2009, Peters et al. 2010, Holtan et al. 2014) and contribute to human health in cities (Tzoulas et al. 2007, Jorgensen and Gobster 2010, Hartig et al. 2014). Depending on their management, UGI has the capacity to support biodiversity (Aronson et al. 2017), which can furthermore have positive effects on psychological well-being of people (Fuller et al. 2007, Dallimer et al. 2012, Marselle et al. 2019). UGI providing multiple benefits and ES is therefore a fundamental brick-stone on the road to resilient cities of the future. The recent COVID-19 pandemic let researchers, planners and urban residents realize, how crucial qualitative UGI in cities are to buffer crises. Recreation visits in Oslo (Norway) for example, were about three times as high as usual during lockdown illustrating the urgent need of accessible urban green for fostering human well-being especially during a crises (Venter et al. 2020).

1.3. Influencing factors on the supply and demand side

Aiming at enhancing the MEA conceptual ES framework and the science-policy interface, the Intergovernmental Platform on biodiversity and Ecosystem Services (IPBES) framework includes three key elements of links between human and nature: nature (as the intrinsic value of nature including

ecosystems and their functions, natural resources and biodiversity), nature's contributions to people (referring to the benefits that humans obtain from nature, i.e. ecosystem services and goods) and good quality of life (referring to the components of human well-being) (Díaz et al. 2015). The IPBES concept emphasizes how the third key element, human well-being, is highly influenced by different sets of values that can vary between societies, knowledge systems (e.g. western science vs. indigenous knowledge systems) and may depend on individual preferences, cultural background, age and gender (Díaz et al. 2015).

Hence, the actual flow of social and cultural benefits (i.e. cultural ES or nature's contributions to people) is complex, challenging to assess as they are spatially heterogeneous, embedded in a socio-cultural and socio-demographic context and measuring them is time-intensive and costly (Gómez-Baggethun and Barton 2013, Haase et al. 2014, Díaz et al. 2015). Assessing the ability of UGI to provide cultural services requires a wider indicator spectrum than the frequently-used quantification of available recreation area, especially when it comes to urban ecosystems (MAES 2014). Gomez-Baggethun and Barton (2013) describe further challenges limiting ES valuation and measurements, especially of social and cultural values of nature in urban areas. They as well as other authors emphasize that high density of population in cities comes along with heterogeneous perspectives on ES valuation, spatially heterogeneous UGI as well as the co-creation of urban disservices and trade-offs between services (Gómez-Baggethun and Barton 2013, Andersson et al. 2019). While trade-offs refer to ES that affect each other negatively, disservices such as view blockage or allergenic potential of street trees are negative aspects of (urban) nature and thus effecting human well-being negatively (Lyytimäki et al. 2008, Haase et al. 2012). Just as ES, disservices and trade-offs are influenced by socio-cultural and socio-demographic preferences. The provision and flow or use of ES, especially cultural ES, benefits and disservices, are thereby influenced by both, the supply (i.e. the structures, components and characteristics of the UGI itself) and the demand side (i.e. personal, cultural and socio-economic characteristics of the population) (Hegetschweiler et al. 2017). Figure 1 illustrates the conceptual framework that is underlying to this dissertation.

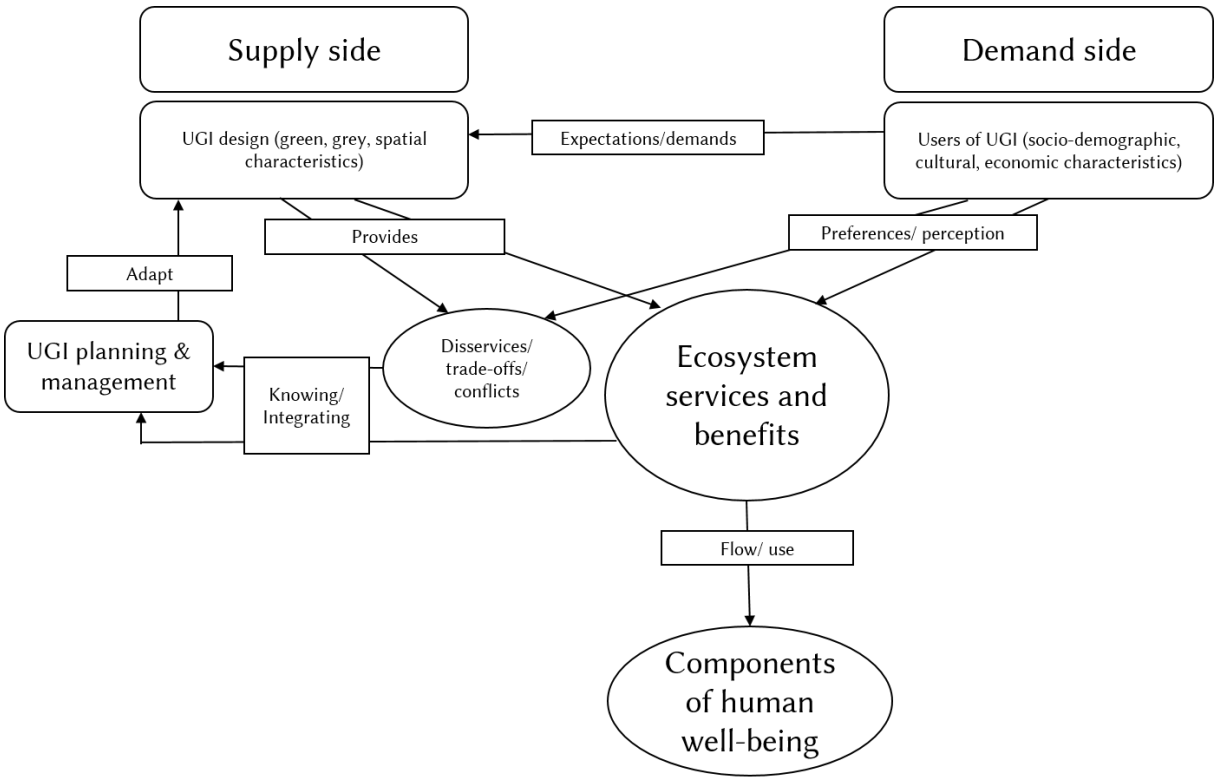


Figure 1: Conceptual framework of the dissertation. Supply and demand factors influence the perception and use of ecosystem services and disservices in urban green infrastructure (UGI) (own illustration based on the confluence model from Hegetschweiler et al., 2017)

Factors on the supply side can be, for instance, tree cover, plant species richness and lower vegetation, to which I refer as "green characteristics" in this dissertation. "Grey characteristics" such as available facilities, lighting or sports infrastructure as well as "spatial factors" describing accessibility, i.e. distance to people's home, and size of the UGI are further characteristics on the supply side that can influence ES and disservice flow. On the demand side there are several aspects that may influence expectations to UGI and the flow and perception of ES ranging from personal beliefs and worldviews to socio-economic status, gender, age and ethnicity of urban residents (Matsuoka and Kaplan 2008, Shan 2014, Andersson et al. 2019). Integrating these multiple expectations into UGI planning strategies can contribute to its fair and resilient design and management that accounts for multiple stakeholders (Buijs et al. 2016, Jacobs et al. 2016).

1.4. Structure of the dissertation

It remains the question of which UGI design characteristics on the supply side can enhance ES and benefit flow and reduce conflicts and how planning approaches can meet the demands and expectations of the local population. The assessment of ES and benefits that are provided by UGI, used and perceived by urban residents should therefore be a basic approach of planning to evaluate shortcomings of and demands to local urban ecosystems. The central approach of this dissertation is therefore the assessment of the citizen's perspective, i.e. actual UGI visitors and residents of Leipzig, and actual ES use and perception in UGI with regard to its design characteristics. After the

introduction of the case study Leipzig and the two methodological approaches in chapter two, the following three research questions are formulated and are structuring the thesis (Figure 2):

(1) Which ES are actually used and which further benefits and disservices are perceived across different age groups of visitors of formal and informal types of UGI?

This question, which chapter three will be about, refers to the demand side, i.e. actual users of UGI. I assess the flow (actual use) and perception of ES, benefits and disservices/disturbances of visitors of different age groups at two types of UGI, namely in urban parks and on brownfields. On the basis of previous studies, I hypothesize that adults and older age groups are more engaged in nature related activities and place more importance on aesthetical ES. Younger people on the other hand, are assumed to value social relations and possibilities for physical activities more than adults or older persons (Chiesura 2004, Matsuoka and Kaplan 2008, Ode Sang et al. 2016). This chapter furthermore highlights disservices/disturbances that are perceived by visitors of formal and informal UGI, i.e. urban parks and brownfields. Results from this chapter aim to shed light on the diverse views within the stakeholder group of UGI visitors and underline frequent disservices/disturbances and conflicts between ES users.

(2) How do green, grey and spatial characteristics of UGI influence ES use and perception?

As a second step, chapter four analyses how selected characteristics of study sites (supply side) can be associated with specific used ES and perceived benefits that have been described in chapter three. I examine the relationship between green UGI characteristics and used ES as well as perceived benefits. Previous studies have shown a positive association between species richness, tree cover and human well-being or social relations (Fuller et al. 2007, Holtan et al. 2014, Shanahan et al. 2014). Furthermore, I test selected spatial as well as grey characteristics as predictors for used ES and perceived benefits. I assume that the provision with adequate facilities and sufficient size is fostering active recreational activities (Kaczynski et al. 2008, Schipperijn et al. 2010). With this, I aim to provide empirical evidence how benefit flow can be enhanced by targeted UGI Design.

(3) What is the citizen's view about the future development of the local UGI regarding major urban themes, challenges and conflicts and how does this match with local planning foci?

This question, which will be dealt with in chapter five, is focussing on the citizen's perspective towards the future development of Leipzig's UGI. This part widens the perspective from study sites of two types of UGI to the general network of urban green and blue spaces in the city. I summarise and quantify concrete ideas, suggestions and topics that are important to inhabitants of Leipzig regarding the improvement and development UGI and highlight emerging problems and conflicts in the city's UGI. To do so, I consulted an online survey about citizen's ideas, topics and visions to improve Leipzig's UGI that was conducted by the city's Office of Green Space and Water. Ideas and suggestions

from survey participants are linked with the major foci of the local planning strategy, the Master Plan Green, to meet major conflicts in UGI and to emphasize (mis)matches and shortcomings between planning and citizens.

This dissertation project aims at providing knowledge about how to design, plan and manage resilient UGI for a heterogeneous urban population by presenting concrete design principles accounting for the citizen's perspective. In the synthesis section, I will hence aggregate results from the three main chapters (chapter 3-5) to central findings that will be the basis for explicit recommendations for UGI planning in Leipzig and, if applicable, other European cities.

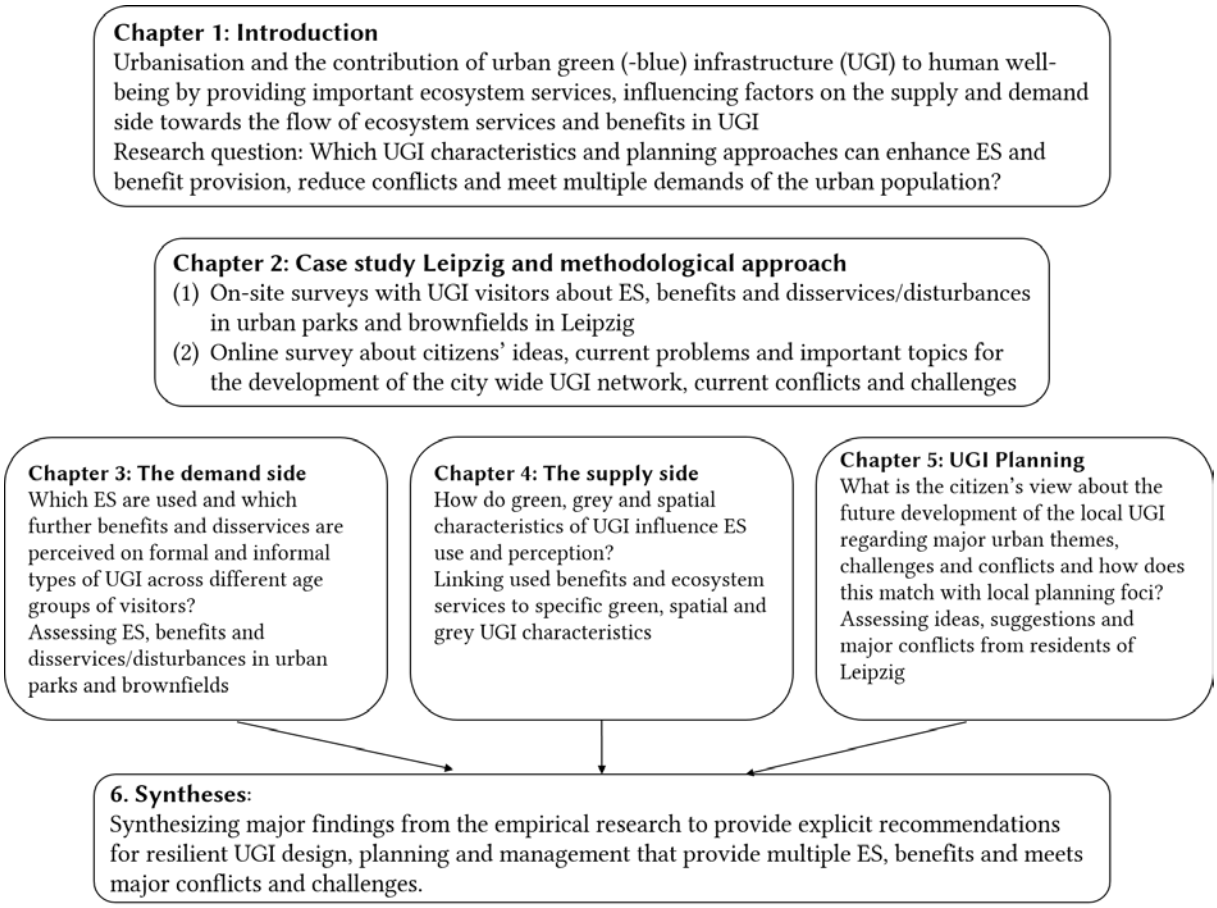


Figure 2: Structure of the dissertation. Chapter one introduces the concepts Ecosystem Services (ES), urban green infrastructure (UGI) and formulates the research questions. Chapter two presents the case study Leipzig and the methodological approach resulting in two databases. Main results of the dissertation are presented in chapter three, four and five. Chapter six synthesizes major findings in order to formulate explicit recommendations for resilient UGI design, planning and management for a heterogeneous urban population.

2. Case study and methodological approach[2]

2.1. Case study Leipzig

The city is about 30,000 ha and currently counts more than 600,000 inhabitants (Stadt Leipzig 2020b). Leipzig was affected by massive population loss and by increasing numbers of vacant apartments and unused brownfields after the German reunification in 1990. Several processes such as demographic decline, suburbanization and emigration shaped the shrinking process (Haase 2008, Mathey and Rink 2020). In the 2000s, the city first experienced moderate growth in the form of re-urbanizsation, and since the early 2010s, there has been dynamic growth, currently by around 10,000 citizens (~ 2-3%) per year. While in the 90's the city was characterised by a period of urban sprawl causing increased land take of valuable agricultural area in the city's periphery, population growth is nowadays driven by mainly young people < 30 years, who prefer to move to neighbourhoods around the city centre often characterised by low available green area per capita and residential buildings of the Wilhelminian time ("Gründerzeit"). The municipality is now pursuing the strategy of the compact green city that balances densification and use of land for transport, housing and economic growth and keeping open and green spaces to ensure human well-being (Stadt Leipzig 2018b). Consequently, pressures on the city's remaining open spaces are strongly increasing (Stadt Leipzig 2019). Unused spaces of former industrial sites or residential buildings in these popular neighbourhoods have now become opportunities for residential and commercial development and are highly valued for investment (European Environment Agency 2015) but can also support urban biodiversity (Muratet et al. 2007) and provide recreational services, either by interim use strategies (Rall and Haase 2011) or informal use (Pueffel et al. 2018).

The term "brownfield" in this dissertation is following the definition of the city's Office of Green Space and Water and include all unused areas, independent of their condition, size or owner that potentially offer any kind of use perspective. Excluded from this definition are unused apartment houses. Brownfields in Leipzig are highly diverse in their characteristics and range from open lawns or ruderal grassland to dense succession forests (Figure 3). Some of them are maintained by their private owners or neighbours or used for (informal) gardening projects. Urban brownfields complete the multitude of recreational green area such as public parks and allotment gardens (about 11% of the area) and forest area, mainly characterised by the riparian forest running from the southwest to the northwest of the city covering about 7% of the total area (Stadt Leipzig 2019).

[2] This chapter synthesizes the relevant information for study site selection and the methodological approach published in (Palliwoda and Priess 2021) and in (Palliwoda et al. 2020)

Figure 3: Examples of urban brownfields in the city of Leipzig with different tree cover. From left to right: two examples of brownfields with low, medium and high tree cover respectively. (Photos: J. Palliwoda)[3]

This dissertation is embedded in the UrbanGaia project. In addition to Leipzig, the cities of Coimbra (Portugal), Genk (Belgium) and Vilnius (Lithuania) are case study cities of project (Figure 4). The project aims at developing tangible indicators and strategies for evaluating the performance of UGI to improve their management and maintenance (see Carmen et al. 2020). Evaluation and synthesis of the project include the ecological analysis, a comparative analysis of the implementation of the UGI concept in policy documents as well the assessment of multiple values and ES of UGI in the case studies that have been published in reports or peer-reviewed papers (see Priess et al. 2021, Leone et al. in preparation). In order to evaluate place-specific ES flows, the project enhanced and developed the MapNat smartphone app further (Priess and Kopperoinen 2016). The current version of the citizen science app can be downloaded at the google play store and the apple app store. Integrating spatial and ecological data as well as multiple stakeholders for evaluating socio-economic benefits of UGI supported by citizen science applications, UrbanGaia is settled as an interdisciplinary and collaborative European project. Results contribute to improve the governance of UGI aiming at increasing biodiversity and enhancing ES provided by them to improve human quality of life and health. This dissertation constitutes of project results from the Leipzig case study.

[3] Parts of this Figure are published as Figure 1 in (Palliwoda et al. 2020) and as Figure A1.5 and A1.6 in (Palliwoda and Priess 2021)

Figure 4: Case studies of the European Biodiversa funded UrbanGaia project: Coimbra (Portugal), Genk (Belgium), Leipzig (Germany) and Vilnius (Lithuania).

2.2. Study sites and visitor survey

2.2.1. Study site selection

The first two research questions that are examined in chapter three and four are based on empirical research on selected study sites in the city of Leipzig. Study site selection comprises two types of UGI to reflect their variety and consider the range of benefits they provide: urban parks and green brownfields, i.e. brownfields that are somehow covered by vegetation (in the following I will refer to them only as brownfields). Most of the city's brownfields are covered by vegetation and undergo natural ecological succession. Some of them are grassy areas managed by residents or private owners (Figure 4). All unused spaces regardless of their ownership or former use in Leipzig are registered by the city and defined as brownfields (Stadt Leipzig 2017a). Based on this dataset and on a cadastre of all public parks in Leipzig (Stadt Leipzig 2017d) study sites were selected.

The two UGI types illustrate two examples on different ends on the maintenance scale for UGI. Management of public parks in Leipzig is in responsibility of the city's Office of Green Space and Water and maintenance is differentiated in four categories: (1) representative areas including ornamental arrangements, (2) intensively used and regularly maintained lawns with a frequent mowing regime, (3) extensively managed areas with biannual mowing frequency, and (4) extensive and near-natural areas without mowing and only basic maintenance activities (e.g. safety maintenance) (Stadt Leipzig 2017c). The majority of Leipzig's public parks is within maintenance category (2) including regularly mown lawns and grasslands. To reflect the diversity of green

characteristics of UGI and to apply statistical analysis with sufficient repetitions I used tree cover (in %) of each park or brownfield as the main green parameter to differentiate study sites. To do so, a stratified random sampling for the two types of UGI and different tree cover classes was applied (Figure 5).

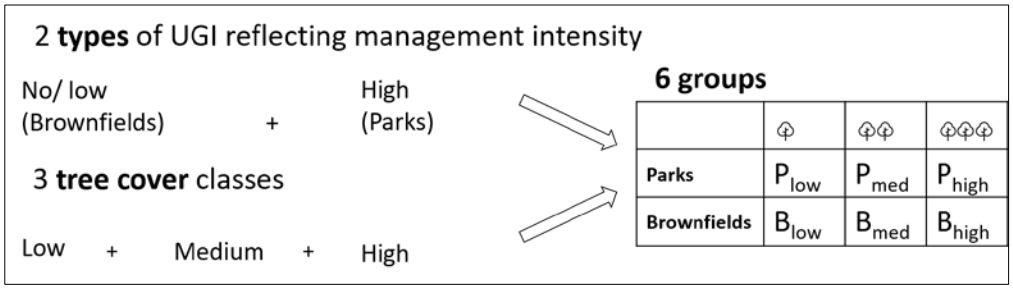


Figure 5: Study site selection process (stratified random selection) on the basis of UGI type and tree cover class

As a first step, the share of tree cover relating to mature trees higher than 5m (EUNIS category) for each public park and brownfield in Leipzig was determined on the basis of analysed digital orthophotos of June 2012 and a surface model of 2010 (Banzhaf et al. 2018). Each site was then classified into three classes of tree cover: low (0-33%), medium (>33 – 67%) and high (>67 – 100%). Next, the stratified random sampling yielded 36 study sites in total (18 parks, 18 brownfields) with six replicates of each tree cover class for both UGI types: six parks with low tree cover (P_{low}), six parks with medium tree cover (P_{med}), six parks with high tree cover (P_{high}) and six brownfields per tree cover class (B_{low}, B_{med}, B_{high}, Figure 5). All study sites were chosen within a 5km radius from the city centre.

As a last step, the stratified random sampling of parks and brownfields was adapted in a post-process. The city's Office of Green Space and Water was consulted to finalize the choice of public parks, i.e. leading to include Abtnaundorfer Park as P_{low} (Figure 6). Brownfields had to be accessible, i.e. not completely surrounded by walls or fences and nor overgrown by shrubs. Figure 6 shows the distribution of the final 36 study sites in the city of Leipzig.

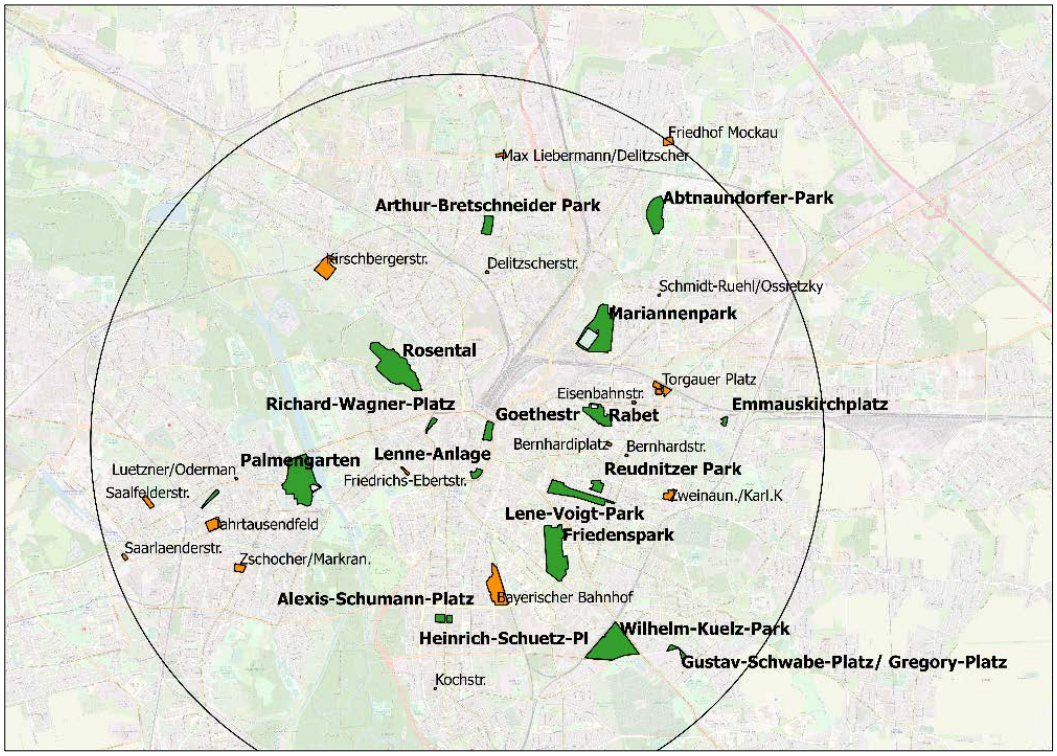


Figure 6: Map of selected 36 study sites in Leipzig within a 5km buffer from the city centre. I chose 18 urban parks (green, names in bold) and 18 brownfields (orange) with varying tree cover. Map source: OpenStreetMap and contributors.

2.2.2. Assessment of UGI characteristics

To identify UGI characteristics that might influence perceived benefits, I selected characteristics that represent three key structural dimensions of UGI: green, spatial, and grey characteristics (Voigt et al. 2014, Hegetschweiler et al. 2017). In addition to tree cover, which was the determining green parameter for study site selection (see chapter 2.2.1.) (Kaczynski et al. 2008, Timperio et al. 2008a, Hofmann et al. 2012), I selected landscape structure diversity, richness of tree species and richness of flowering species (Fuller et al. 2007, Dallimer et al. 2012) as green characteristics. Size of the site and inhabitant density within 300 m (Van Herzele and Wiedemann 2003, Schipperijn et al. 2010, Wright Wendel et al. 2012) were tested as spatial characteristics. For grey characteristics of UGI, I assessed seating possibilities as important park amenities supporting passive or resting relaxation (McCormack et al. 2010, Voigt et al. 2014), the presence of lighting contributing to safety (Giles-Corti et al. 2005), and the presence sports facilities for active physical interactions (Gearin and Kahle 2006, Ries et al. 2008, McCormack et al. 2010). Figure 17 visualizes UGI characteristics of each structural dimension that were assessed in each of the 36 study sites.

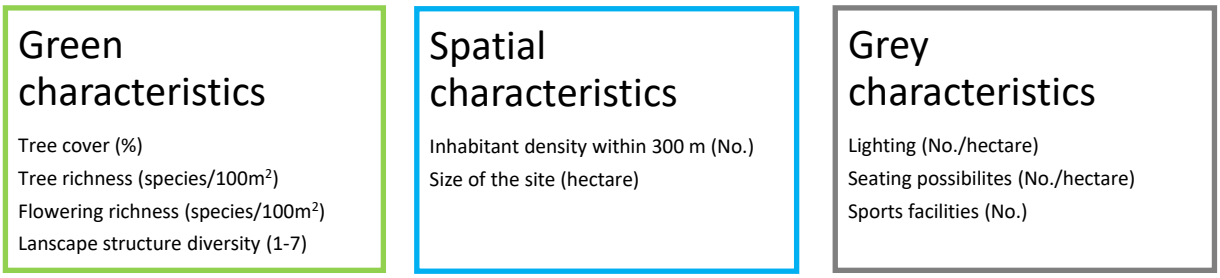


Figure 7: Assessed UGI characteristics of three structural dimensions (green, spatial, and grey) in 18 urban parks and 18 green brownfields.[4]

Tree cover, defined as the proportion of the study site that is covered by trees ≥5 m in height (as delineated in 2.2.1), and richness in tree and flowering species comprised the green characteristics. For assessing species richness, ArcGIS (version 10.6) was used to generate randomly distributed points representing the centre of 15x15 m sample plots on all study sites. The total area of these sampling plots (minimum two sampling plots for each site) covered at least 1 % of the total area of the park or brownfield (Hermy and Cornelis 2000). Within these sample plots, I identified all woody species at a height of 5 meters or above. On small brownfields <0.65 ha (i.e. size of the smallest park, n=9), all present woody species at a height of 5 meters or above were mapped. Richness in woody species (tree richness) was scaled to richness per 100 m² for each study site. I used these values to compare all study sites of different sizes including varying sizes of mapped area. In addition to woody species, I identified all herbaceous species that were flowering at the time of mapping. These were also identified within the same 15x15 m plots in parks and large brownfields or in two 5x5 m random plots on small brownfields. I determined their species, height, coverage (after Braun-Blanquet) and flowering colour (Strath et al. 2007). Flowering richness was also scaled to richness per 100 m². All vegetation assessments were conducted in August and September 2017. In the field, I additionally estimated the presence of the following land use/land cover types at my observation units for ES use assessments (see chapter 3.2.1): grassland/meadow, ruderal grassland, woodland/trees, shrubs, water bodies, urban gardening structures and flowerbeds. I then calculated the landscape structure diversity (value 1-7) by summing up the presence or absence of each of these land use/land cover types.

Spatial characteristics comprised the density of the human population within 300 m of the edge of each study site as well as the size of the sites. I calculated the number of inhabitants in a 300 m Euclidian distance surrounding each UGI site based on a dataset provided by the city of Leipzig (Stadt Leipzig 2018a). The distance of 300 m, representing a walking time of five minutes, is frequently used to analyse access to UGI (Barbosa et al. 2007, Toftager et al. 2011).

Infrastructural features and facilities were defined as grey characteristics. At each site I counted all available permanent seating possibilities (benches, attached chairs, etc.), the number of lights and

[4] This figure is published in a modified version as Figure 2 in (Palliwoda and Priess 2021)

sports facilities (table tennis, basketball or soccer field, running tracks, etc.). Infrastructure assessments were conducted in summer 2017 and seating possibilities and lights were scaled to occurrences per hectare.

2.2.3. Observation of visitor density in UGI

On the 36 study sites, I conducted structured observations including surveys with randomly selected visitors (section 2.2.4.) supported by a well-trained scientific assistant (MSc). Every site was visited eight times between April and September 2018 covering each of four time slots twice: morning (8-11), noon (11-14), afternoon (14-17) and evening (17-20). In total, every site was observed for 12 hours: two hours during the first mapping period (April – July) and one hour in the second mapping period (August – September). Observations were conducted on weekdays and weekends and during fair weather conditions, i.e. not carried out on rainy days. Assessments were performed on observation units clearly delineated by paths or other landmarks such as hedge rows or walls. We counted all people entering the observation units and recorded their primary activity. Observed ES use was limited to visible activities like biking, walking, jogging, dog walking or sitting, reading, sunbathing, doing sports (the four latter are defined as "Other activities"), some aesthetical & experiential services (e.g. watching ducks) and societal relations (e.g. picnicking, groups of people as meeting people). Observed use of regulating and most experiential & aesthetical services could only be assessed when visitors were part of a group of which at least one person was surveyed. The rest of the group was then counted as using the same ES. The observation allowed me to calculate total user density for each site per hectare per hour.

2.2.4. Visitor survey about ecosystem service use patterns

Within observation units, we randomly selected adults and teenagers (older than 14 years), by asking persons every fifth minute. Visitors that appeared younger than 14 years were only interviewed when in company of adults (ADM 2021). Surveys and observations were pretested on one brownfield and in one park in April 2018.

For the assessment of ES use, I adapted a questionnaire based on the MapNat smartphone application that was enhanced in the UrbanGaia project[5] (Priess and Kopperoinen 2016). The survey was set up in German and respondents mainly preferred oral questions which the interviewer was reading to them. For the survey, I selected 24 out of 30 ES available on MapNat and 6 out of 9 problems (disservices) that are relevant for urban areas (Supplementary material S1 for a translated version of the survey). ES definition and aggregation in MapNat are based on the common international classification of ES (CICES) (Haines-Young and Potschin 2013). As most citizens are unfamiliar with the term "ecosystem service" or "disservice", the term was avoided in the app and the app-based survey. Instead, respondents were asked to choose one use/enjoyment or disturbance of nature that

[5] App development was led by the team from the Leipzig case study (J. Palliwoda, J.A. Priess)

they were using or felt disturbed by at that moment followed by additional questions about use frequency, importance and motivation (6 motivation categories: Nature/ landscape or wilderness, tranquillity or seclusion, physical space for activity, social or cultural interaction, close to home or accessible, other motivations). Due to the fact that only two respondents stated disservices, I excluded disservices from this analysis. However, to capture disservices and further benefits, a following question about perceived benefits and disservices/disturbances was an open ended question with the following two sub-questions:

What do you like in this park/brownfield?

What do you dislike or feel disturbed by?

Finally, we asked respondents about age, gender and their place of residence or, if people were taking (lunch) breaks, their work place (street and postcode).

2.2.5. Aggregation of observation and visitor survey data

All data were processed in R, version 3.6.1, MAXQDA version 12.1.3, and ArcGIS version 10.6. Survey data were translated into English language, statistical analysis was carried out with the "stats" and "vegan" package (Oksanen et al. 2020, R Core Team 2020) and data visualization with the "ggplot2" package (Wickham 2016).

Ecosystem service, benefits and disservice aggregation

For the analysis I aggregated the 20 ES used by visitors into the following seven groups: provisioning ES, regulating ES, physical interactions, dog walking, biking, social relations and experiential & aesthetical ES. Provisioning services include all kinds of collecting food or material. I am aware that other authors have addressed them as recreational services (e.g. in Plieninger et al. 2013). Nevertheless, I will classify them as provisioning ES to represent the diversity of ES use on my study sites. Most activities that represent recreational and active uses in UGI (walking, sport fishing, jogging and other uses such as sunbathing, doing sports or reading) were aggregated as physical interactions (with nature) (Haines-Young and Potschin 2013). However, two of them were predominant in study sites (biking in parks and dog walking on brownfields) and were thus kept as single categories. Picnicking and barbecuing were classified as social relations because sites served as meeting points with other people (Plieninger et al. 2013).

For the analysis of perceived benefits and disservices/disturbances, I assigned answers of the open-ended questions to keywords or key parameters, which were then aggregated into categories (Table 1). I differentiated all generated positive categories into two benefit types: **grey benefits** (spatial or infrastructure-related park or brownfield features, comments regarding maintenance or use regulations) and **nature benefits** (categories that refer to contributions of nature to people in terms

of aesthetical, spiritual, recreational and intellectual values, the physical dimension of nature/ nature itself as well as regulating ES such as micro climate regulation) (Millennium Ecosystem Assessment 2005, Haines-Young and Potschin 2013, Díaz et al. 2015). Disservices/disturbances, which contradicted a benefit category were grouped with that category, illustrating individual and partly opposite perceptions of similar aspects among respondents (Table 1). I then counted the number of responses per category in each of the parks and the brownfields where people were interviewed.

Table 1: Categories of benefits and their (partly) contradicting disservices/disturbances perceived by respondents in urban parks and brownfields from the open question of the survey. Several answers were possible. Several mentions within one category by one respondent were counted as one. Benefits are divided into nature benefits (light green: contributions of nature to people, ecosystem services (ES), physical dimension of nature, nature itself) and grey benefits (grey: spatial or infrastructure-related features, comments regarding maintenance).

	Benefit categories	Keywords/key parameters	Disturbance/dis-service categories	Keywords/key parameters
Nature benefits	Environmental education & gardening	Environmental education, identification tags on plants, Urban gardening activities		
	Green landscape/aesthetics	Beautiful landscape, green landscape, green or nature as a whole, experience nature		
	Natural elements	Reference to elements of nature: trees, flowering aspects, animals, water/pond, meadow	Little/no nature	No, not enough trees/flowering aspects or vegetation/green, dry/yellow vegetation
	Regulating ES	Shade, quiet/noise reduction	Noise/little shade	No/not enough shade, hearing noise from surrounding streets
	Sense of place	Sense of place, history of park, cultural heritage		
	Social & cultural interactions	Meeting point, other people, initiatives, children/family, intercultural exchange, neighbourhood initiatives, events, possibilities to barbeque	Other users/behaviour/bicycles	Feeling disturbed by (groups of) other persons (e.g. teenagers, people from other cultures) or events, fast bicycles, other people barbecuing and causing smoke or leaving trash, too many people, too many people
	Urban wilderness	Nature-like, near-natural conditions, no/low maintenance, wilderness aspects, discover		
Grey benefits	Art & buildings	Graffiti, statues, buildings, monuments (for brownfields: available infrastructure)		
	Dog-friendly	Suitable site for dogs: fenced, possibility to let dogs of the leash, designated dog areas, other dog infrastructure	Dogs	Feeling disturbed or scared by dogs, dog litter
	Freedom/no regulations	No regulatory agency, no regulations, freedom, move freely	Safety/crime	Alcohol abuse/people drinking alcohol drug dealing, lack of/poor lighting, feeling not safe
			Vandalism	Graffiti, broken/tagged benches
	Infrastructure	Benches, paths, playgrounds	Missing/bad infrastructure	Not enough/missing infrastructure or services (e.g. benches, toilets, kiosk)
	Park design & maintenance	(architectural) design of the site, safety, cleanliness, maintenance, open view	Unsuitable design & maintenance	Not enough meadow, unsightly design, site is too small, not enough space, lacking or poor maintenance of vegetation or water bodies
			Litter/waste	Too much litter/waste, missing waste bins
	Seclusion	No other people/not so crowded, tranquillity, escape		
	Sports facilities	Table tennis, fitness, running tracks, beach volleyball, basketball, football		
	Size/availability & location	Size, proximity, central location, accessibility, "good to have it there"	Potential loss	Removal/future building development of site

2.3. Online survey of the local planning strategy Master Plan Green

Chapter five is based on the analysis of two open-questions from a city wide online survey asking for ideas, suggestions and relevant topics for the future development of Leipzig's UGI to capture the citizen's perspective. Results from these open-ended questions have not been evaluated by the initiators due to time and resource constraints. As the content of the online-survey is relevant for my dissertation project, I cooperated with the city's Office of Green Space and Water for a joint analysis.

With regard to increasing inhabitant numbers, increasing pressure on remaining open areas and climate change the city put up an integrated urban development concept (INSEK 2030) for the development of the compact green city (Stadt Leipzig 2017b). The concept includes all sectors and topics that are important for the future development of the city within the next 10-15 years such as housing, education and sustainable mobility as well as green and open areas. As part of INSEK the Master Plan Green (*Masterplan Grün*) is currently being developed (Stadt Leipzig 2020c). The Master Plan Green formulates functions and services of UGI such as its contribution for human health and climate change adaptation. In addition to health and climate change adaption, the plan is focussing on further guiding themes, biodiversity, environmental justice, and sustainable mobility. It attempts to set up actions plans including the formulation of practical aims and locally specific foci for the preservation and development of Leipzig's UGI.

The process included an online-survey to participate citizens' view on current use patterns, problems and relevant topics regarding the future development of Leipzig's UGI. The online survey was developed and analysed by the city's Office of Green Space and Water and a local urban planning firm (StadtLabor[6]) and was available from March-May 2019 at the official website (Stadt Leipzig 2020a). In total, 3,599 citizens participated in the survey. In addition to questions about the current use, valuation and conflicts or problems of UGI, the survey explores ideas, topics and visions for the future development of Leipzig's UGI in two open ended questions. In the last section, the survey asked for socio-demographic data of respondents. The complete survey can be found in the supplementary material (Survey S2, in German only). For the purpose of this study the analysis focuses on the two open-ended questions about participants' ideas, visions and topics related to the future development of UGI in Leipzig. The questions were as follows:

Do you have specific ideas about how Leipzig's green could be improved?

Are there further topics of UGI that are important to you? Do you have suggestions and topics that should be included in the Master Plan Green?

[6] https://www.stadtlabor.de/

The results of the closed questions about current use, valuation and conflicts or problems of UGI are published in a report (StadtLabor Tröger+Mothes GbR 2019, in German only). My study complements the report with a quantified qualitative analysis of the respondents' ideas, visions and further important topics to improve Leipzig's UGI.

3. The demand side: Use and perception of ecosystem services, benefits and disservices in Leipzig.

3.1. Introduction[7]

From the range of ES that are provided by UGI, regulating services like micro-climate regulation, noise reduction and air filtration as well as cultural ES are of high significance for the well-being of urban inhabitants (Bolund and Hunhammar 1999, Breuste et al. 2013). Cultural ES like nature experiences, recreation and social cohesion are especially important for urban dwellers because they are used, perceived or experienced locally in people's direct environments (Andersson et al. 2015). However, they are embedded in a social-cultural context, often intangible and thus underrepresented in literature (Haase et al. 2014, Hegetschweiler et al. 2017). The relevance, flow and perception of specific ES further depends on the socio-economic and environmental characteristics of their location (Gómez-Baggethun and Barton 2013) as well as on preferences that are shaped by socio-cultural and personal characteristics of the beneficiaries, i.e. urban residents, themselves (Hegetschweiler et al. 2017). I thus argue it is essential to include UGI visitors as relevant local stakeholders in the assessment, in order to evaluate relevant ES and disservices flows (Seppelt et al. 2011).

Several studies analysed socio-demographic characteristics of citizens such as age or gender as predictors for UGI preferences or differences in use frequencies and motivations. In these studies, senior citizens often show preferences for other vegetation structures and use parks for different activities than young people (Chiesura 2004, Bjerke et al. 2006, Shan 2014). For instance, prefer older people less dense vegetation structures in urban parks (Bjerke et al. 2006) and perceive urban brownfields with spontaneous vegetation in Leipzig and Dresden (Germany) more positively than younger people (Mathey et al. 2016). Older age groups additionally use parks for nature-related activities more often and place more importance on aesthetical values and landscape characteristics than younger people (Chiesura 2004, Kienast et al. 2012, Shan 2014, Ode Sang et al. 2016).

In addition to benefits, UGI can include aspects that can be perceived negatively or have a negative effect on human well-being ranging from man-made (waste, vandalism) to (partly) natural (allergenic plants, mosquitos, or intruding animals) aspects, to which I refer here as "disservices/disturbances" (Lyytimäki et al. 2008, Plieninger et al. 2013). In existing studies, disservices/disturbances of UGI are often limited to the analysis of health-related ecosystem disservices like allergenic potential (D'Amato 2000, Ćwik et al. 2018, Battisti et al. 2019) and air quality issues (Gómez-Baggethun and Barton 2013) or safety issues caused by dense vegetation structures and poor lighting in UGI (Koskela and Pain 2000, Hami and Emami 2015). In addition to this, some activities in UGI can be disturbing for other users and the creation and management of UGI providing multiple ES can thus be very challenging

[7] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

for planners (Tzoulas and James 2010, Liu et al. 2018). Some benefits can co-exist and create synergistic ES provision, meaning that two or more ES support each other or even increase simultaneously. On the other hand, others may create trade-offs (two benefits impair each other: one decreases while the other increases) or are perceived as disturbing by different socio-demographic or cultural groups (Haase et al. 2012, Gómez-Baggethun and Barton 2013, Kremer et al. 2016). A study in Finland, for instance, shows that older persons feel more disturbed by public nuisance and littering of a sea shore in Helsinki than younger people (Lodenius 2004). Another example from Sheffield, UK highlights that older age groups feel more concerned about their reduced mobility causing security risks and place more importance on easily accessible UGI than younger persons (Jorgensen and Anthopoulou 2007).

The main aim of this chapter is to highlight ES, perceived benefits and disservices/disturbances that citizens of different age use and perceive in specific UGI. This can improve the development of UGI meeting the demands of its users by providing empirical evidence of associations between design or maintenance and how it is perceived by users. This knowledge can help to develop and maintain resilient and multifunctional UGI and at the same time reduce disturbances and trade-offs.

This chapter of the dissertation is addressing the following research questions:

1) Which ecosystem services, benefits and disservices/disturbances are used and perceived in urban parks and brownfields?
2) How do these differ between users of different age?
3) How do perceived benefits relate to each other? Are there correlations or contradictious trends?

3.2. Analysis of observation and visitor survey data[8]

This chapter is based on the observation and on surveys with randomly selected visitors on the 36 study sites as delineated in section 2.2. I analysed data about the actual ES use, perceived benefits and disservices/disturbances and use motivation from respondents as well as observed visitor density.

3.2.1. Demographic characteristics of respondents and differences between age groups

Respondents were grouped into the following age groups: Kids & teenagers (<18y), Young adults (18-30y), Adults (31-64y) and senior persons (65+y) (Jim and Chen 2006). I counted the frequency of used ES groups as well as benefits and disservices/disturbances across age groups. To determine if there are significant differences in ES group use, perceived benefits and disservices/disturbances between age groups in urban parks, I applied the chi-square test of independence. Sample sizes for kids & teenagers and for older persons were too low on brownfields and thus age differences are not statistically tested for this UGI type. The analysis of perceived benefits and disservices/disturbances

[8] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

excluded kids & teenagers, because for kids we recorded the same aspects their parent or guardian mentioned.

To calculate the distance between addresses and UGI sites, I used the Network Analyst tool of ArcGIS, calculating the shortest route from the estimated place of living or work (averaged from street + postcode) to the nearest point of the circumference or nearest entrance of the site. I limited the distance analysis to respondents that lived or worked in the city of Leipzig to refer to local UGI travelling distance. Instead of the algebraic mean, the median of distance to home of all respondents in each site was calculated to reduce the influence of outliers. Furthermore, I excluded respondents from the distance analysis, who neither specified a postcode nor a street name.

3.2.2. Synergies and trade-offs between perceived benefits

To analyse spatial correlations between pairs of all benefits (nature and grey benefits) on each study site, the weighted Spearman's rank correlation test (weight = number of surveys on each study site) was applied separating urban parks from brownfields. For this analysis, I calculated the frequency of answers for each benefit for each urban park and brownfield and applied the correlation test for these frequencies. To confirm robustness of correlation coefficients, bootstrapping with 1000 resamples of study sites was applied to calculate upper and lower quantiles on 95% significance level (Table S4 and S5 in supplementary material). Positive values of correlations coefficients imply that two benefits are positively influencing each other (synergies), negative values imply trade-offs.

3.3. Results on ecosystem service use patterns in two types of UGI

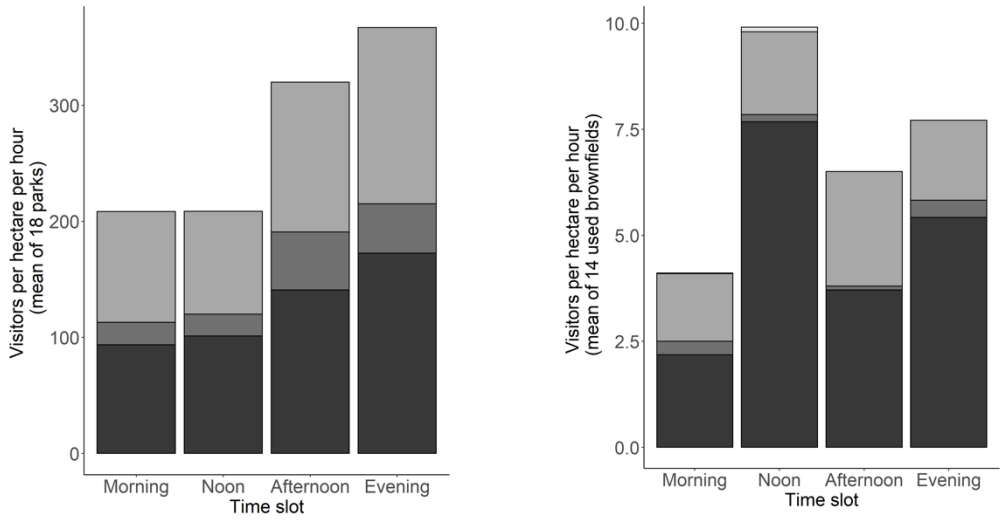
3.3.1. Observed visitor density and ecosystem service use

I observed more than 20,000 visitors on all study sites (8,356 women; 8,963 men; 2,304 children and 4 people with diverse gender; including respondents; Table 2). On brownfields, the share of observed female visitors was lower than in urban parks (Table 2). Only 42% of observed visitors on brownfields were (apparently) women or children, while in parks we specified 55% of observed visitors as female or children. From the 18 observed brownfields, only 14 were visited by people. Hence, results represent only 14 and not 18 brownfields. From brownfields that were not used at all, three were sites with high tree cover and one was with medium tree cover.

Table 2: Observed and interviewed visitors in parks and brownfields and their demographic characteristics and Ecosystem Service (ES) use. The number without brackets shows the number of observed people, the number inside the brackets is the number of survey respondents for each ecosystem service. The most frequently observed ecosystem service use is marked in grey.

		Parks	**Brownfields**
Demographic characteristics of visitors			
Women: total number – %		*8,356 – 43% (778 – 48%)*	*220 – 35% (105 – 41%)*
Children: total number – %		*2,304 – 12% (84 – 5%)*	*46 – 7% (13 – 5%)*
Use of site as shortcut (no specified ES)		124	5
Ecosystem Service	**Ecosystem Service Group**		
Biking	Biking	8,320 (16)	47 (0)
Walking the dog	Dog walking	1,155 (228)	281 (131)
Walking	Physical interactions	7,545 (361)	104 (25)
Jogging		535 (16)	3 (0)
Other activities in nature (e.g. reading, sunbathing, playing football)		639 (194)	57 (18)
Gardening		16 (10)	8 (6)
Sport fishing		11 (8)	0
Meeting people	Social relations	502 (111)	46 (12)
Barbequing, picnicking		121 (50)	1 (1)
Nature mediates smell/noise/visual impacts	Regulating ecosystem services	212 (146)	17 (14)
Nature provides shade & shelter		91 (76)	13 (13)
Being inspired by nature	Experiential & Aesthetical ecosystem services	20 (13)	0
Enjoy landscape beauty		168 (162)	17 (17)
Watching animals/ plants		92 (40)	0
Experience diversity of animals/ plants		35 (27)	1 (1)
Experience cultural heritage/ sense of place		13 (13)	2 (2)
Sacred or religious plants/ animals		11 (6)	0
Environmental education		5 (5)	0
Collecting fibres/ material from plants	Provisioning ecosystem services	7 (5)	3 (3)
Collecting food from plants		13 (13)	2 (2)
Total visitor number		**19,635 (1,624)**	**624 (255)**

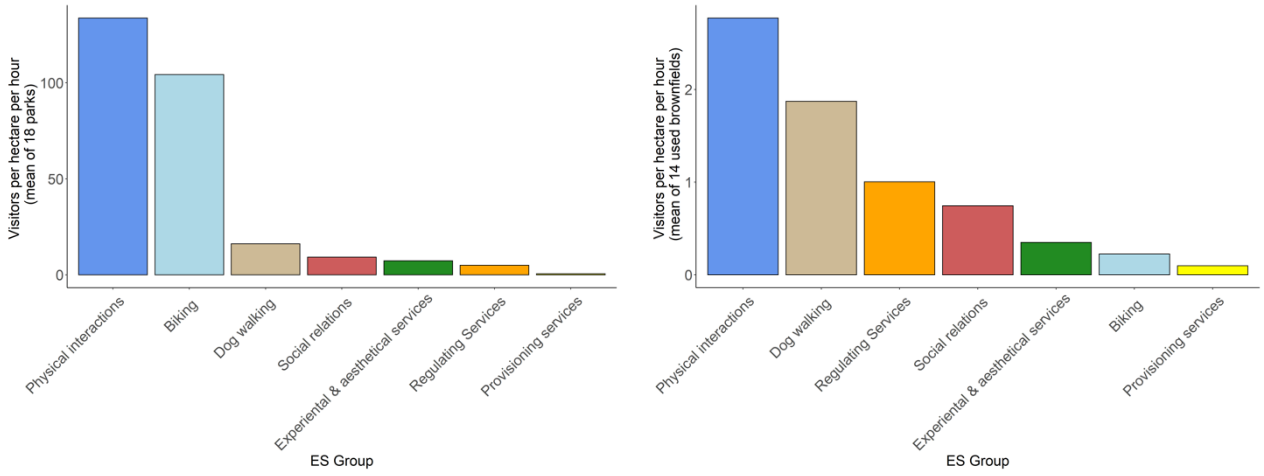
The highest mean user densities (people per hectare per hour) in parks were mapped during afternoons and evenings. Brownfields were used mainly at noon and in the evening and least in the morning (Figure 8). Gender distribution in parks including children is more equal in parks than on brownfields, which were less used by children or women.



a) b)

*Figure 8: Mean observed visitor densities in time slots and their apparent or, if interviewed, specified gender in **a)** urban parks (n=18) and on **b)** brownfields(n=14) in the city Leipzig. Users are scaled to person * hectare -1* hour-1. Please note the different axis scales of parks and brownfields.*

Biking and physical interactions (mostly walking) dominated observed activities and ES use in parks, while a smaller fraction of citizens used other ES groups (Figure 9a). Brownfields were predominantly frequented by citizens walking their dogs and physical interactions (mostly walking or other nature uses such as reading or playing table tennis) (Figure 9b).



a) b)

*Figure 9: Mean observed user densities per ES group in a) urban parks and on b) brownfields in Leipzig. Users are scaled to person * hectare -1* hour-1. Please note the different axis scales of parks and brownfields.*

3.3.2. Ecosystem service use of survey respondents

Demographic characteristics of respondents

Of the approximately 19,600 observed park visitors, I interviewed 1,624 citizens of whom 778 were female, 760 were male, two were diverse gender and 84 were children (Table 2). On brownfields, we asked 255 people out of 624 observed visitors (105 women, 135 men, 2 diverse, 13 children). In total, I managed to ask about 41 % of observed brownfield users while in parks, only 8% of the users were surveyed (see Figure S3 in supplementary material). From the 14 brownfields that were used by people, on one brownfield with high tree cover we only observed drug use and dealing, and as such, no interviews were conducted there (see Table S6 in supplementary material). Hence, survey results for brownfields represent 13 brownfields only, mainly sites with low and medium tree cover[9].

After excluding respondents using the sites only as shortcuts, I analysed 1500 surveys for parks and 250 for brownfields. Although observed use on brownfields was dominated by male persons (men: 48%, women: 35%), gender distribution of respondents was a bit more evenly distributed in the surveys (men: 53%, women: 41%) confirming general higher response rates of women towards surveys (Smith 2008). The majority of the respondents in both UGI types were either young adults (34% in parks, 37% on brownfields) or adults (40% in parks, 46% on brownfields). Interviewed visitors of brownfields were significantly younger with lower variance (t-test: $p<0.001$; mean: 36 y, 1st quartile: 25 y, 3rd quartile: 45 y) than visitors of parks (mean: 39 y, 1st quartile: 25 y, 3rd quartile: 55 y). For both UGI types, urban parks and brownfields, there was no apparent correlation between age and distance travelled. The median of the distance from home or work to the nearest entrance for parks is 814 m (1st quartile: 321 m, 3rd quartile: 1,881 m) and 448 m for brownfields (1st quartile: 295 m, 3rd quartile: 953 m). On average, about 22% of park respondents live or work within 300 m representing a five-minute walking distance; on brownfields, this proportion is about 35% (Figure 10)[10].

[9] This paragraph bases on text published in a modified version in (Palliwoda et al. 2020)

[10] This paragraph bases on text published in a modified version in (Palliwoda and Priess 2021)

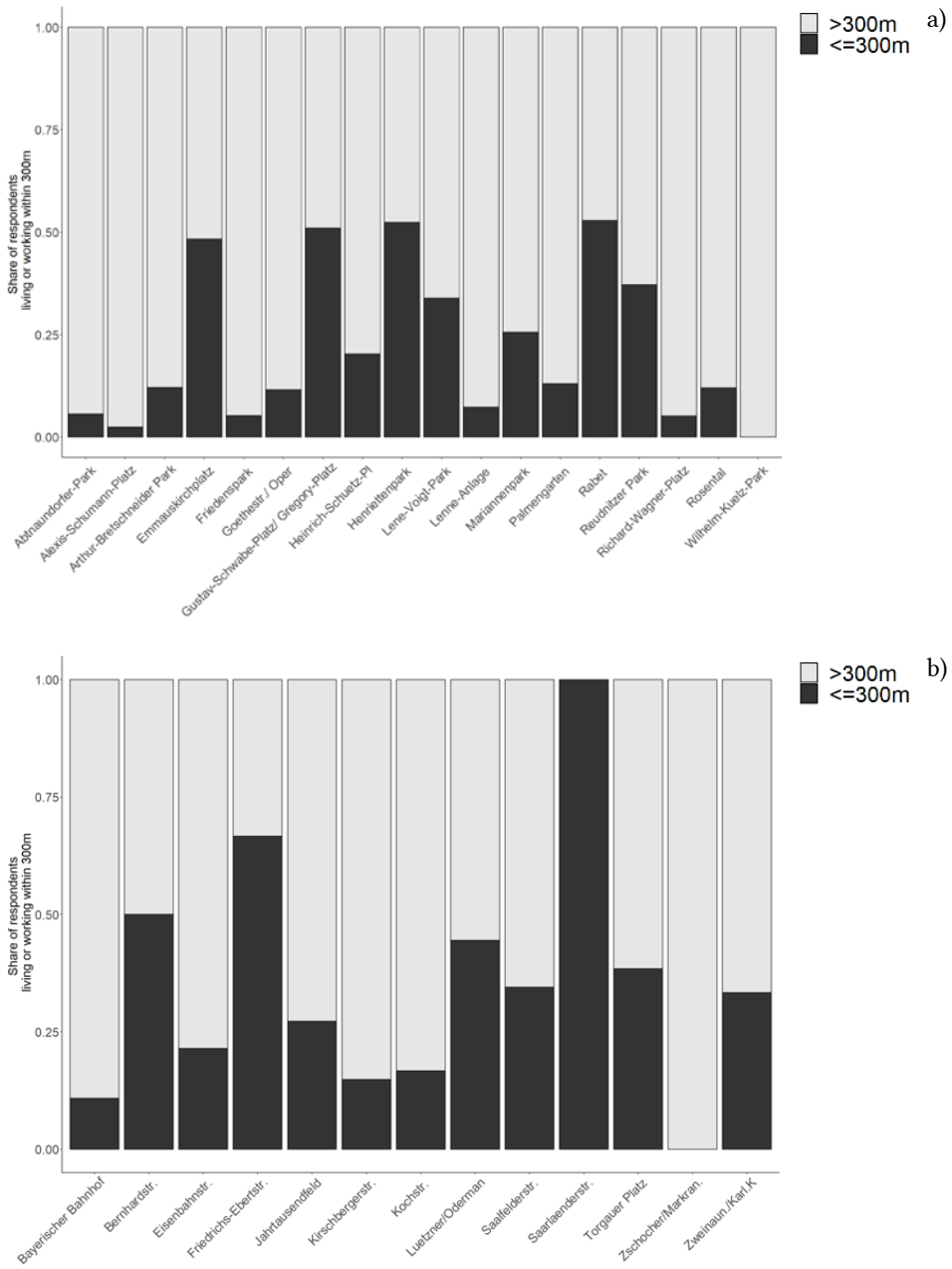


*Figure 10: Share of respondents living within 300 m from the site in **a)** urban parks (n=18) and **b)** green brownfields (n=13).*

Ecosystem service use across age groups in urban parks

In parks, I recorded 20 different ES used by respondents. The main activities of respondents in all parks were walking (24% of respondents), dog walking (15%), other activities in nature (e.g. playing football or reading – 13%) and enjoying landscape beauty (11%). Figure 11 visualises the most frequently used ES in urban parks for all age groups that were specified in the surveys.

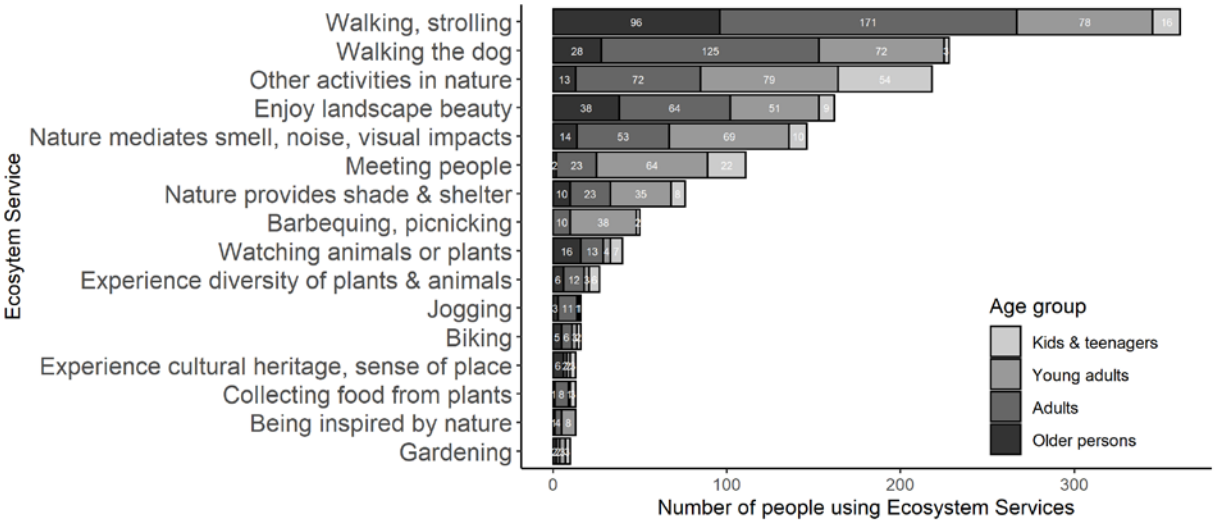


Figure 11: Used ecosystem services of respondents of different age groups from surveys (n=1500) in urban parks (question with predefined ecosystem services). Ecosystem services that were used from less than 10 respondents were aggregated in "Other activities in nature" for graphical reasons[11].

The chi-square test reveals significant (p<0.001) differences in ES use between the four age groups in urban parks (Table 3). Kids and teenagers were mainly doing other activities in nature (e.g. doing sports) and collected food or material from plants more often than other age groups (highest Pearson's residuals)[12]. The most frequently used ES that 15% of the young adult respondents specified in the surveys were other activities (e.g. doing sports, reading, sunbathing) and walking. The statistics analysis implies that this age group significantly more often used ES aggregated as social relations (barbequing, meeting people) than older age groups. Walking (29% of adults) was the main activity of adult respondents followed by dog-walking (21%), which the chi-square confirms. Older park visitors specified walking (40% of senior respondents) and enjoying the landscape (16%) as their most frequently used ES (Figure 11). Enjoying landscape and other experiential & aesthetical services are used more often by older persons than by the other age groups.

[11] This figure is published as Figure A1.7 in (Palliwoda and Priess 2021)

[12] It must be noted that only few comments for provisioning services and for kids & teenagers were mapped and thus statistical power is low for this age group.

Table 3: Pearson's residuals from chi-square test of difference between used ecosystem service groups of age groups from respondents in urban parks. Highest positive residuals mean a positive association of the age group with the ES group. The high residuals for provisioning services for kids & teenagers may be treated with caution as there were only few responses for this ES group.

Used ES group	Kids & teenagers (<18y)	Young adults (18-30y)	Adults (31-64y)	Older persons (65+y)
Biking	0.33	-1.05	-0.15	1.52
Dog walking	-4.13	-0.64	3.56	-1.43
Experiential and Aesthetical ES	0.5	-2.38	-0.6	4.02
Physical interactions	1.11	-2.8	0.9	1.79
Provisioning services	3.15	-2.07	1.05	-1.11
Regulating services	-0.86	3.26	-1.34	-1.95
Social relations	2	6.37	-3.9	-4.69

Ecosystem service use across age groups on brownfields

Citizens on urban brownfields used 14 different ES. Sites were mainly visited for dog walking (52%) from all age groups. Brownfields were furthermore used for walking (10%) as well as other activities such as playing table tennis or relaxing (7%). Sporadically, brownfields were used for meeting people or visitors enjoyed landscape beauty or noise regulation. Some of the brownfields visitors where consuming illegal drugs, which was aggregated in the category "Other activities in nature" (Figure 12).

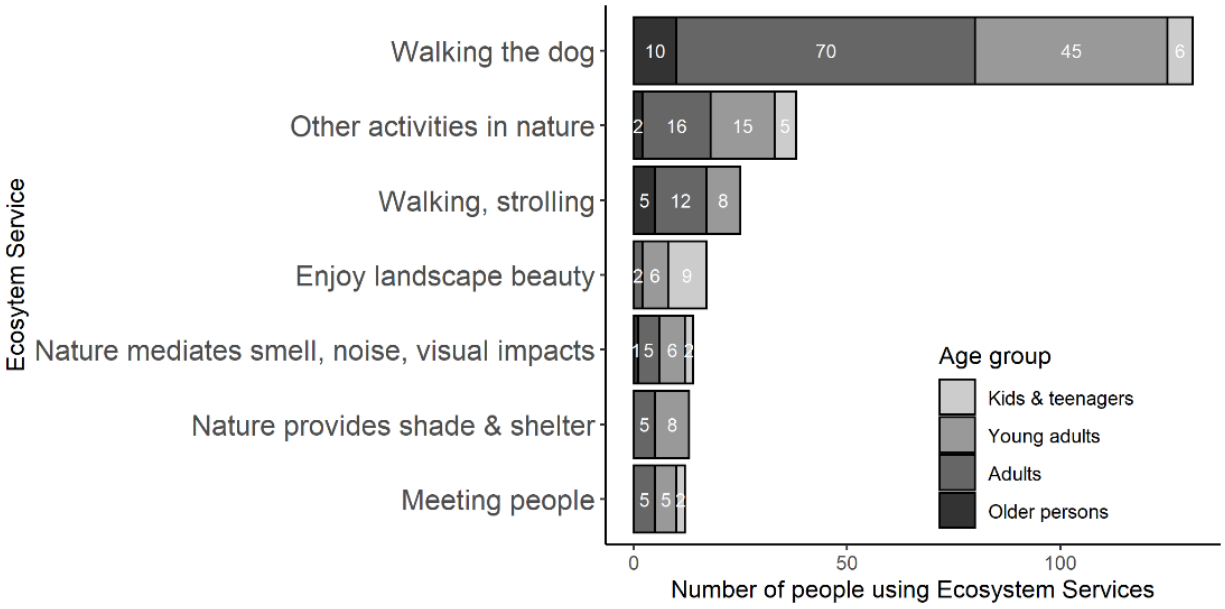


Figure 12: Used ecosystem services of respondents of different age groups from surveys (n=250) on brownfields (question with predefined ecosystem services). Ecosystem services that were used from less than 10 respondents were aggregated in "Other activities in nature" for graphical reasons[13].

[13] This figure is published as Figure A1.8 in (Palliwoda and Priess 2021)

Motivation for site use

In addition to the use of ES, respondents were asked to choose from six motivation categories, why they used the particular park or brownfield for the specified ES. As shown in Figure 13, "Close to home or accessible" is the most frequent motivation mentioned by visitors of both UGI types (61% of respondents in parks, 43% on brownfields) (Palliwoda et al. 2020). Comparing both UGI types, I found significant differences (chi-square test, $p<0.001$), e.g. were "Tranquillity or seclusion" and "Physical space for activities" more important to brownfield users (18% and 16% on brownfields vs. 8% and 7% in parks, highest Pearson's residuals, data not shown).

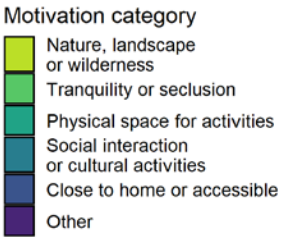


Figure 13: Specified motivations for UGI use from respondentsin parks and brownfields.

3.3.3. Perception of benefits across age groups[14]

Perception of benefits in urban parks

Figure 14 shows all mentioned positive aspects including nature benefits perceived by respondents in urban parks. The chi-square test reveals significant differences in benefit perception between age groups (*p<0.001*). Older persons (65+ y) mentioned green landscape/aesthetics as well as urban wilderness[15] aspects including near-natural maintenance more frequently than the other age groups (highest positive Pearson's residuals, Table 4). Natural elements such as trees, flowering aspects or water elements were other important green benefits for older persons. Adults between 31 and 64

[14] This section bases on text published in a modified version in (Palliwoda and Priess 2021)
[15] It must be noted that only few comments for older persons and urban wilderness were mapped and thus statistical power is low for this age group.

mentioned infrastructure such as playgrounds, benches and paths more often than other age groups (Table 4). However, similar to older persons, they valued natural elements and features regarding park design & maintenance such as safety and cleanliness most frequently. The youngest age group, young adults (19-30 y), valued spatial aspects such as a decent size/availability & location of the park most frequently followed by park design & maintenance aspects. Comparted to other age groups, young adults placed more importance on sports facilities (Table 4).

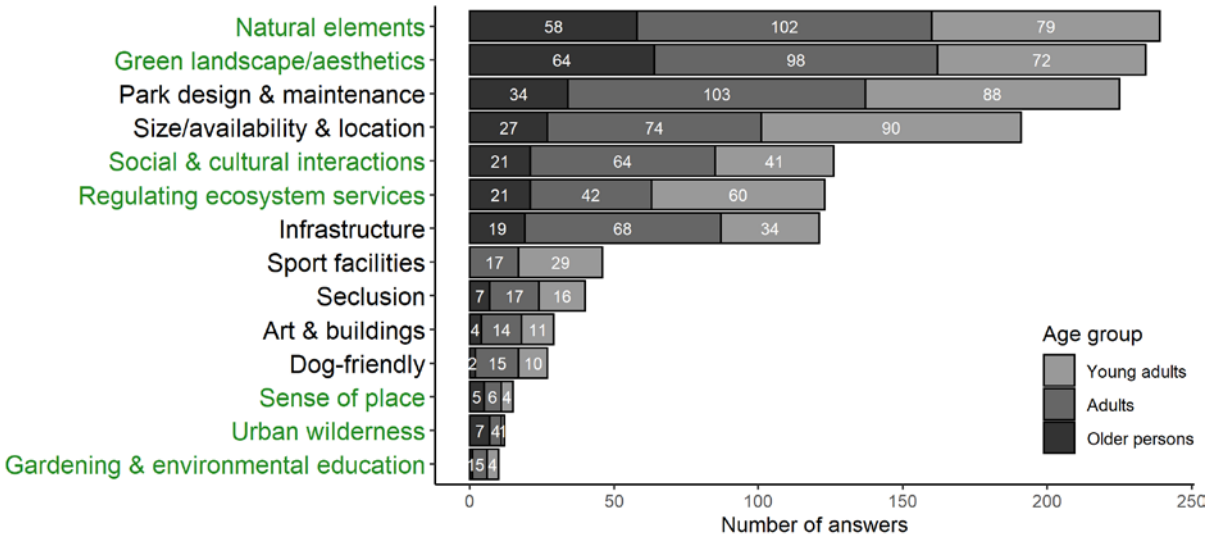


Figure 14: Frequencies of perceived benefits in urban parks mentioned by visitors of different age groups in Leipzig (categorized answers from open question). Multiple answers were possible. The white numbers display the number of answers for each age group. Nature benefits are written in green[16].

Table 4: Pearson's residuals from chi-square test of difference between perceived green and grey benefits of age groups from respondents in urban parks. Highest positive residuals mean a positive association of the age group with the benefit.

Benefit	Young adults (18-30y)	Adults (31-64y)	Older persons (65+y)
Art & buildings	0.04	0.37	-0.62
Dog-friendly	-0.04	0.93	-1.36
Gardening & environmental education	0.13	0.3	-0.64
Green landscape/ aesthetics	-1.68	-0.43	3.03
Infrastructure	-1.69	2.07	-0.78
Nature elements	-1.12	-0.25	1.96
Park design & maintenance	0.4	0.46	-1.27
Regulating ES	2.05	-1.61	-0.44
Seclusion	0.26	-0.12	-0.19
Sense of place	-0.68	-0.22	1.3
Size/ availability & location	2.18	-1.04	-1.48
Social & cultural interactions	-0.91	1.2	-0.55
Sports facilities	2.83	-0.7	-2.94
Urban wilderness	-1.65	-0.55	3.16

[16] This figure is published as Figure 3 in (Palliwoda and Priess 2021)

Perception of benefits on brownfields

Suitability for dogs as a positive green brownfield aspect was mentioned most frequently by older persons and second- and third-most by adults and young adults, respectively (Figure 15), although dog-walking overall was the main activity (52% of the respondents) of all age groups (see figure 12). Adults mostly valued size/availability & location including statements that the site is the only available UGI near their home. Young adults appreciated wilderness aspects including low maintenance of vegetation the most, which was also important to adults. Furthermore, young adults liked brownfields for their social & cultural interactions. For older age groups, this opportunity seems to decrease in valuation or not be important at all compared to other benefits (Figure 15).

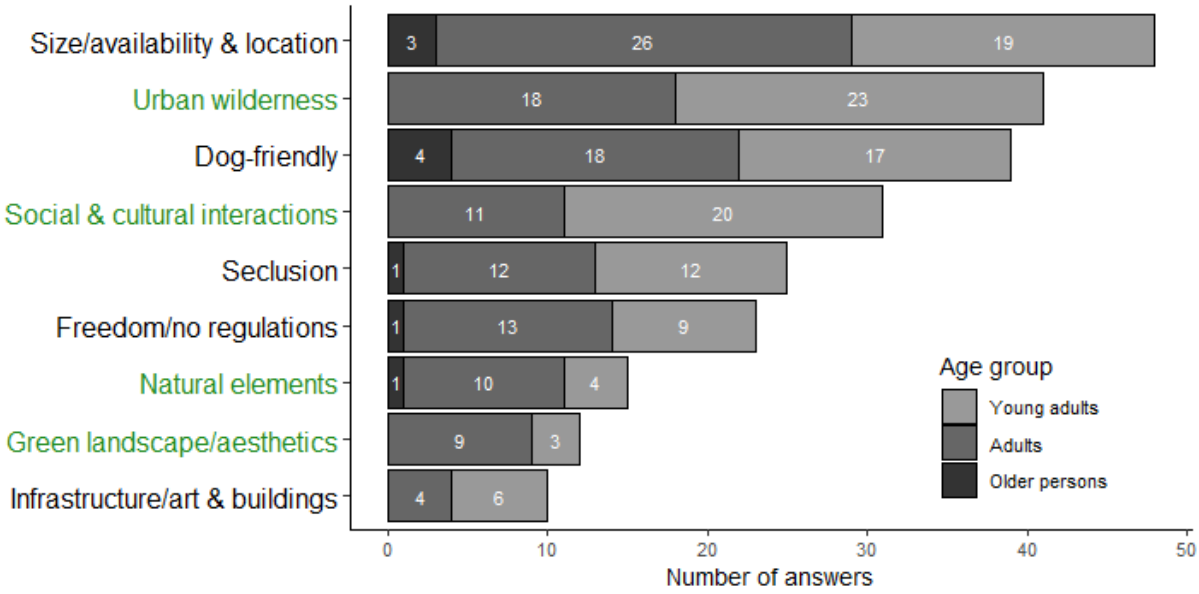


Figure 15: Frequencies of perceived benefits on brownfields mentioned by visitors of different age groups in Leipzig (categorized answers from open question). Multiple answers were possible. The white numbers display the number of anwers for each age group. Nature benefits are written in green[17].

3.3.4. Synergies and trade-offs between benefits[18]

To identify positive (synergies) or negative spatial interactions (trade-offs) between pairs of perceived grey and green benefits in urban parks, I applied the weighted Spearman's correlation test (Table 5). In parks, statements about social & cultural interactions show strong positive correlations with perceived infrastructure (0.8) and sports facilities (0.87). I found a slightly negative relationship between social & cultural interactions and regulating ES, though this correlation is not significant. Regulating ES show moderate correlation with seclusion (0.51). Answers referring to art & buildings (graffiti, monuments) correlate moderately negative to social & cultural interactions (-0.6) and sense of place (-0.5) and positively to urban wilderness (0.6) of parks. Perception of sites being dog-friendly

[17] This figure is published as Figure 3 in (Palliwoda and Priess 2021)
[18] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

correlates positively with seclusion of parks (0.77) as well as brownfields (0.58). The aspects of urban wilderness, dog-friendly, freedom/no regulations, size/availability & location, and seclusion mainly positively correlate with each other on brownfields. Enjoying social & cultural interactions as well as urban wilderness on brownfields strongly correlates with people valuing size/ availability & location of the site (0.91 and 0.89). However, many high positive correlation coefficients for pairs of benefits perceived on brownfields point out that users often mention the same positive aspects and benefits on each of the 13 sites.

*Table 5: Correlation matrix (weighted Spearman's correlation) for pairs of perceived benefits in 18 urban parks and 13 urban green brownfields. Numbers below the black diagonal line show correlation coefficients for aspects of urban parks, above the line correlations for urban brownfields. Respondents could name multiple categories. Categories representing nature benefits are in light green; grey benefits are grey. Significant (*on 95% confidence interval for 1000 bootstrapped resamples, see table S4 and table S5 in supplementary material) positive or negative correlations ≥0.5 between nature benefits and grey benefits are in dark green; correlations between two grey benefits are marked in grey.*

Urban brown-fields / **Urban parks**	Gardening & environmental education	Green landscape/ aesthetics	Natural elements	Regulating ecosystem services	Sense of place	Social & cultural interactions	Urban wilderness	Art & buildings	Dog-friendly	Freedom/ no regulation	Infrastructure	Park design & maintenance	Seclusion	Size/ availability & location	Sports facilities
Gardening & environmental education	1														
Green landscape/ aesthetics	-0.19	1	-0.1			0.13	0.64		0.56*	0.52	0.15		0.9*	0.34	
Natural elements	0.24	0.08	1			-0.16	-0.08		-0.02	0.31	-0.65		-0.18	0	
Regulating ecosystem services	0.05	0.3	0.32	1											
Sense of place	0.02	-0.24	0.11	-0.24	1										
Social & cultural interactions	0.45	0.02	-0.02	-0.38	0.17	1	0.77		0.74	0.65*	0.65		0.19	0.91*	
Urban wilderness	-0.26	0.27	0.13	0.08	-0.25	-0.48	1		0.91*	0.89*	0.45		0.71	0.89*	
Art & buildings	-0.41	0.26	-0.27	0.23	-0.5*	-0.6*	0.6*	1							
Dog-friendly	0.2	0.29	0.24	0.42	-0.09	0.05	0.11	0.14	1	0.82*	0.37		0.58*	0.89	
Freedom/ no regulation										1			0.59	0.8*	
Infrastructure	0.23	0.32	0.29	-0.22	0.03	0.8*	-0.14	-0.36	0.09		1		0.16	0.5	
Park design & maintenance	0.31	0.08	-0.06	0.02	-0.3	0.16	-0.01	0	0.24		0.1	1			
Seclusion	0.1	0.15	0.3	0.51*	0.01	-0.14	0.11	0.02	0.77*		-0.03	0.35	1	0.34	
Size/ availability & location	0.1	0.05	-0.04	-0.2	-0.08	0.25	-0.12	-0.24	-0.32		0.4	0.5	0.01	1	
Sports facilities	0.38	0.14	-0.01	-0.26	0.19	0.87*	-0.47	-0.48	0.08		0.72*	-0.04	-0.13	0.16	1

3.3.5. Perception of disservices/disturbances across age groups[19]

Perception of disservices/ disturbances in urban parks

The main disservice/disturbance perceived in all age groups was litter and the lack of waste bins followed by undesired activities of other users (Figure 16). Although social & cultural interactions such as meeting people were often used (Figure 11) and appreciated (Figure 14) in urban parks, especially by adults and young adults, these interactions can be disturbing for others: people barbequing or sitting in groups as well as overcrowded parks (other users/behaviour/bicycles) were often perceived as disservice/disturbance among respondents. Older persons especially felt more disturbed by other users compared to other age groups as the chi-square test reveals ($p<0.001$, Table 6). Also criminal activities and safety aspects were disturbing for park users. Young adults felt more disturbed by street noise and insufficient shade than other age groups. However, this effect might be caused by one urban park (P11_1, Table S6 in supplementary material) that is directly located on a street with no view protection and is predominantly used by young adults.

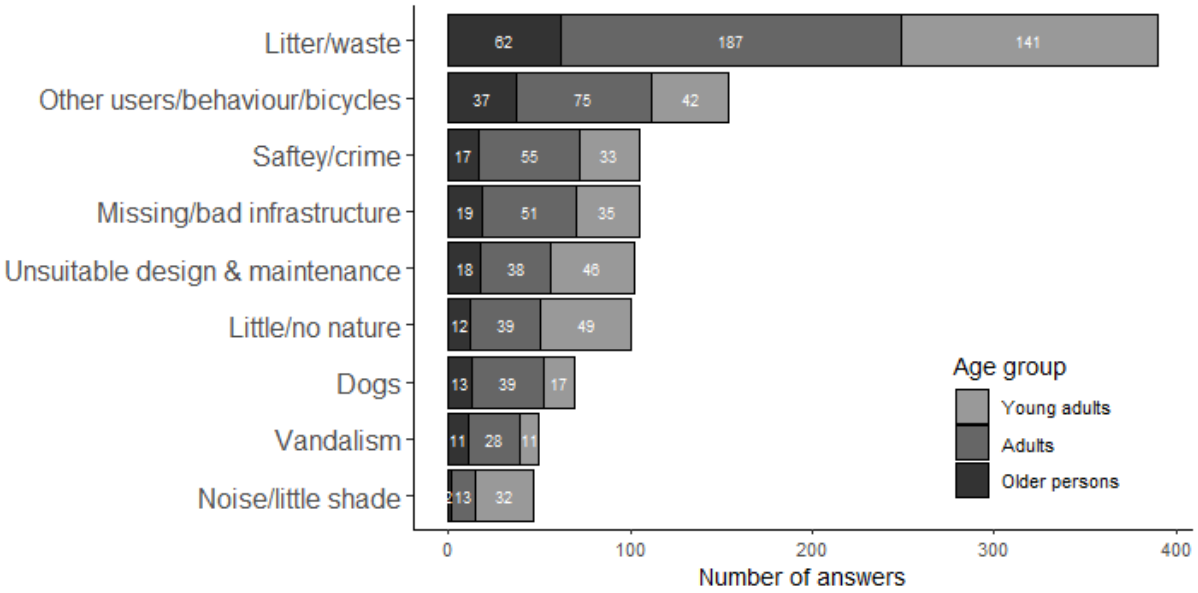


Figure 16: Perceived disservices/disturbances in urban parks across age groups. Multiple answers were possible. The white numbers display the number of answers for each age group.[20]

[19] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

[20] This figure is published as Figure A1.9 in (Palliwoda and Priess 2021)

Table 6: Pearson's residuals of chi-square test for differences between perceived disservices/disturbances of age groups in urban parks. Positive values mean a positive association between age group and disturbance, negative values mean negative association between age group and disturbance (p<0.001)*. Highest positive residuals are marked in grey.*

Disservice/ disturbance	Young adults (18-30y)	Adults (31-64y)	Older persons (65+y)
Dogs	-1.59	1.18	0.37
Little/no nature	2.13	-1.14	-1.22
Missing/bad infrastructure	-0.49	0.27	0.27
Noise/little shade	3.64	-1.92	-2.12
Other users/behaviour/bicycles	-1.84	0.35	2.11
Safety/crime	-0.81	0.84	-0.21
Litter/waste	-0.01	0.33	-0.54
Unsuitable design & maintenance	1.5	-1.41	0.15
Vandalism	-1.67	0.95	0.85

Perception of disservices/ disturbances on brownfields

When asked for negative aspects on brownfields, many respondents called litter being dumped, the lack of waste bins, and insufficient maintenance as the main disturbance/disservice (Figure 17). The positive valuation of urban wilderness aspects including low maintenance activities on the one hand and sites being perceived as neglected on the other hand illustrates the contradictory perception of benefits and disturbances/disservices among respondents. Other frequently mentioned disturbances/disservices of brownfields were "lacking or no nature" mainly referring to the removal of mature trees and the potential loss of the site due to planned conversion, e.g. for housing.

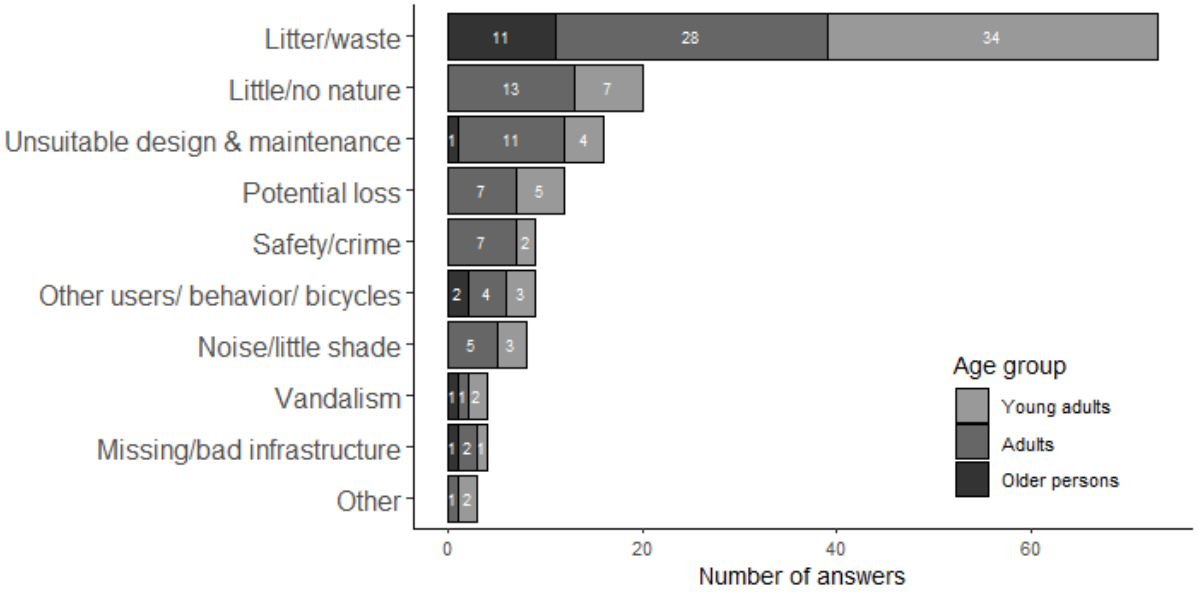


Figure 17: Perceived disservices/disturbances on urban brownfields across age groups. Multiple answers were possible. The white numbers display the number of answers for each age group.[21]

[21] This figure is published as Figure A1.11 in (Palliwoda and Priess 2021)

3.4. Discussion of ecosystem service, benefit and disservice flow in UGI

3.4.1. General use patterns in UGI

Urban parks and brownfields in Leipzig are used for various cultural ES as well as regulating services such as providing shade or reducing noise. Biking and physical interactions such as walking and other activities in nature (e.g. reading, sunbathing) were most prevalent in in urban parks, which confirms findings from other European studies (Bertram and Rehdanz 2015, Bijker and Sijtsma 2017, Rall et al. 2017). Most of the studied brownfields were actually used, especially by citizens who live close by and mainly for dog walking, confirming other studies addressing brownfield use (Rall and Haase 2011, Pueffel et al. 2018). The low median distance to respondents' home on brownfields furthermore underscores their importance for citizens from the neighbourhood. Compared to parks, on brownfields we mapped only a small number of bikers, which may be due to the lack of available infrastructure for biking such as connecting and smooth paths (Lu et al. 2019). Like other UGI studies, we observed very little use of spiritual or educational services, implying either low demands or the provision by other facilities or institutions like churches (Bertram and Rehdanz 2015) or by ecosystems in non-urban or rural areas (Plieninger et al. 2013, Rall et al. 2017). The four most important benefits for park respondents were green landscape/aesthetics, natural elements, park design & maintenance, and size/availability & location. On brownfields respondents furthermore appreciated urban wilderness including near-natural conditions very frequently[22].

These benefits represent four of the six key human dimensions of environmental quality that Gobster and Westphal (2004) identified in an urban greenway in Chicago, USA: aesthetics, naturalness, cleanliness, and access. Wilderness and the availability of brownfields as well as natural elements and the green landscape/aesthetics in parks were highly valued by users confirming the importance of the aesthetic, naturalness and access dimensions. It seems that study sites in Leipzig are capable of providing these quality dimensions while the cleanliness dimension is reflected in the littering problem as the main disservice/disturbance on both UGI types. This issue should be of high relevance in UGI planning in order to provide high quality green spaces and should be compensated by, e.g. adapted maintenance and cleaning cycles. I found that citizens are mainly motivated to use brownfields as well as parks due to proximity to their home, which goes in line with the frequent mentioning of size/availability & location as positive aspects. Proximity and availability of UGI referring to the access quality dimension should therefore be a further key element of green space planning in cities (Wolch et al. 2014) to increase distributional justice for densely populated districts and provide ES for all citizens[23].

[22] This paragraph bases on text published in a modified version in (Palliwoda et al. 2020)
[23] This paragraph bases on text published in a modified version in (Palliwoda and Priess 2021)

3.4.2. Ecosystem service use and perceived benefits across age groups[24]

Wilderness aspects and natural elements refer to the naturalness dimension and are very important to older persons (Gibson 2018). Besides flowering aspects and water bodies, the most frequently mentioned natural element in urban parks were trees. Trees in parks and streets contribute to people's well-being by reducing stress, noise and air temperature and improve aesthetical values and scenery (Lohr et al. 2004, Roy et al. 2012). Lohr et al. (2004) reported that young people between 18 and 21 years place less importance on trees as being important for their quality of life than older age groups. Similarly, my study reveals that natural elements such as large trees and flowering aspects were mainly appreciated by older persons and less by young adults between 18 and 30. Older age groups accordingly enjoyed landscape beauty and other experiential & aesthetical services, a nature benefit that necessarily includes natural elements, more often than young adults. Enjoying nature or landscape beauty, representing the aesthetic dimension, and the possibility to get in contact with nature as one important UGI benefit, especially for older age groups, has also been highlighted by other studies (Chiesura 2004, Matsuoka and Kaplan 2008, Shan 2014).

Young adults, on the other hand, placed more importance on sports facilities compared to other age groups. In addition, they valued design & maintenance aspects of urban parks most, e.g. separate corners for different activities, safety aspects or large open lawns as well as a decent park size or proximity to their home (size/availability & location), referring to the cleanliness and access dimension. These results suggest that nearby UGI designed for activities like doing sports, reading or meeting people is especially important for young adults as these were their most frequently performed activities. Studies in other European cities (Gothenburg and Amsterdam), in Santa Cruz in Bolivia and a national survey in Germany found similar results for park visitors of different age groups, in which younger people were more engaged in sporting and meeting others, whereas older age groups were more frequently walking, watching and enjoying nature favouring a more natural design of UGI (Wright Wendel et al. 2012, Gartenamtsleiterkonferenz 2014, Ode Sang et al. 2016, Gibson 2018, Knight et al. 2018). In accordance with these studies, my findings confirm these cross-cultural age specific preferences for ES and benefits derived from UGI.

3.4.3. Reducing trade-offs with UGI design and brownfields[25]

Besides benefits, there are some age group specific disservices/disturbances, such as feeling disturbed by activities of other people, which was especially criticized by older persons 65 years and above. They disliked other visitors' behaviour or activities such as groups of people being noisy or leaving litter and causing smoke from barbequing, as well as the overuse of UGI (overcrowded parks). These conflicts must be considered in design and maintenance of UGI. The implementation of separate areas for different activities such as barbeque areas including sufficient waste bins, especially in intensively

[24] This section bases on text published in a modified version in (Palliwoda and Priess 2021)
[25] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

used neighbourhood parks, for instance, can contribute to reduce these conflicts. However, separate areas that are less visible and under less surveillance by other park users might foster criminal activities, groups of people consuming drugs and alcohol or vandalism. Safety & crime were among the main concerns of UGI users, and perceived safety risks can lead to decreasing use (Koskela and Pain 2000, Adinolfi et al. 2014). UGI design should therefore support usability by not only including appropriate infrastructure and spatial configuration but also by maintaining it on a regular basis and by providing sufficient lighting. However, the negative impacts of increased lights on the night sky and the absence of natural darkness towards biodiversity (Longcore and Rich 2004, Pauwels et al. 2019) but also human health (Lyytimäki and Rinne 2013) must be considered in UGI planning. Applying measures to reduce disturbances and conflicts, UGI can then function as places to strengthen social cohesion with neighbours instead of creating disservices (Peters et al. 2010).

Another frequently mentioned problem was the presence of unleashed dogs and their faeces in public parks. Only a few parks in Leipzig provide designated dog areas and facilities, and when provided, they are usually not fenced in such that dogs may escape the designated area. Based on this study, I can state that urban brownfields contribute to decrease this conflict. Although being far from visited as frequently as urban parks, green brownfields are mainly used by dog walkers confirming findings from other studies in Leipzig (Rall and Haase 2011, Pueffel et al. 2018). Brownfield visitors appreciated the availability of the open spaces, which are often more secluded than urban parks and hence provide suitable space for dogs. The average brownfield user mainly lives close by and these sites were often the only available UGI near their homes. I thus argue to view highly frequented brownfields not only as important for dog owners, but for a broader audience and to integrate these informal sites into the city-wide UGI network to reduce use and user conflicts in public parks and to increase the availability of UGI close to people's homes.

Often connected to dog suitability, the "wild" or near-natural character (wilderness) is one of the main positive aspects of brownfields that users appreciate underlining the chances of informal and less-manicured types of UGI for providing nature experiences and adding more nature to the city (Chiesura 2004, Rall and Haase 2011). However, confirmed by this and previous studies, littering is one of the main disturbance/disservice on brownfields and some people find them rather unattractive clearly preferring well-maintained public parks (Rall and Haase 2011, Bixler and Floyd 2016, Farahani and Maller 2019). Nevertheless, cities can be hotspots for nature conservation, nature experiences and biodiversity, especially when UGI contains spontaneous and less-manicured vegetation (Dunn et al. 2006, O'Farrell et al. 2012, Breuste et al. 2013). I thus call for diverse UGI including "wild areas" with regular waste removal that can fulfil diverse users' preferences, contribute to urban biodiversity and simultaneously reduce trade-offs between ES and recreational activities in public green spaces (Kabisch et al. 2016).

3.5. Interim conclusions[26]

The growing number of citizens in Leipzig can be expected to increase demand for and use of the city's UGI. In this chapter, I highlighted ES use and the perception and use of nature benefits and disservices/disturbances by UGI users. Some benefits support multifunctional UGI use whilst others show antagonistic relationships, requiring careful and purposive planning and management. UGI users' contrasting perceptions and valuation of features and other users' activities increase the challenge for UGI planning and management, especially in Leipzig's context of growing demands and shrinking brownfield areas.

In addition to managed urban parks, my results demonstrate that unmanaged green urban brownfields contribute to the ES provision by providing partly complementary services. The sites being used for their seclusion exemplarily illustrate the importance for spatial planning to address and to provide space for ES that can be disturbing for others. The role of unmanaged sites, be it for dog walking or lovers of urban wilderness, should not be ignored by planners, as the shift of these uses into highly frequented urban parks could lead to increasing conflicts between UGI users (McCormack et al. 2010, Liu et al. 2018). The integration of low-maintained and secluded sites or areas can thus avoid trade-offs between ES and contribute to multifunctional UGI. The high appreciation of urban wilderness on brownfields furthermore suggests that many urban citizens support nature-oriented and reduced management decreasing not only costs, but increasing nature experience and fostering urban biodiversity.

[26] This section synthesizes relevant conclusions published in (Palliwoda and Priess 2021) and in (Palliwoda et al. 2020)

4. The supply side: influence of site characteristics on ecosystem service use and perception of benefits in UGI

4.1. Introduction

ES provided by UGI range from habitat supply to provisioning and regulating services to cultural services (Millennium Ecosystem Assessment 2005, Gómez-Baggethun and Barton 2013). The latter are of high importance in cities because they directly contribute to the physical and psychological well-being of people (Tzoulas et al. 2007, Kessel et al. 2009, Lee and Maheswaran 2011). UGI, for instance in the form of urban parks, provide space for recreation, physical exercise, social and cultural interactions (Peters et al. 2010, Gómez-Baggethun and Barton 2013, Krellenberg et al. 2014), to experience and interact with nature (Gobster and Westphal 2004, Palliwoda et al. 2017) and provide aesthetical as well as educational values (Bertram and Rehdanz 2015). The actual flow or use of these ES and benefits that are (potentially) provided by UGI is not only determined by preferences and socio-demographic characteristics as it has been highlighted in the previous chapter, but also by accessibility and design characteristics of the UGI itself (Hegetschweiler et al. 2017). UGI should therefore include appropriate features and facilities needs to be available within reachable distances (Van Herzele and Wiedemann 2003, Elmqvist et al. 2015).

There are several guidelines and thresholds that are formulated by researchers and city planners suggesting a minimum amount of UGI within a certain distance to people's place of living (Barbosa et al. 2007, Stadt Leipzig 2017b). Some authors, for example, recommend a maximum distance of 250-300 m to the nearest green space (Barbosa et al. 2007, Toftager et al. 2011, Stadt Leipzig 2017b) because citizens are more likely to use close-by green spaces than ones that they have to travel further distances to (Schipperijn et al. 2010, Toftager et al. 2011, Stessens et al. 2017). Physical interactions and the flow of benefits and ES increase with safe and well-kept parks within close distance from people's home (Bird 2004, Toftager et al. 2011, Schipperijn et al. 2013, Langemeyer and Connolly 2020). Plenty of studies furthermore underline a minimum size of (the nearest) UGI as an important use-determining factor revealing that large UGI are used more frequently (Giles-Corti et al. 2005, Schipperijn et al. 2013, Hegetschweiler et al. 2017). Still, small parks in dense neighbourhoods can be especially important for social interactions (Peschardt and Stigsdotter 2013) and may be used for other cultural ES than large urban parks (Van Herzele and Wiedemann 2003, Nordh et al. 2011, Wright Wendel et al. 2012)[27].

Although these spatial characteristics of UGI, distance and size, are among the most important factors influencing their use (Van Herzele and Wiedemann 2003, Schipperijn et al. 2010, Lin et al. 2014), also grey characteristics of UGI such as safety, benches or sports infrastructure, are important for citizens and determine ES supply and therefore (potential) use (McCormack et al. 2010, Voigt et al. 2014).

[27] This paragraph bases on text published in a modified version in (Palliwoda and Priess 2021)

Several studies analysed the importance of facilities available for physical interactions in UGI and found, for example, positive influences of trails, lighting, sports infrastructure and benches (Kaczynski and Henderson 2008, Kaczynski et al. 2008, Schipperijn et al. 2013, Voigt et al. 2014, Schetke et al. 2016)[28].

Together with grey characteristics, also biotic features like biological diversity or trees (green characteristics) are affecting UGI use and activities (Voigt et al. 2014). UGI visitors place importance on the presence of large trees, wooded areas and general greenness and naturalness of local UGI (Giles-Corti et al. 2005, Kaczynski et al. 2008, Bijker and Sijtsma 2017). In urban green spaces, tree canopy and density can be an important parameter for people's preferences (Hofmann et al. 2012). Well-maintained urban parks with moderately dense vegetation seem to provide a sense of safety in societies all over the world, shown in a review about safety aspects in urban green (Sreetheran and van den Bosch 2014). A study in Norway underpins people's preferences for moderately densely treed parks (Bjerke et al. 2006), and Australian citizens seem to prefer moderate to low levels of tree canopy for recreational use (Shanahan et al. 2014). At the same time, researchers in Baltimore, USA, found that tree cover positively influences social relations and interactions (Holtan et al. 2014). In addition to tree or vegetation density, it seems that species richness in vegetation, often connected to colours of flowering species (Lindemann-Matthies et al. 2010), is positively related to aesthetic appreciation and people's psychological well-being (Fuller et al. 2007, Dallimer et al. 2012). Contrastingly, some urban dwellers, e.g. in Leipzig and Dresden, Germany also appreciate informal sites with low management activities like urban brownfields (Mathey et al. 2016, Pueffel et al. 2018)[29].

However, there is a lack of research providing empirical evidence of how UGI characteristics can influence the actual use of specific cultural and other ecosystem (dis-)services by urban dwellers. Not much is known about the effect of UGI characteristics on perceived UGI benefits and ES (Kremer et al. 2016). I argue that knowledge about this relationship is essential as it determines the quality of UGI and thus the provision with ES (Hegetschweiler et al. 2017). This chapter aims to find relations between green characteristics such as tree cover or plant diversity and other characteristics of UGI and ES use of users as well as perceived benefits in parks and brownfields by a applying a statistical model. Knowing which components of UGI may support which benefits can improve the development and management of UGI, better meeting the multiple demands of their users. The chapter addresses the following research questions:

1) How does tree cover influence the use of observed and surveyed ecosystem service use and use motivation?
2) Are there other green, spatial or grey characteristics that influence ecosystem service use?

[28] This paragraph bases on text published in a modified version in (Palliwoda and Priess 2021)
[29] This paragraph bases on text published in a modified version in (Palliwoda et al. 2020)

3) Which green, spatial and green UGI characteristics may influence the perception of benefits?

I will discuss how UGI planning considering the design of specific green, spatial and grey components can contribute to multifunctional ES and benefit provision and reduce trade-offs between users and uses.

4.2. Data analysis to identify the influence of UGI characteristics

This chapter analyses survey responses about ES use and perceived benefits from the observation and survey as described in the method section 2.2. in relation to assessed UGI characteristics.

4.2.3. Differences between tree cover classes[30]

I applied pairwise Kruskal-Wallis one-way Analysis of Variance (ANOVA) for both UGI types on a 95% confidence interval assuming as a null hypothesis that species richness were independent of tree cover class (low, medium, high). To test the relationship between motivations for site use and tree cover class, I used chi-square tests of independence including their Pearson's residuals of each factor level.

4.2.4. Linkage between UGI characteristics, ecosystem service use and perceived benefits[31]

For the purpose of this chapter, which is to reveal the influence of UGI characteristics towards ES use and benefit perception, four indicators were derived:

(i) Observed visitor density quantifying the total number of visitors for each study site (visitors *hectare^{-1}*hour^{-1})
(ii) Observed visitor density per ES group (visible primary activity) (visitors *hectare^{-1}*hour^{-1} per ES group)
(iii) Proportion of used ES groups among respondents of surveys (number of users for ES group * total number of respondents^{-1})
(iv) Proportion of selected nature benefits among all mentioned benefits (number of mentioned nature benefit category * total number of all mentioned benefits^{-1})

To examine possible relationships between UGI characteristics and all indicators, several generalised linear models (GLMs) and redundancy component analysis (RDAs) were performed. Statistical significance was defined at a 95% level.

[30] This section bases on text published in a modified version in (Palliwoda et al. 2020)
[31] This section synthesizes the relevant information for data analysis published in (Palliwoda et al. 2020) and (Palliwoda and Priess 2021)

For indicator (i), observed total visitor density, I applied a GLM with quasipoisson distribution in separated models for each structural dimension (green, spatial, and grey characteristics). For brownfields, total visitor density was modelled as a function of only green and spatial UGI characteristics as on brownfields no facilities (grey characteristics) were present or mapped. The "green model" included tree cover, tree and flowering richness as explaining variables. Inhabitant density within 300 m and size of the site was tested in the "spatial model", and number of seating possibilities per hectare, number of lights per hectare as well as the sum of available sports facilities were tested in the "grey model".

To display linear correlations between UGI characteristics (explanatory variables) and observed visitor density per ES group (response variables) in parks and brownfields (indicator ii), I performed two RDAs, separated for both UGI types with all green, grey and spatial parameters as constraining (explaining) variables. For brownfields, only green and spatial parameters were considered as explaining variables. The RDA summarises combinations of the UGI characteristics into components that best explain variation on the Hellinger transformed (referring to proportions rather than total counts and giving low weight to ES groups with low counts of users) visitor densities per ES group for 18 parks and 14 used brownfields (Kindt and Coe 2005). I fitted the RDA-model by applying stepwise backward selection removing non-significant predictors.

For modelling proportions of ES group uses among respondents (indicator iii) as a function of green, spatial or grey UGI characteristics, I used GLMs with quasibionmial family for overdispersed data with a logit link. Models were run separating UGI structural dimensions and for each ES group. Explaining variables in the green, spatial and grey model were accordant to models for indicator (i). GLMs for indicator (iii) could only be performed if they were used in at least ten sites per UGI type (= ten replicates) and thus only applied to physical interactions, regulating services, social relations, dog walking and experiential and aesthetical services in urban parks. Due to the fact that most aggregated ES groups were used on less than ten brownfields, I did not perform analysis of this indicator for survey results on brownfields. When regression models did not show significant results, I furthermore applied the Kruskal-Wallis one way of variance (ANOVA) to test for differences in proportions of ES uses between tree cover classes (low, medium, high) in parks.

To test the influence of green, grey and spatial UGI characteristics on indicator (iv), only the four most frequently mentioned nature benefits were tested in quasibinomial GLMs (green landscape/aesthetics, natural elements, regulating ES, and social & cultural interactions), separated for each structural dimension and each benefit. Other nature benefits such as urban wilderness or sense of place were mentioned in only a few urban parks and sample sizes were thus too small. Response variables were the proportions of selected nature benefit in all mentioned benefits, respectively. Explaining variables in the green, spatial and grey model were accordant to models for indicator (i) and (iii). The analysis

was only applied for urban parks because brownfields usually do not contain any grey facilities and sample sizes were too low (n < 10 for most benefits) for this type of test.

Due to different measurement units of explaining variables, I calculated standardized beta coefficients with the "reghelper" package (Hughes 2020) in the green, spatial and grey models. The best model for indicators (i), (ii), and (iv) was then selected with the Bayesian Information Criterion (BIC) accounting for small sample sizes (n=18) preferring the least complex model with "BMA" package (Raftery et al. 2020).

4.3. Results on the influence of UGI characteristics towards ecosystem service use and perception

4.3.1. UGI characteristics of study sites in Leipzig[32]

I identified 78 species (on 408 mapped tree individuals) in parks and 67 species (on 1824 mapped individuals) on brownfields, indicating higher tree species richness in parks. Table 7 shows the mean richness values and their standard deviation for three tree cover classes in parks and brownfields. Tree richness per 100 m² increases with increasing tree cover for both types with brownfields showing higher standard deviations, which points to their heterogeneity in tree richness. Flowering richness increases with decreasing tree cover in parks. I found more flowering species per area in all brownfields than in parks. The ANOVA shows significant differences for tree richness between sites of B_{low} and B_{high} (p=0.04) and for flowering richness between B_{med} and B_{high} (p=0.04). Flowering richness also differs significantly between parks and brownfields (p=0.01) and is higher in all brownfields.

Table 7: Mean and standard deviation (sd) of richness of tree, shrub and flowering species per tree cover class (low, med, high) per 100 m² in parks (P) and brownfields (B); (n per group = 6)

Study site group	**Mean (and sd) tree richness per 100m²**	**Mean (and sd) flowering richness per 100m²**	**Tree cover range in %**
P_{low}	0.74 (0.45)	1.26 (1.11)	0 – 33
P_{med}	0.85 (0.41)	0.4 (0.31)	>33 – 67
P_{high}	1.04 (0.69)	0.19 (0.36)	>67 – 100
B_{low}	0.31 (0.23)	7.85 (11.85)	0 – 33
B_{med}	0.8 (0.81)	8.43 (5.09)	>33 – 67
B_{high}	1.2 (0.71)	1.37 (3.25)	>67 – 100

Park size range from about 0.7 hectare to almost 21 hectare. The mean size of parks was higher (7.52 hectare, sd = 7.89) than the mean size of brownfields (1.5 hectare, sd = 2.23). The smallest brownfield was only 0.06 hectare, while the largest brownfield was about 5 hectare. Seating possibilities in urban parks ranged from about 2 to 17 per hectare, while most brownfields did not contain any seating

[32] This section bases on text published in a modified version in (Palliwoda et al. 2020)

possibilities (Table S6 in supplementary material). Lights were also present in almost every park except in four parks. Sports facilities were counted in half of the parks and range up to 8 (sum of all facilities).

4.3.2. Visitors' motivations for UGI use[33]

We asked respondents to choose from six motivation categories, why they used the particular park or brownfield for the specified ES. Results show that "Close to home or accessible" as the most frequent motivation mentioned by visitors of both UGI types (59 – 66% of respondents in parks, 35 – 46% on brownfields, Figure 18). To reveal differences of proportions of motivation categories between the three tree cover groups, I applied chi-square tests and found significant differences for both types (p<0.001). Differences between tree cover classes in parks are mainly caused (highest Pearson's residuals) by the categories "Nature, landscape or wilderness" being most frequently chosen in P_{med} (22% of respondents) and "Social or cultural interaction" stated more often in P_{low} (9%) than in P_{med} (3%) and P_{high} (4%) as figure 4a displays. On brownfields, the category "Tranquillity or Seclusion" shows high variation between tree cover classes, with a strong dominance in B_{med} (35%) compared to B_{low} and B_{high}.

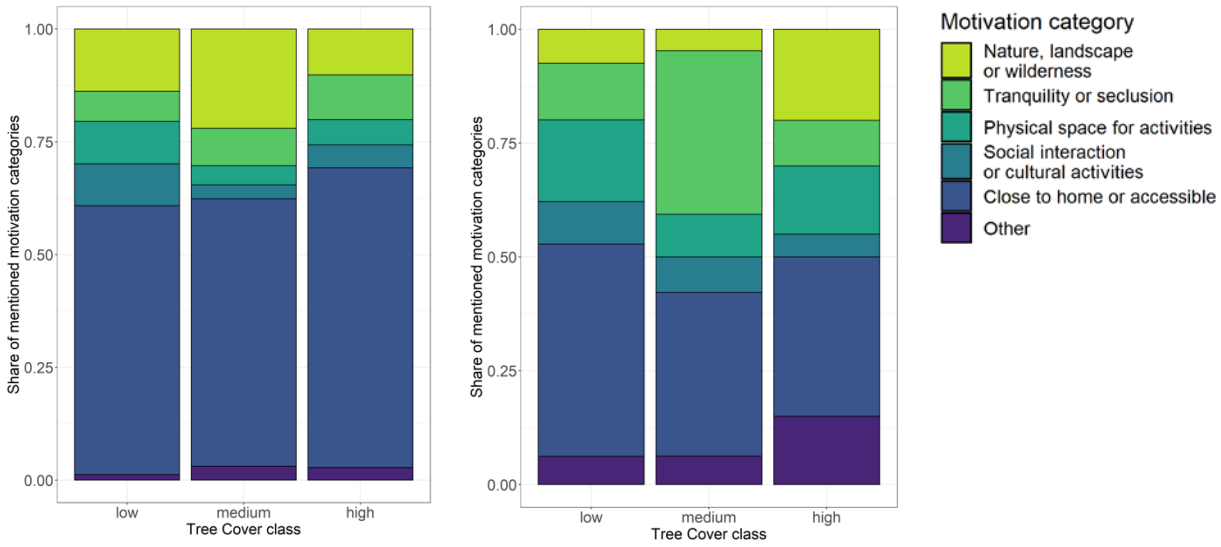


*Figure 18: Respondents and their motivation (6 pre-defined categories) for **a)** parks with low tree cover (n of respondents =572), medium tree cover (n of respondents =518) and high tree cover (n of respondents =393) and for **b)** brownfields with low tree cover (n of respondents =161), medium tree cover (n of respondents =64), and high tree cover (n of respondents =20). Data include only valid answers for motivation[34].*

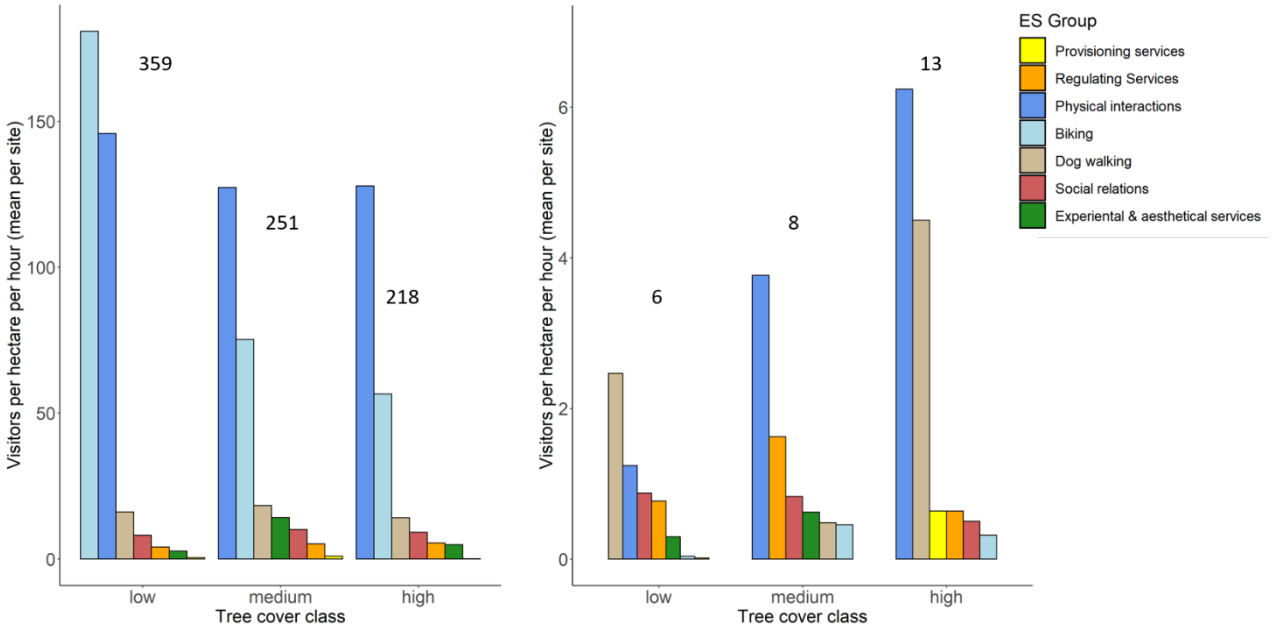
[33] This section bases on text published in a modified version in (Palliwoda et al. 2020)

[34] This Figure is published as Figure 4 in (Palliwoda et al. 2020)

4.3.3. Influence of UGI characteristics on observed visitor density[35]

Green, grey and spatial UGI characteristics were tested as predictors for observed total visitor density in a GLM in 18 urban parks and 14 brownfields (indicator i).

With increasing tree cover, we counted fewer visitors in both UGI types, though calculated brownfield visitor densities show that most people per hectare were counted on sites with high tree cover when only calculated for used brownfields (nB_{low} = 6, nB_{med} = 5, nB_{high} = 2) (Figure 19). It is noteworthy that only 3 out 6 observed B_{high} were used at all and thus B_{high} is actually less used than B_{med} and B_{low}.



a) b)

*Figure 19: Mean visitor density of all users (observed and interviewed) per ecosystem service (ES) group and tree cover class (low, medium, and high) for **a)** parks and **b)** brownfields. Numbers above the bars indicate total visitor, summarised for all ES group, density per tree cover class. Users are scaled to person * hectare^{-1} *hour^{-1}; means and visitor density are calculated only for sites used by visitors. Please note the different y-axis scales of parks and brownfields.*[36]

However, neither tree cover nor any other green or grey parameter was a significant predictor in the GLM for visitor density for both UGI types. Only inhabitant density within 300 m showed a positive influence on total visitor density in parks (β= 0.45, p=0.02) (Figure 20). For brownfields, I found no significant predictor for total visitor density in the GLMs.

[35] This section bases on text published in a modified version in (Palliwoda et al. 2020)

[36] This Figure is published in a modified version as Figure 2 in (Palliwoda et al. 2020)

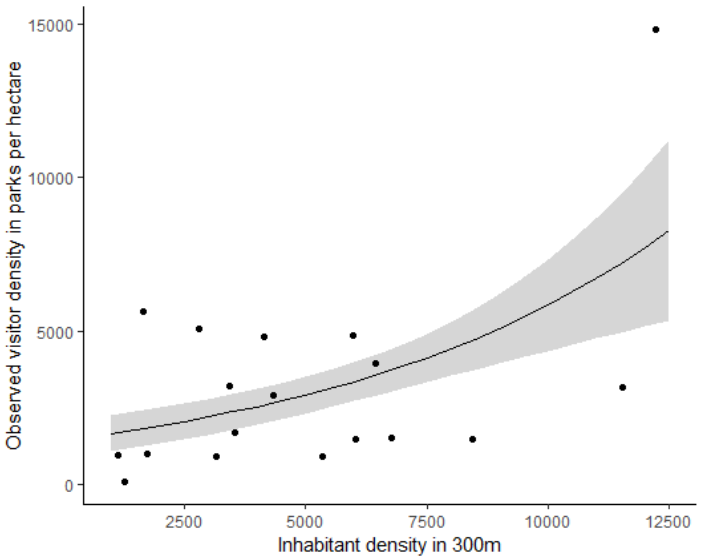


Figure 20: GLM (Poisson family) with inhabitant density in 300 m (explaining) and observed visitor density (response) showing a significant positive relationship (β= 0.45, p*=0.02) for urban parks.*

Green, grey and spatial UGI characteristics were tested as explaining variables for visitor density per ES group in RDAs for 18 urban parks and 14 used brownfields (indicator ii).

To display all green, spatial and grey park characteristics that differentiate use patterns of ES groups, figure 21 shows the results of the redundancy analysis with the final explanatory variables as constraining variables (RDA). Table 8 includes the loadings for the first three components of the RDA explaining 47% of the variance in observed ES groups ($p \sim 0.04$ on 1000 permutations). The size of the park is the only significant variable in the model and contributes most to the first component (explaining 35%). The loading for inhabitant density in 300 m is highest in the second component although not significant (explaining 10%). Biking is positively related to size of the park, i.e. was often assessed in large parks. Physical interactions were associated with small parks and available seating possibilities. Dog walking and experiential & aesthetical ES were more frequently observed in parks with low inhabitant density in 300 m and higher richness in tree species.

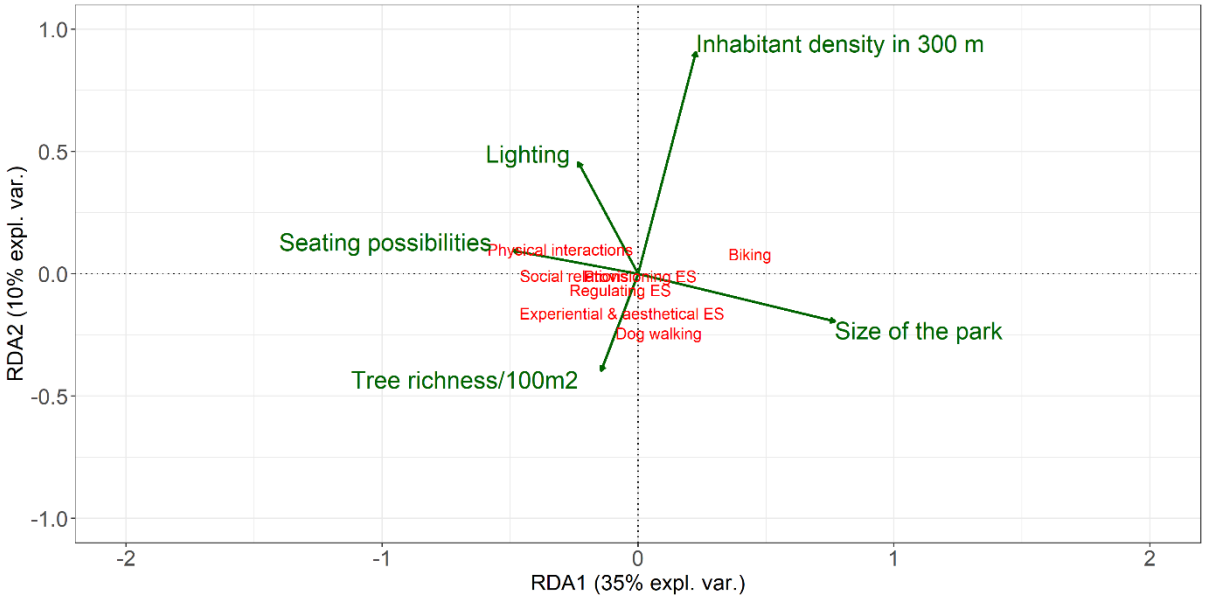


Figure 21: Fitted RDA with final predictors for observed ES use in urban parks showing the first two axes. Combined they explain 45% of the total variance.

*Table 8: Loadings of the first three components (scaling method 2) of the RDA that explain 47% of the total variance of observed ES use in urban parks. The highest loadings in the first two components are marked in grey. Significance level: * < 0.05*

Variable	RDA1	RDA2	RDA 3
Size*	0.77	-0.19	0.35
Inhabitant density in 300 m	0.23	0.91	0.19
Tree richness/ 100m^2	-0.14	-0.4	-0.28
Seating possibilities	-0.49	0.1	0.32
Lighting	-0.23	0.45	-0.16
Cumulative proportion of explained variance	0.35	0.45	0.47

When performing the RDA for brownfields with green and spatial characteristics only, three predictors were left although none of them was tested significant (Figure 22, table 9). The final model explains 37% of the variance and illustrates trends of observed ES use and associated brownfields characteristics. Size was one of the most important explaining variables: especially dog walking was often observed on large brownfields. Landscape structure diversity was positively associated with physical interactions and experiential & aesthetical ES. Social relations and regulating ES were frequently observed on brownfields with high flowering diversity.

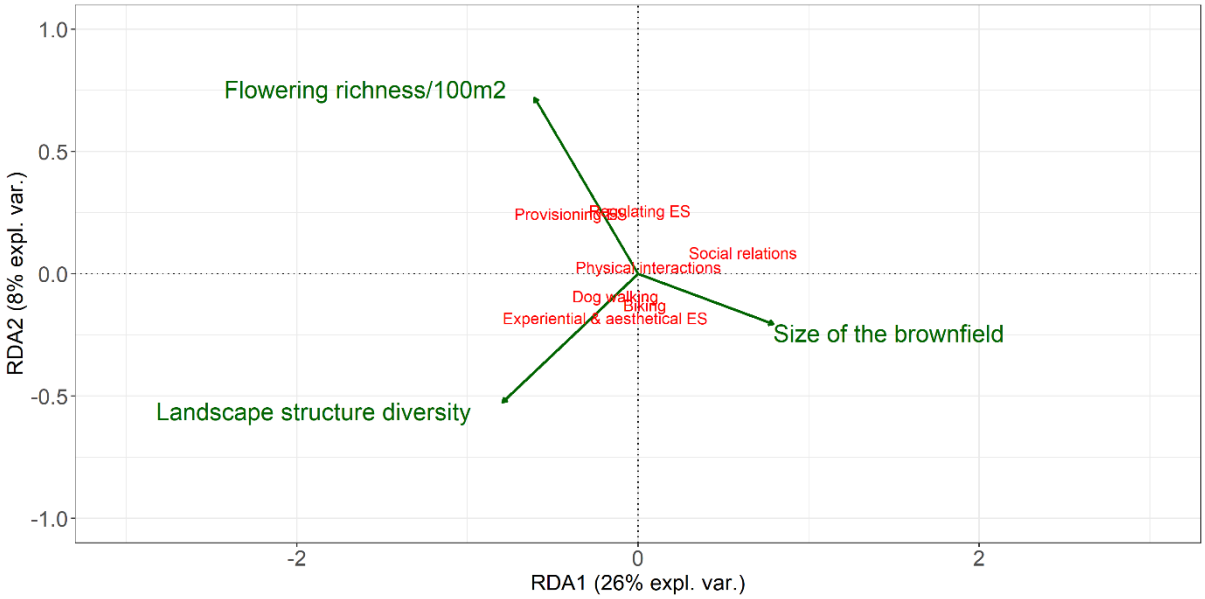


Figure 22: Fitted RDA with final predictors for observed ES use on brownfields showing the first two axes. Combined they explain 34% of the total variance.

Table 9: Loadings of the first three components (scaling method 2) of the RDA that explain 37% of the total variance of observed ES use on brownfields. The highest loadings in the first two components are marked in grey.

Variable	RDA1	RDA2	RDA 3
Size	0.79	-0.21	0.57
Flowering richness/ 100m^2	-0.61	0.72	0.34
Landscape structure diversity	-0.79	-0.53	0.31
Cumulative proportion of explained variance	0.26	0.34	0.37

4.3.4. Influence of park characteristics on ecosystem service use of survey respondents[37]

Proportions of ES groups used by respondents in urban parks (indicator iii) were tested in separated GLMs for green, spatial and grey explaining variables and for ES groups. For dog walking, I found no significant predictors in neither of the green, grey or spatial models.

Physical interactions, where urban ecosystems provide space for walking, jogging or other nature uses, were the most important group among park respondents in all three tree cover groups. The GLM reveals tree cover as a predictor for proportions of physical interactions showing a significantly slight negative relationship illustrating increasing use of this ES group in parks with decreasing tree cover (Figure 23). Inhabitant density in 300m and the number of sports facilities furthermore both had a significant positive influence on physical interactions (Table 10). It must be noted that sports facilities and inhabitant density strongly correlate as the pre-analysis shows (Spearman' rank correlation 0.86).

[37] This section bases on text published in a modified version in (Palliwoda et al. 2020)

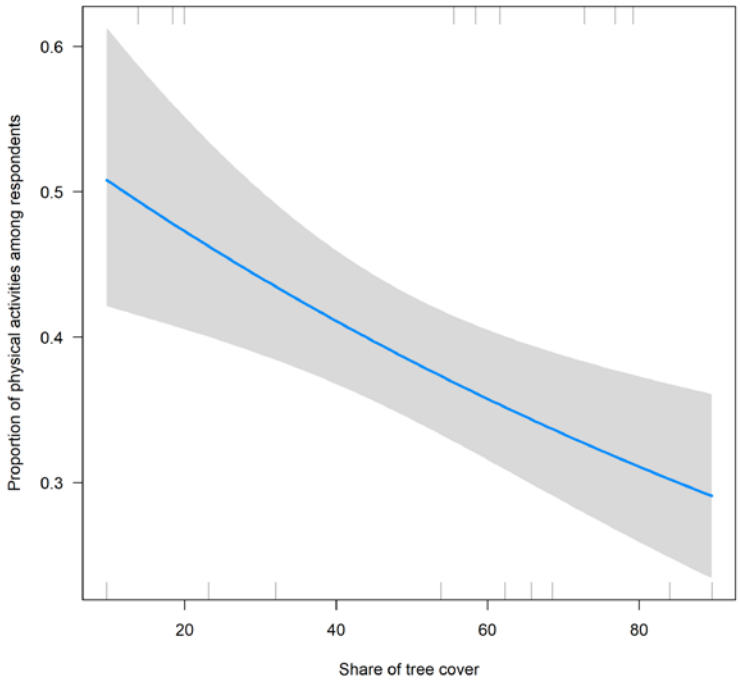


Figure 23: GLM (quasibinomial family) with tree cover as explaining variable for the share of physical interactions that were used by survey respondents in parks (response) showing a significant negative influence (β = -0.18, p = *0.005). The shaded area represents the confidence interval for the response variable.*

Although regulating services were used in all tree cover classes of parks, we mapped a slight increase with increasing tree cover (13% of respondents in P_{low}, 20% in P_{high}). The use of providing shade and shelter, for example, increases with higher levels of tree cover (3% in P_{low}, 4% in P_{med} and 9% in P_{high}). The GLM with tree cover as predictor for the share of used regulating ES shows a positive but not significant influence of tree cover (β=0.17, p=0.08, data not shown). Other predictors for regulating ES were not found in the spatial or grey models.

Experiential and aesthetical ES did not show a linear relationship to tree cover but were most frequently enjoyed by respondents in parks with medium tree cover (26% of respondents). However, the ANOVA showed no significant differences in experiential and aesthetical ES use between tree cover groups. The fact that two out of six parks with medium tree cover contain water bodies may have influenced the high shares of experiential uses. Visitors were watching animals or plants often at ponds (e.g. feeding ducks). The spatial model reveals inhabitant density in 300 m as a negative influence to experiential & aesthetical uses (Table 10).

Social relations such as picnicking or meeting people, was positively influenced by high richness in flowering species (Table 10).

Table 10: Results from separated generalized linear models for green, spatial and grey park characteristics and used ecosystem service (ES) groups among respondents. Only significant coefficients (<0.05, ** <0.01, *** <0.001) of the best model (lowest BIC) within each structural dimension after Bayesian Model averaging are shown. The chi-square value specifies the difference in deviance between the model and the null-model (ANOVA), Df indicates degrees of freedom. The best of the three models (lowest BIC) is marked in grey.*

	Green model			Spatial model		Grey model		
Proportion of used ES group among respondents	Tree cover of the site [%]	Species richness trees [species/ 100m^2]	Species richness flowering [species/ 100m^2]	Inhabitant density within 300 m [No. of people]	Size of the site [hectare]	Lights [No./ hectare]	Seating possibilities [No./ hectare]	Sports facilities [No.]
Experiential & aesthetical ES				-0.32* BIC: -41.06 χ^2: 20.69 Df: 16	-			
Dog walking	-	-	-	-	-	-	-	-
Physical interactions	-0.18** BIC: -39.92 χ^2: 13.52 Df: 16			0.18** BIC: -38.51 χ^2: 15.72 Df: 16				0.15* BIC:-42.14 χ^2: 11.14 Df: 16
Regulating ES	-	-	-	-	-	-	-	-
Social relations			0.32* BIC: -38.26 χ^2: 21.4 Df: 15					

4.3.5. Influence of UGI characteristics on perception of benefits[38]

Separated GLMs for four most frequently mentioned nature benefits (natural elements, green landscape/aesthetics, social & cultural interactions, regulating ES) were performed (indicator iv). I found no significant predictors for green landscape/aesthetics or nature elements in urban parks (Table 11).

The perception of parks providing regulating ES was significantly positively influenced by tree cover in the final green model. In the spatial model, inhabitant density within 300 m showed a slightly negative relationship to this benefit (Table 11).

For social & cultural interactions, tree cover and inhabitant density within 300 m show an opposite influence compared to regulating ES. Tree cover relates negatively in the green model and inhabitant density within 300 m positively in the spatial model to social & cultural interactions (Table 11). Inhabitant density within 300m shows the strongest positive influence to social & cultural interactions. There are two significant explaining variables for social & cultural interactions in the final grey model, seating possibilities as well as sports facilities (e.g. table tennis, basketball courts), whereby sports facilities show a stronger influence. Both predictors have a positive influence on social & cultural interactions. Neither species richness nor size of the site showed significant influence on any of the four nature benefits.

[38] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

Table 11: Results from separated generalized linear models (quasibinomial family) for green, spatial, and grey urban green space characteristics and four nature benefits. Only significant coefficients (< 0.05, ** < 0.01, *** < 0.001) of the best model (lowest BIC) within each structural dimension after Bayesian Model averaging are shown. The chi-square value specifies the difference in deviance between the model and the null-model (ANOVA), Df indicates degrees of freedom.*

	Green model			Spatial model		Grey model		
Proportion of nature benefit among answers	Tree cover of the site [%]	Species richness trees [species/ 100m^2]	Species richness flowering [species/ 100m^2]	Inhabitant density within 300 m [No. of people]	Size of the site [hectare]	Lights [No./ hectare]	Seating possibilities [No./ hectare]	Sports facilities [No.]
Green landscape/ aesthetics	-	-	-	-	-	-	-	-
Natural elements	-	-	-	-	-	-	-	-
Regulating ES	0.43 (*) BIC: -41.21 χ^2: 16.84 Df: 16			-0.41 (*) BIC: -42.1 χ^2: 15.81 Df: 16		-		
Social & cultural interactions	-0.5 (*) BIC: -41.21 χ^2: 25.2 Df: 16			0.76 (***) BIC: -38.1 χ^2: 84.83 Df: 16			0.49 (**)	0.62 (***) BIC: -38.8 χ^2: 69.64 Df: 15

4.4. Discussion on the influence of UGI characteristics on ecosystem service use and benefit perception

This chapter provides findings how green characteristics of UGI, especially tree cover, as well as inhabitant density in the neighbourhood and the presence of certain facilities can influence the use of certain ES and the perception of benefits in UGI.

4.4.1. Green characteristics influence on park use and benefit perception

I found tree cover significantly positively influencing perceived benefits referring to regulating ES such as noise regulation or shade provision and, although not statistically significant, positively associated with actual uses of regulating ES. This underlines the importance of shaded areas supporting urban climate regulation that is a highly relevant ES in UGI (Jim and Chen 2006, Breuste et al. 2013, Voigt et al. 2014, Riechers et al. 2016). Trees providing shade are furthermore positively related to physical activity, especially in the summer, as studies have shown (Timperio et al. 2008a, McCormack et al. 2010, Kabisch and Kraemer 2020). Nevertheless, the integration of open areas and lawns are just as important for physical activities such as playing football or doing other sports (Timperio et al. 2008b, Ćwik et al. 2018) and my results from park surveys indicate significantly more physical interactions in parks with lower levels of tree cover. Open lawns provide opportunities for active recreational activities, often performed in groups and with a social component (Peters et al. 2010). This connection is underlined by the significant positive association between low tree cover and perceived benefits referring to social & cultural interactions. Some respondents exemplified this

by describing the sites as places where "they see and are being seen by other people". Interestingly, a study in Baltimore, USA, found high tree cover in the neighbourhood positively influencing social capital (Holtan et al. 2014). In their study, Holtan et al. (2014) refer to total tree cover on neighbourhood level instead of park level showing a positive influence of tree cover on social bonds and social interactions. My study complements these findings by revealing a reverse relationship between tree canopy and perceived social benefits when it is examined on UGI level. As most urban parks in Leipzig fall within the medium or high tree cover class and natural tree growth will lead to increased tree cover over the years, these findings underscore the importance of including open areas and lawns in parks in densely populated neighbourhoods. [39]

High visitor densities and more aesthetical and experiential uses on sites with medium tree cover reflect the hypothesis that UGI visitors seem to prefer moderately dense vegetation that has been shown in other studies (Kaplan and Kaplan 1989, Bjerke et al. 2006, Lafortezza et al. 2008, Shanahan et al. 2014). These findings go hand in hand with the frequent mentioning of "Nature, landscape or wilderness" as motivations to visit P_{med}, supporting the assumption that park users prefer UGI designs of mixed open spaces and shaded areas for aesthetical services and nature experiences. These results additionally illustrate diverse tree cover and vegetation structures as important UGI features to ensure the provision of multiple ES comprising physical recreational interactions, social &cultural interactions, shade provision as well as experiential & aesthetical services. The presence of water bodies as UGI components can furthermore increase aesthetical and experiential services (Plieninger et al. 2013). Water bodies are often populated by animals, contributing to the increase in nature interactions and experiences, which are often limited in UGI (Gobster 2007). Previous studies confirm that park users mention water elements in urban green as important and aesthetical features (McCormack et al. 2010, Qiu et al. 2013, Hami and Emami 2015). The integration of water elements in UGI planning can thus contribute to the development of multifunctional green infrastructure in cities.[40]

4.4.2. Spatial characteristics influence on park use and benefit perception[41]

Plenty of respondents found parks in densely populated residential areas suitable for children, meeting other families or for other social & cultural interactions. The use of physical interactions among respondents was furthermore positively influenced by inhabitant density in the neighbourhood and the observed use density of people walking or doing other physical activities was higher in small parks. In this respect, can small parks in residential areas with high inhabitant density function as places for everyday social life and activities, which can contribute to reducing the feeling of loneliness and thereby improving psychological health as well as physical health by promoting physical activity (Van Herzele and Wiedemann 2003, Maas et al. 2009, Toftager et al. 2011, Wright Wendel et al. 2012).

[39] This paragraph bases on text published in a modified version in (Palliwoda and Priess 2021)
[40] This paragraph bases on text published in a modified version in (Palliwoda et al. 2020)
[41] This section bases on text published in a modified version in (Palliwoda and Priess 2021)

In parks that are located in neighbourhoods with low residential density, additionally positively influenced by high tree cover, visitors appreciated regulating ES and experiential & aesthetical ES more frequently. As revealed in section 3.3.4, the perception of social & cultural interactions vs. regulating services even show a slightly oppositional relationship underlining different functional levels of parks referring to their location of either inside or outside densely populated areas (Van Herzele and Wiedemann 2003). Public parks with high tree cover outside residential areas can fulfil more nature related uses such as enjoying fresh air and quietness while easily accessible neighbourhood UGI predominantly support social relations and physical activity (Maas et al. 2009, Shan 2014). Park visitors in Leipzig liked neighbourhood parks, i.e. parks in densely populated districts, for their "different cultures, from young to old" and described them as a "meeting point for different cultures".

4.4.3. Grey characteristics influence on park use and benefit perception[42]

Physical interactions seem to be favourably used in parks with low tree cover that are located in densely populated neighbourhoods containing facilities for active recreation (sports facilities). Results contributes to findings from other studies revealing facilities for sports, play and relaxation as important characteristics for UGI users by confirming a positive correlation between actually performed physical interactions and these desired facilities (McCormack et al. 2010, Voigt et al. 2014). I could furthermore illustrate a positive association between facilities for resting (sitting possibilities) or sport facilities and perceived social & cultural interactions although more sports infrastructure was counted in parks with high inhabitant density in the neighbourhood. It thus cannot be clearly determined if inhabitant density or sports facilities finally influence social & cultural interactions or physical interactions. Other studies point out the importance of high-quality facilities for active (doing sports, physical activity) or resting (sitting) recreational activities in public parks (Gearin and Kahle 2006, Kaczynski et al. 2008, McCormack et al. 2010). Complementing these findings, these facilities can additionally stimulate social & cultural interactions. The presence of soccer fields, for example, connects children and teenagers of different ages and cultures and the availability of open lawns can create a busy atmosphere for active recreation or socializing (Peters et al. 2010, Ignatieva et al. 2017, Ćwik et al. 2018).

4.4.4. Influence of green and spatial characteristics on brownfield use[43]

My findings furthermore imply that tree cover seems to be a relevant determinant of brownfield use intensity, as B_{low} and B_{med} sites were visited more frequently compared to B_{high}. Only two out of six observed brownfields with high tree cover were used for ES. Safety issues, which are strongly related to gender (Sreetheran and van den Bosch 2014), could explain lower visitor numbers as well as gender differences (approx. 65% male users) that we mapped on brownfields. This underlines previous studies

[42] This section bases on text published in a modified version in (Palliwoda and Priess 2021)
[43] This section bases on text published in a modified version in (Palliwoda et al. 2020)

counting fewer people on woodlands than on open spaces and generally less female than male visitors on brownfields (Rall and Haase 2011, Rink and Arndt 2011). Although some B_{high} sites are frequently used by visitors and / or of high ecological value by providing habitat for plant and animals species, public use and acceptance of unmanaged sucession or "urban wilderness" in Leipzig or elsewhere is often low (Breuste 2004, Kowarik 2005, Lafortezza et al. 2008, Rink and Arndt 2011, Shanahan et al. 2014). I also identified the size of the site as an important factor explaining dog walking on brownfields, indicating that large sites were used more often for this activity. Large brownfields may provide more space which visitors use for instance to unleash their dogs, which is prohibited in public parks and a frequent issue of conflict (disservice/disturbance) as revealed in section 3.3.5.

4.5. Interim conclusions[44]

My analysis provides new insight of how citizens actually use and value different sites of managed and unmanaged UGI with different green, grey and spatial characteristics. In this chapter, important UGI characteristics that can encourage the perception of nature benefits and ES use were highlighted.

Public parks that are ideally nearby people's home can provide different ES for their users depending on their tree cover. Parks with medium to high tree cover encourage the use of regulating services such as noise reduction and shade provision, which are directly experienced by people. Trees providing sufficient shade are therefore important green elements of UGI. Results furthermore confirm that urban parks with a mixture of open and shaded areas, potentially including water bodies can increase not only the use of regulatory but also experiential & aesthetical ES. Well-equipped neighbourhood parks with open lawns facilitate physical interactions and social interactions in residential areas. Thus, the diversity of tree cover, landscape elements as well as adequate facilities all contribute to multifunctional ES provision and use and should be considered in UGI planning and management. Large brownfields with low to medium tree cover provide additional space for several ES and are especially used for dog walking.

[44] This section synthesizes relevant conclusions published in (Palliwoda and Priess 2021) and in (Palliwoda et al. 2020)

5. Planning and management of UGI: visions and ideas from citizens with regard to guiding local themes

5.1. Introduction

To meet challenges that occur from ongoing urbanisation in global and European cities, many growing cities are focusing on densification rather than urban sprawl, simultaneously aiming at maintaining or increasing environmental quality and avoiding land sealing and loss of natural or agricultural land (European Environment Agency 2015, 2016b). City concepts like the compact green and sustainable city rely on mixed land use with nearby infrastructure for education, recreation and transportation leading to land competition between grey and green-blue infrastructure (UGI) (Burton 2000, European Environment Agency 2015). The compact green city thus requires a smart integration of multifunctionality, environment and governance (BMUB 2007, Haaland and van den Bosch 2015, Artmann et al. 2019). An efficient and strategically planned urban UGI providing multiple ES including social and economic benefits is thereby playing a key role in the city concept (Artmann et al. 2019).

It is commonly accepted that UGI such as urban parks, urban forests, vacant lots as well as rivers, streams, canals and ponds provides essential ES and benefits to the urban population (Bolund and Hunhammar 1999, European Environment Agency 2014, Haase et al. 2014). The actual flow and provision of benefits and ES increase with the UGIs' accessibility, availability and with their quality, referring to available facilities, maintenance and vegetation (Schipperijn et al. 2010, Hegetschweiler et al. 2017, Andersson et al. 2019). UGI with medium and high structural or landscape structure diversity including multiple biotopes, multi-layered vegetation structure and different facilities, for example, host nature-related activities such as bird-watching and enjoying fresh air (Vierikko et al. 2020).

The heterogeneity of the urban population furthermore leads to heterogeneous perspectives and demands on urban ecosystems (Gómez-Baggethun and Barton 2013, Andersson et al. 2019). Different expectations from urban nature can thereby lead to conflicting demands among different user groups. Residents with a migration background in the Netherlands, for example, use urban parks more often for family-gatherings and barbequing (Peters et al. 2010), which might be perceived as a nuisance by other user groups (Lyytimäki and Sipilä 2009). Diverging expectations make it challenging for planners to meet the demands of diverse stakeholders under the pressure of increasing urban populations. The assessment and integration of multiple views and perceptions into UGI planning are thus urgently needed to minimize potential conflicts between different stakeholders or ES (Hansen and Pauleit 2014). But how can UGI planning fulfil these multiple demands in a growing city competing with increasing spatial demands for housing, public service, transport and education? How should UGI be designed, managed and maintained to meet the quality standards researchers, planners and citizens are calling for and to avoid user conflicts as far as possible? This chapter aims at assessing diverse ideas and visions of citizens for urban UGI development, underlying conflicts and problems and the match and mismatch between citizens' demands and local planning foci.

The ES and UGI concepts including their inherent multifunctionality show a rising tendency to be considered in decision-making (Kabisch 2015, Di Marino et al. 2019, Hansen et al. 2019). Both concepts support the planning of compact green cities by integrating multiple values shaped by different dimensions (e.g. socio-cultural values, economic values, ethical values) of UGI (Artmann et al. 2017). In fact, governance and planning strategies including active participation of citizens and public consultations are leading to increased acceptance of decision-making as well as increased environmental, institutional, and social resilience of UGI (Buijs et al. 2016, Dennis and James 2016b, Jacobs et al. 2016). In the current COVID-19 pandemic, we have come to realize how important accessible urban UGI is, providing multiple benefits for human well-being and for the resilience of cities during a crisis.

The situation for medium-sized and larger cities in Germany illustrates a typical pattern of urbanization processes and redevelopment of growing cities in the European Union leading to shrinkage and then re-growing (European Commission 2011). Therefore, to an increasing extent, open land is being (re)used, e.g., for infrastructure, education and housing purposes, and the city's UGI is characterized by increasing use density. To meet the multiple demands to UGI in Leipzig, the local planning strategy 'Master Plan Green' (Stadt Leipzig 2020c) is currently being developed. The strategy will present spatial foci for implementing and maintaining ecosystem functions and services of UGI in the city-wide context including the creation of a multifunctional network connecting neighbourhoods. The Master Plan Green is led by five guiding themes structuring the discussion about UGI development: *biodiversity, climate adaptation, environmental justice, healthy living & environmental conditions (health), and sustainable mobility* (Stadt Leipzig 2020c). These guiding themes are not only relevant in the city of Leipzig but also leading the current debate about the future development of cities all over the world (European Commission 2011, Elmqvist et al. 2013, Wolch et al. 2014). The compact green city with high-qualitative UGI is thereby part of the solution to meet current challenges like increased energy use for transportation, unjust living conditions, social segregation and threatened biodiversity that arise from increasing land use change (European Commission 2011, Güneralp et al. 2013, Müller et al. 2013).

In this light, I analyse the citizens' perspectives and ideas for the future development of UGI in a compact green city under the framework of the guiding global themes that are also leading the local planning strategy in Leipzig. In this chapter, I

1) Summarize ideas and suggestions on how to improve UGI and topics that are important to citizens for its future development,
2) Identify emerging major problems and conflicts in Leipzig's UGI and
3) Link ideas, suggestions and topics with the five guiding themes biodiversity, climate adaptation, environmental justice, health and sustainable mobility.

I will then discuss problems and conflicts to identify solutions on the basis of ideas and suggestions and illustrate the citizens' views on the guiding themes relevant for the development of urban UGI. The aim of the chapter is to emphasize a citizens' perspectives to decrease potential conflicts and integrate multiple values into UGI planning and to reveal deficits between planning and the citizens' visions on future developments of urban UGI.

5.2. Data analysis of the online survey about future development of Leipzig's UGI

Chapter five is based on the online survey as part of the participation process of the Master Plan Green as it is delineated in section 2.3. The survey was set up to explore use patterns, use frequencies and satisfaction with the city's UGI. In addition to these questions, in two open-ended questions, respondents were asked for ideas, suggestions and topics that are important to them regarding the future development of Leipzig's UGI. Results from these open-ended questions are analysed in this chapter.

All data were processed in MAXQDA (version 12.1.3) and R (version 3.6.1). In a first step, I tagged every answer from the online survey with categories representing frequently mentioned ideas and further topics in MAXQDA. Categories were developed from the ideas, suggestions and topics addressed in the answers (frequently mentioned words, phrases and parameters). Respondents could name more than one category (e.g. suggestions referring to near-natural maintenance and rubbish/more rubbish bins). Counts of each category was quantified in R (R Core Team 2020) and visualised with the R-plotting-package ggplot2 (Wickham 2016).

Next, I aggregated frequent emerging conflicts and problems that emerge in Leipzig's UGI on the basis of the categorized answers from the open questions.

In a third step, all categories were allocated to the five guiding themes of the Master Plan Green (biodiversity, climate change adaptation, environmental justice, health, and sustainable mobility). The allocation was done on the basis of existing literature and in two expert workshops with three other researchers and one further member of the city's Office of Green Space and Water. Workshop members had professional backgrounds in landscape and urban ecology, urban and environmental sociology and green space planning. Guiding themes are not (yet) predefined in the Master Plan Green.

5.3. Results on ideas and topics for future UGI development with regard to guiding themes

5.3.1. Ideas, topics and visions of citizen's

In total, the 1,851 respondents raised 3,808 ideas (question 1) that were aggregated into 41 categories. From the 1,228 valid responses about further important topics (question 2), we summarized 2,917

suggestions that were aggregated into 43 categories (Figure 24). Ideas and topics mainly cover similar aspects and could thus be arranged into the same comprehensive framework of categories. More than 56% of respondents were female, 0.5% specified diverse gender and 39% were male. The average age of respondents was 39 years and about two-thirds of respondents have an income of more than 2,000€ per month. The average income was 1,750€. A majority of respondents (96%) were born in Germany. In the following, only the ten most frequent categories that were mentioned from respondents in both open-ended questions are described in the text, the others are listed in table S7 in the supplementary material.

The most frequently mentioned category for both questions referred to the installation of rubbish-bins and rubbish-related problems in UGI (498 answers in ideas, 170 answers in topics, Figure 24). Citizens asked for more rubbish bins, including an adapted design to avoid rubbish dispersion by animals, and possibilities for waste removal of dog faeces ("dog stations"). Following this aspect, two categories referring to quantitative aspects were prevalent among responses, namely generally more green spaces (283 answers in ideas, 236 answers in topics) and more trees in streets, backyards, and parks or less deforestation or removal of existing trees on streets and in the riparian forest (313 responses in ideas, 162 answers in topics). Increasing biodiversity in terms of integration of wildflower meadows as habitat for insects and butterflies in urban parks (increase biodiversity) was suggested by 148 persons within topics and by 209 persons for the ideas question. The next category includes requests for improving and expanding infrastructure in UGI for pedestrians and cyclists, raised by 122 respondents in ideas and 210 respondents in topics. Other categories that were following were requesting the improvement and installation of adequate facilities such as benches, playgrounds and accessible paths (Improve facilities and paths), the preservation or renaturation of brownfields and vacant lots between buildings (Preservation of brownfields), the wish for the presence of regulatory authorities in order to impose more consequences for those disturbing the activities of others in public green spaces, e.g., for dog owners not removing dog faeces or users littering (More regulatory authority & fines), less space for parking and speed limits for cars in residential areas in favour of the expansion of UGI (Less cars/parking space) as well as generally less construction of new houses and soil sealing in the city (Less building development). Table S7 in the supplementary material displays all other categories including their definition and examples.

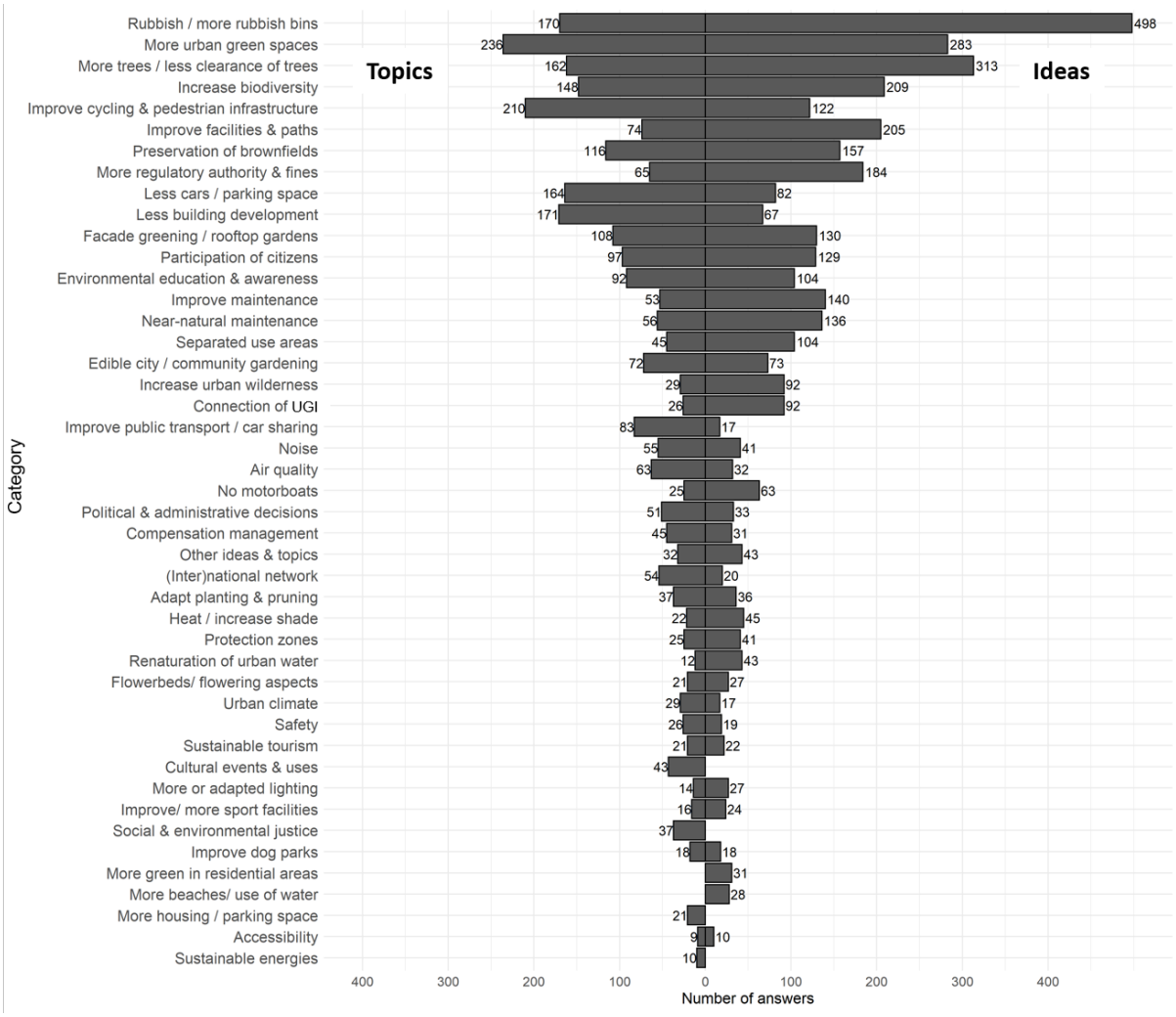


Figure 24: Ideas (n=3,808 from 1,851 respondents) and further topics (n=2,917 from 1,228 respondents) important to citizens regarding the improvement of UGI in Leipzig, aggregated into categories. In an open question respondents could name ideas to improve Leipzig's UGI and further topics that are important to them and should be included in the Master Plan Green.

5.3.2. Emerging conflicts and problems in UGI

Ideas, suggestions and topics regarding Leipzig's UGI illustrate some diverging or even contradicting perspectives and reveal current problems and conflicts.

Littering and the request for the installation of waste bins was one the most frequently mentioned issues among ideas and topics on how to improve UGI. Together with suggestions to install diverse adequate facilities for recreation (Improve facilities & paths, Improve/more sport facilities) and the improvement of maintenance activities, this illustrates the problem of *quality and usability* of UGI. Ideas about more and adapted facilities imply, for example, citizens asking to promote barbequing, sports or play for children. On the other hand, there were several respondents who desire more nature experiences, biodiversity and tranquillity in UGI (Increase biodiversity, protection zones). The promotion of biodiversity and tranquillity may conflict with some recreational activities, which reflects not only the contradicting demands among citizens but also between citizens and planning

focusing on biodiversity on one and environmental justice on the other hand. Further ideas and suggestions referring to quality and usability aspects brought up the problem of accessibility for people with disabilities, for instance the need for barrier-free toilets and walkable paths especially for older people (Accessibility).

Another main important conflict dimension of UGI can be summarized as o*ther users and activities*. There were numerous comments that raise disturbing activities and user groups such as people leaving their dogs off-leash, cultural events, groups of teenagers being noisy and barbeques causing smoke and litter, and citizens wish for more regulatory authority or separated use areas to diminish disturbing uses (Separated use areas, More regulatory authority & fines). Mobility-related answers further illustrates conflicts between pedestrians and cyclists in urban green spaces exemplified by respondents requesting separated walking and cycling lanes in highly frequented parks (Improve cycling & pedestrian infrastructure). The conflict referring to other users and activities thus implies the diverging demands to UGI among citizens ranging from quiet and nature-oriented recreation to resting or active recreation activities.

Other comments about specific user groups additionally raised issues relating to *safety and security*. Insufficient security or perceived unsafety in public green spaces is often caused by past criminal activities, dense vegetation or poor lighting (More or adapted lighting, Safety). Additionally, the problem of drug trafficking and groups of people drinking alcohol was often raised as a reason to avoid specific UGI locations or to increase the presence of regulatory authority staff (More regulatory authority & fines).

5.3.3. Allocation of ideas and suggestions to the five guiding themes of the Master Plan Green

Based on the analysis above, I linked categories of ideas and further topics that were suggested by respondents with the five guiding themes of the Master Plan Green to underpin citizens' perspectives (Figure 25 and Table 12). The five guiding themes can be cross-categorical meaning that some idea and topic categories may be allocated to more than one guiding theme. Twenty percent of the total number of mentioned ideas and 14% of the topics important for respondents refer to the protection or preservation of urban biodiversity as shown in figure 25. Another 18% of ideas and 17% of topics were allocated to climate adaptation and measures contributing to the reduction of climate impacts such as façade greening and rooftop gardens. Environmental justice including procedural, institutional and distributional justice aspects comprised 19% of ideas and 17% of topics. Health related suggestions made up only 3% of all suggested ideas and 5% of mentioned topics. Seven percent of ideas and 16% of topics could be arranged into suggestions for sustainable mobility.

About one-third of suggestions in ideas and topics respectively were not linked to the five guiding themes and are aggregated into three further themes. A share of suggested ideas and topics not allocated to the one of five guiding themes referred to the quantity or spatial extent of UGI (9% of ideas, 15% of topics), i.e. respondents call for the establishment of more and the preservation of existing green spaces and for less building construction and soil sealing. However, there were also respondents that request for more housing development due to increasing inhabitant numbers and scarce living space underlining diverse demands and growing pressure on open space in the city. Other ideas and topics that I did not consider to be covered by one of the five guiding themes referred to politics and administration (6% of ideas and 6% of topics) including suggestions to collaborate with stakeholders from NGOs, the regulatory authority and other municipalities. Socio-cultural and economic aspects of UGI (19% of ideas, 11% of topics) such as cultural events, the limitation of motor boats on water and the development of sustainable tourism in the city covered a majority of suggestions that could not clearly be linked to one of the guiding themes. Socio-cultural aspects of UGI mainly raises maintenance aspects of UGI, illustrated by the wish for more rubbish bins in UGI and improved maintenance.

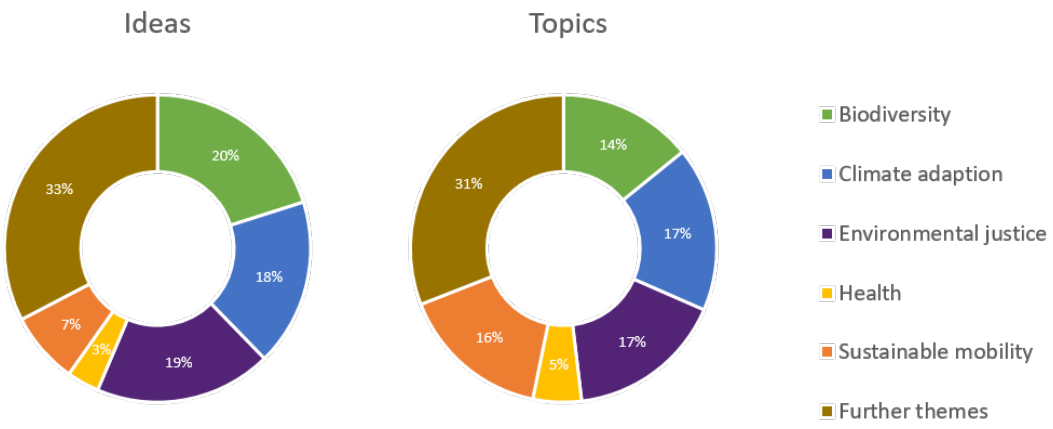


Figure 25: Allocation of ideas (n=3,808) and topics (n=2,917) that are important to citizens regarding the improvement of UGI in Leipzig, to the five guiding themes of the planning strategy Master Plan Green. Categories, that were cross-categorical, i.e. could be allocated to two ore more guiding themes, were counted twice (or more).

Table 12: Allocation of citizens' ideas and further important topics to the five guiding themes of the Master Plan Green. Some ideas, suggestions and topics were allocated to more than one guiding theme.

Guiding theme	**Ideas and topics of respondents**
Biodiversity	· Increase urban wilderness · Increase biodiversity · Renaturation of urban water/ riparian forest · Protection zones · Near-natural maintenance · More trees/ less clearance of trees
Climate adaptation	· Urban climate · Façade greening/ rooftop gardens · Sustainable energies · Preservation of brownfields · Compensation management · Heat/ increase shade · More trees/ less clearance of trees · Adapt planting & pruning
Environmental justice	
Procedural justice:	· Participation of citizens · Environmental education & awareness · Social & environmental justice · Edible city/ community gardening
Interactional justice:	· Safety · Accessibility · Improve facilities & paths (playgrounds, benches, barbeque areas etc.) · More or adapted lighting · Improve/ more sports facilities · Improve dog parks · Flowerbeds/ flowering aspects · Separated use areas
Distributional justice:	· More green in residential areas · More beaches/ use of water
Health	· Air quality · Noise · Heat/ increase shade Improve/ more sports facilities
Sustainable mobility	· Less cars/ parking space · Improve public transport/ car sharing · Improve cycling & pedestrian infrastructure · Connection of UGI
Further important themes:	
Quantity	· More urban green spaces · Less building development · More housing/ parking space
Politics & administration	· Political & administrative decisions · More regulatory authority & fines · (Inter)national network
Socio-cultural & economic aspects	· Sustainable tourism · No motorboats · Cultural events & uses · Rubbish/ more rubbish bins · Improve maintenance
	Other ideas & topics

5.4. Discussion on the citizen's perspective towards future UGI development with regard to guiding themes

Ideas and topics addressed by the survey respondents illustrate diverse demands and concepts to improve UGI, but also potential conflicts and concerns. Citizens' ideas and requests to improve the city's UGI exemplify the heterogeneous and diverging demands (Gómez-Baggethun and Barton 2013) and thus the challenge for planners to integrate multiple value sets. Involving multiple stakeholder preferences and interests, in this study, illustrated by the citizens' perceptions and views towards the future development of urban green and blue spaces, supports the implementation of the UGI concept with its multifunctionality (Hansen and Pauleit 2014).

5.4.1. Citizens' ideas and suggestions to decrease frequent problems and conflicts in urban UGI

My analysis identifies three main problem dimensions in UGI referring to *quality & usability*, *other users & activities,* and *safety & security*. The heterogeneity of ideas and suggestions illustrates the discrepancies in expectations among citizens and between citizens' preferences and planning objectives.

Quality & usability

The scope of the local planning strategy mainly focuses on high-quality UGI providing essential functions and benefits for human well-being. A number of ideas from citizens underpin quality and usability demands to Leipzig's UGI (Stadt Leipzig 2017c). Van Herzele and Wiedemann (2003) summarize five quality attributes of urban green spaces: space, nature, culture and history including social activities and sufficient maintenance, quietness and facilities. Clearly, the problem with rubbish and insufficient number of rubbish bins in UGI is a major focus in citizens' suggestions for quality aspects, and planning should concentrate on a use-density adapted waste management with shorter cleaning and maintenance cycles. Further suggestions from respondents mainly concentrate on more and better facilities for sports, play, relaxing and waste management as well as improved maintenance. Specific groups desire specific facilities and a balanced supply will increase the usability of UGI. The availability of playgrounds and facilities for children and teenagers, for example, contribute to recreational activities for families and caregivers (McCormack et al. 2010, Flowers et al. 2019). Sports facilities such as skate parks or football fields facilitate social interactions, especially for kids and teens and simultaneously encourage physical activity supporting physical health (Kaczynski and Henderson 2008, Peters et al. 2010). In contrast, older or less mobile persons have a more urgent need for adequate seating possibilities and safe paths facilitating recreational quality & usability of UGI (Kabisch and Kraemer 2020).

Not only well maintained facilities enhance the quality and usability of UGI – many respondents of the Leipzig survey support the integration of a more nature-oriented maintenance and areas supporting biodiversity (nature as a quality attribute referring to Van Herzele and Wiedemann 2003). In addition to preserving biodiversity for its own sake, species-rich urban habitats offer urban residents opportunities to experience, (re-)connect and interact with nature (Miller 2005, Palliwoda et al. 2017), like through urban gathering of wild fruits and edibles (Poe et al. 2014, Hurley and Emery 2018) or watching and experiencing wildlife (Apfelbeck et al. 2020). More trees in public green spaces and on streets, as suggested by respondents, further contribute to the UGI quality attribute 'nature' and provide many benefits. Trees do not only provide ES such as carbon storage and air quality improvement, but also provide social values like aesthetic and psychological health benefits (Lohr et al. 2004, Roy et al. 2012).

Other users & activities

The survey results reveal conflicting activities and user groups as a second main problem in UGI. Conflicting uses mostly refer to people walking their dog off-leash, groups of people barbequing or being noisy and leaving behind litter. Dogs and dog faeces were among the most frequently mentioned conflicts when people where asked what they feel disturbed by (StadtLabor Tröger+Mothes GbR 2019). This issue is reflected in ideas and requests suggesting to increase controls by the regulatory authority and to charge dog owners for illicitly leaving their dogs off the leash in public parks. Still, there are more than 20,000 dog owners in the city (LVZ 2017) that will have to walk their dog, usually in nearby green spaces. The integration of alternative types of UGI such as minimally maintained brownfields for user groups that potentially disturb other park visitors can reduce trade-offs and conflicts between users (see section 3.4.3 or Palliwoda and Priess 2021). Other ideas and suggestions call for separating uses and activities, for example, by integrating areas for barbequing, sports activities or dogs in public parks that are clearly separated from the rest of the park. This may also include the clear separation of walking and cycling lanes or areas in highly frequented urban parks often used for transit as this conflict was raised by numerous respondents. In contrast to these suggestions, public park design in Leipzig aims at fostering jointly used green spaces with fair and respectful treatment of different user groups instead of strict separation of these areas by fences (Stadt Leipzig 2017c). Place-specific conflicts between activities therefore need to be carefully evaluated by integrating residents' knowledge to facilitate fair UGI use. Designated use areas or fairness zones containing appropriate facilities and infrastructure, for example barbeque areas with permanent grills and picnic tables or dog parks with dog-related infrastructure, offer opportunities to diminish conflicts between users. The diversification of UGI including the integration of small green spaces, community gardens, as well as accessible urban brownfields with reduced maintenance activities may not only reduce overuse and use conflicts, but can also support urban biodiversity and a diverse ES delivery (de Oliveira et al. 2011, Mathey et al. 2015, Graça et al. 2018).

Options to integrate unmaintained brownfields into public UGI for recreation, however, are limited due to the issue of the city's or owner's legal obligation to maintain safety. The participation of residents, NGOs or citizen groups in maintenance and interim use strategies on selected brownfields in neighborhoods especially affected by increasing inhabitant numbers could offer opportunities to reduce pressures on public UGI and strengthen social cohesion and resilience (Buijs et al. 2016). There seems to be a high willingness to participate in UGI management and maintenance as this wish was expressed by numerous respondents.

Safety & Security

As ideas and topics from respondents imply, increasing the presence of the regulatory authority in public UGI cannot only reduce misuses and violations against public restrictions but is also primarily to promote safety and security. Safety aspects often refer to criminal activities and the general feeling of not being safe. The presence of criminal activities like illegal drug dealing, especially in the evening, is one of the major disturbances in Leipzig's UGI (see section 3.3.5. or Palliwoda and Priess 2021). The installation of sufficient lighting as well as the presence of authorities can increase perceived safety and therefore usability of UGI, especially for vulnerable groups like older persons or women (Koskela and Pain 2000, Veitch et al. 2006, McCormack et al. 2010).

5.4.2. Citizens' ideas and suggestions allocated to the five guiding themes of the Master Plan Green

The local planning strategy Master Plan Green focuses on five guiding themes (biodiversity, climate adaptation, environmental justice, health, and sustainable mobility) strongly overlapping with topics and challenges leading the global debate about the development of sustainable and compact cities (European Commission 2011, Elmqvist et al. 2013, European Environment Agency 2015). I linked concrete ideas and suggestions to these five themes to evaluate the citizen's perspective towards them and to underscore their contribution to the provision of multiple UGI values. Finally, I summarize other themes that are important to respondents and cannot clearly be allocated to one of the guiding themes.

Biodiversity

According to the respondents' ideas, fostering biodiversity in urban UGI could include protected areas with limited usability for recreation, using native and regional plant species instead of exotic plants and creating diverse habitats that supply space for diverse species across taxonomic groups. Patches with (native) flower meadows, more nature-oriented plantings, the integration of unmaintained "wild corners" and near-natural maintenance techniques as suggested by several respondents would support the creation of diverse habitats for plants, insects, birds, and butterflies (Hunter and Hunter 2008, Kowarik 2013, Aronson et al. 2017). The advantage of a near-natural and wildlife-inclusive design and maintenance is that they are not only supporting plant and animal diversity but have the potential to

reduce general maintenance costs due to less time spent on mowing or the removal of leaf litter (Escobedo and Seitz 2009, Aronson et al. 2017, Watson et al. 2019, Apfelbeck et al. 2020). Furthermore, reduced mowing frequency of urban lawns and the integration of forb-rich perennial meadows contribute to aesthetical values as well as climate change adaptation by their increased water-retention capacity compared to intensively managed lawns (Yuan et al. 2017, Ignatieva and Hedblom 2018). The renaturation of urban streams and rivers as suggested by some respondents, further contributes to increasing valuable habitats for plant and animal species in a compact green city (Jim 2013). Well designed and managed urban UGI can then tackle the loss of biodiversity on a local level by offering a high range of (novel) habitats that can host different species assemblages than their counterparts in rural areas (Niemelä 1999, Kowarik 2011).

However, near-natural maintenance might lead to other costs, for example in transporting the increased amount of mowed grass, and a change in management often comes with a negotiation process with historical preservation objectives or conflicting preferences among citizens. Providing appropriate supporting information about benefits of natural perennial meadows, for example, can increase the citizens' acceptance of these maintenance measures (Southon et al. 2017).

Climate adaptation

Climate change and adaptation strategies are leading global and local debates about sustainable and resilient urbanization. Cities in Europe are mainly affected by temperature extremes, flooding and decreasing precipitation rates in the summer (European Environment Agency 2012, 2016a). Climate change is linked with multiple socio-economic factors and adaptation strategies must thus be considered in many sectors (European Environment Agency 2016a). Only a few comments directly refer to climate change and include, for example, a respondent's wish for more shade from trees and the use of climate-adapted plant species in urban green spaces with regard to increasing heat and droughts in the summer caused by climate change. I furthermore allocated suggestions and ideas referring to the use of sustainable energy sources, compensation management, preserving brownfields and the integration of UGI in buildings (façade and rooftop greening) to this guiding theme. The preservation of brownfields as open spaces was a frequent request from respondents and together with a strict compensation management for housing development they can sustain cooling patches in dense residential districts contributing to climate adaptation in Leipzig. More urban vegetation cover in terms of urban trees, façade greening and rooftop gardens further supports adaptation to climate change by increasing storm water retention, air cleaning and temperature reduction (Fallmann et al. 2014, Revi et al. 2014). The cooperation of companies in construction and other fields and the support of the city of Leipzig with its recently launched a grant program to foster rooftop greening (Stadt Leipzig 2020d), can be important steps towards a sustainable and climate-change-adapted housing development.

Environmental justice

This guiding theme addressed by respondents calling for the establishment of active citizenship for the design, implementation and maintenance of Leipzig's UGI via participating in cleaning activities or self-organized gardening groups. These and similar suggestions contribute to procedural justice (Low 2013). The involvement of citizens in the establishment and management of UGI, supported by grass-root initiatives, facilitates environmental, social and institutional resilience (Buijs et al. 2016) and offers chances to increase ecosystem-service provision of UGI (Dennis and James 2016a). Bottom-up processes, participation of residents and the inclusion of the community members can furthermore reduce negative consequences such as green gentrification due to new urban green spaces in residential areas (Haase et al. 2017, Ali et al. 2020) and increase perceived UGI quality (Fors et al. 2018). Urban gardening initiatives enhance social and ecological diversity and justice, strengthen ecological knowledge and social cohesion among other benefits (Camps-Calvet et al. 2015). Ecological education and raising awareness about the importance of (urban) biodiversity and its protection additionally underscores the active role of citizens in UGI management. Other important topics for citizens include appropriate and safe facilities (playgrounds, benches, sports facilities), improved lighting and safety of UGI as well as designated use areas for all visitor groups, noting here the citizens' ideas to accommodate the interactional dimension of environmental justice (Low 2013). Requests for more access to beaches and green spaces in residential areas can be allocated to the distributional dimension of environmental justice.

Health

Several responses referred to health-related pressures in the growing city such as noise and air pollution caused by increasing traffic. Noise reduction and air quality improvement due to UGI is acknowledged by respondents, and equal access to UGI is vital to extend these health-related functions to the maximum number of community members. Accessible residential green spaces and trees can absorb air pollutants and reduce road traffic noise in urban areas (Hartig et al. 2014, Schaffer et al. 2020). Well-equipped, safe and diverse public UGI further facilitates psychological and physical health by providing sports facilities encouraging physical activity, for example, which is requested by many respondents (Tzoulas et al. 2007, Lee and Maheswaran 2011, Akpinar 2016). Heat and the provision of tree shade was another frequently mentioned topic to be considered in UGI planning and management. Large and connected urban green spaces reduce air temperatures and increase air ventilation and are therefore important adaptive strategies to reduce heat stress in cities (Ren et al. 2011, Revi et al. 2014).

Sustainable mobility

Although not all ideas about sustainable mobility can be linked to UGI design and management, respondents provide UGI-relevant suggestions for this guiding theme. For instance, several respondents suggested the removal of parking spaces for cars in favor of green spaces or cycling paths

underpinning priorities for urban green and sustainable mobility instead of motorized traffic. The establishment of a compact green city promoting green mobility measures like cycling can contribute to reduced energy consumption used for transport (European Environment Agency 2015). The integration of trees along streets combined with other maintained or spontaneous roadside vegetation are frequently requested by respondents and can thus promote sustainable mobility. A study in Berlin underpins this request by pointing out that cyclists prefer streets with high levels of street trees and would accept a longer route to avoid streets with low vegetation levels (Nawrath et al. 2019). The connection of green and blue spaces and the establishment of greenways was often requested by respondents and does not only support biodiversity but can encourage inhabitants to shift to walking or using their bicycles (Cerin et al. 2017, Lu et al. 2019). The combination of a connected green network with the public transport network can then increase access and usability of remote UGI for residents (Artmann et al. 2017, Andersson et al. 2019).

Further important themes addressed by respondents

Although most ideas and suggestions could be directly or indirectly linked to one or several of the five guiding themes of the Master Plan Green, I identified three additional UGI-relevant important themes: (i) increasing the quantity and spatial extent of accessible UGI under the pressure of growing inhabitant numbers, (ii) politics and administration strengthening the collaboration with stakeholders, and (iii) integrating a wider perspective of socio-cultural and economic values of UGI.

There are numerous ideas and comments referring to the quantity of UGI and open spaces illustrated by the request for more green spaces, preserving existing green spaces and decreased soil sealing caused by housing development. Increasing the spatial extent of UGI is a challenging task in a growing city due to competing land demands for social, economic and environmental needs (European Environment Agency 2015) that is also illustrated by other comments that request more housing development to tackle housing shortage. Nevertheless, the urgent need for accessible urban and peri-urban UGI becomes especially visible during the COVID-19 pandemic that reveals an increased use of urban green spaces during lockdowns (Venter et al. 2020). In their study, the authors highlight the importance of large inner-city parks as well as accessible and not overcrowded UGI in the urban periphery for human well-being during the crisis. Improved connectivity to sub-urban UGI, small green spaces in neighborhoods and planting more trees in the cityscape could offer chances to increase the quantity of accessible UGI in compact green cities (Artmann et al. 2017). Strong partnerships between the municipality and adjacent regions in the periphery are thus needed to ensure an adequate UGI supply for residents of a growing city.

Another theme not clearly covered by the five guiding themes includes ideas and suggestions about political and administrative decisions including the cooperation with other (inter)national authorities and NGOs. This points to the chances of local planning authorities to integrate multiple views of various stakeholders into planning and management of UGI. The consideration of heterogeneous

demands and best practice examples from different actors can then help to develop multifunctional UGI for all user groups (Hansen and Pauleit 2014) and furthermore foster a comprehensive planning authority that integrates multiple sectors relevant for urban development .

Lastly, I summarized ideas and suggestions referring to fostering cultural events, the installation of rubbish bins and promoting sustainable tourism in the city as socio-cultural and economic aspects of UGI. Going along with the focus of the Master Plan Green on ecological aspects of UGI, i.e. biodiversity, socio-cultural and economic functions should be part of the planning strategy in the same measure. Although partly covered by themes like environmental justice and health, socio-cultural aspects of Leipzig's UGI should be widened in the planning process to include the whole range of cultural uses, improve maintenance and meet people's heterogeneous demands to increase usability. The economic dimension especially is scarcely integrated in European UGI planning as it is in Leipzig, yet it remains an important component of multifunctionality (Hansen et al. 2019). Raising this issue in the Master Plan Green as some respondents suggest may then contribute to a resilient UGI development in Leipzig.

5.5. Interim conclusions

In this chapter I highlight ideas, visions and topics from respondents of an online survey to improve and develop UGI in the city of Leipzig. Categorized responses illustrate heterogeneous perspectives implying perceived conflicts and problems and reveal diverse visions about the future of UGI. Different demands and functions of UGI must therefore be constantly negotiated between citizens and planners and between multiple planning aims. As the analysis of current conflicts and problems in UGI illustrates, plenty of suggestions from respondents contribute to the improvement of deficits regarding quality & usability, safety & security and conflicts between different users & activities. A majority of suggestions are cross-categorical and can be linked to one or several of the five leading guiding themes of the Master Plan Green: biodiversity, climate adaptation, environmental justice, health, and sustainable mobility. However, about one-third of suggested topics and ideas raise awareness about further themes complementing the Master Plan Green. With this analysis, we attempt to illustrate the citizens' perspectives, ideas and suggestions regarding guiding themes that are shaping local and global urban planning strategies. Integrating the diverse and partly diverging expectations of citizens to the local UGI network, can contribute to its resilient planning that meets specific demands of the local population and reduces conflicts.

6. Synthesis

6.1. Central findings and contributions of the thesis

In the following sections, I will highlight central findings, assess limitations of the study and how future research can meet them, formulate concrete suggestions for planning that deviate from the central findings in order to improve resilience and justice aspects of UGI, and assess the transferability of my findings to other locations.

In times of ongoing urbanisation coming along with increasing pressure on remaining open spaces for the development of infrastructure for housing, transport, education and economy, persistence and implementation of UGI becomes ever more important to support human well-being. UGI provides multiple ES and the flow of benefits depends on personal preferences and site characteristics and thus explicit indicators for their assessment are missing (Haase et al. 2014, Hegetschweiler et al. 2017). In a statistical analysis, several UGI characteristics were found to enhance or decrease ES and benefit flow. Further, I identified and explained current conflicts and problems in Leipzig's green and blue spaces and which topics should be approached in UGI planning from the citizens' perspective. The spatially explicit assessment of ES and benefit flows and the linkage to site characteristics reveals relationships between specific design elements and specific benefits that can be transferred to concrete UGI design implications enhancing inclusiveness, resilience and ES and decrease trade-offs and conflicts between users and activities (section 6.2). Results hence present valuable information for local and, if results can be transferred to other places, UGI design and management on larger spatial scales (section 6.3).

In summary, I can state the following central findings:

- Main ES that were used in urban parks are physical interactions, dog walking and enjoying landscape aesthetics. Brownfields were predominantly used for dog walking and mostly appreciated for their wilderness and availability & location as an alternative UGI often close to people's home. The proximity to people's home was the main motivation for visitors to choose specific urban parks or brownfields.
- There are differences in ES flow and benefit perception between age groups in urban parks. Young adults placed high importance on sports facilities and social relations, adults used urban parks more often for dog walking and appreciated grey infrastructure such as benches or playgrounds and for older persons, landscape aesthetics and other experiential & aesthetical ES were more important.
- Tree cover is a significant predictor for the flow of physical interactions, regulating ES and social & cultural interactions in urban parks. Brownfields with low or medium tree cover were used more often than brownfields with high tree cover. Inhabitant density in the neighbourhood influences the use and perception of social & cultural interactions, regulating and experiential &

aesthetical ES. The availability of infrastructure for doing sports and relaxing furthermore has a positive effect towards physical interactions and social & cultural interactions. There is no significant association between richness in tree or flowering species and ES use or benefit perception.

- Main disservices/disturbances and problems in UGI arise from conflicts between users and activities, safety and insufficient quality and usability, especially littering.
- The integration of a better waste management (more rubbish bins) and other socio-economic aspects, more biodiversity and near-natural conditions, adequate recreational facilities and increasing the spatial extent of UGI in terms of more trees or the preservation of open space and brownfields were central requests from citizens of Leipzig.

This dissertation embeds locally assessed ES and benefit flows as well as the citizen's perspective and visions for the future development of UGI into the framework of guiding themes of urban development. In addition to a place-specific assessment of actually used ES rather than potential uses, this dissertation accounts for the negative aspects, i.e. disservices and disturbances, of nature in socio-ecological systems such as urban parks. Compared to the number of increasing research on ES, disservices/disturbances are less represented in studies, although knowing these negative effects of nature is urgently needed to meet intended management objectives and minimize (unintended) trade-offs (Shackleton et al. 2016). These disservices/disturbances go along with major conflicts and problems that have been raised by respondents of the online survey. Accounting for these conflicts and further topics regarding future UGI design from the citizens' perspective, chapter five offers unique insights into citizens' demands to a city-wide UGI network. Integrating this view into UGI design, planning and management offer chances to: firstly, meet and decrease arising conflicts and problems and secondly, increase acceptance and success of planning objectives and practises. Due to the high number of participants, results are representative to represent resident's perspectives regarding current guiding urban planning themes like biodiversity, justice and climate change adaptation in growing cities.

6.2. Limitations of the study and implications for further research

6.2.1. Ecosystem service assessment on selected study sites

Field observations combined with random surveys are suitable for quantifying most resting and moving activities like picnicking, walking or dog walking, selected by visitors as their main current ES use. However, limitations of this approach, for instance, include addressing bikers, who are difficult to stop for an interview, resulting in a limited understanding of why bikers choose a route through urban parks or brownfields instead of using streets (could be to avoid street noise, benefit from a safer biking environment, or to enjoy the green scenery). To capture ES flow for people on bikes it would be useful to set up ES assessments via online surveys targeting at cyclists.

Furthermore, I limited the mapping of ES use to the period from 8 a.m. to 8 p.m. being aware that typical late evening or night time uses such as picnicking or meeting people were only partly captured.

Some UGI visitors use two or more ES during one visit, for example, enjoying the scenery/beautiful landscape while taking a walk (Shan 2014). As I intended to map actual ES uses and not the frequently reported ES potentials, I limited the answer to the main ES use to avoid that respondents switch perspectives from actual to potential use. This might potentially lead to the underrepresentation of ES (e.g. sense of place, noise mediation), which are not as tangible as others (e.g. walking) (Plieninger et al. 2013). However, this issue was met by the integration of the open-ended questions about positive (benefits) and negative (disservices/disturbances) aspects of the site that broadened the assessment of used ES. In their own words, visitors described any benefits or disservices/disturbances of the site they perceived. With this qualitative approach, I aimed to avoid biases in actual personal perceptions by predefining any benefits or disservices/disturbances. Nevertheless, open-ended questions may not cover all benefits (or disservices) that respondents derive from UGI because people may not be aware of intangible benefits such as intellectual values.

Some urban parks or brownfields are specifically used by certain age groups and therefore aspects of that site may be overrepresented in survey results among these age groups. For instance, if a park with much sports infrastructure is primarily used by young adults then this might be reflected in high frequencies of the benefit "sports facilities" among this age group. However, I argue that effects of present characteristics and perceived benefits can still be captured by surveying actual users of certain UGI, whom we assume to choose this specific UGI according to their personal preferences. Future research may concentrate on a targeted selection of visitor groups in specific UGI, e.g. by approaching vulnerable groups like older persons or children (as in Kabisch and Kraemer 2020).

The linkage with green UGI characteristics, especially with species richness, implies further limitations. Species assessments were conducted on randomly distributed plots in 2017 that may not be representative for 2018 or cover total species richness of the study site. During the questioning, perceptions of respondents may be influenced by their direct environment (observation unit) where surveys were conducted, and they may not refer to the park or brownfield as a whole. Hence, people's perceptions and present UGI characteristics that were tested in the GLMs may not always refer to the same spatial unit. It remains for future research to disentangle direct relations between park (or other types of UGI) characteristics and the flow of the whole range of ES in this park, e.g. by assessing ES use on different observation units and locations within an urban park.

6.2.2. Online survey about ideas and topics for the future development of Leipzig's UGI

With regard to the open questions with partially very specific recommendations, not all ideas, suggestions and topics important to individual respondents could be discussed here, neither be integrated in a strategic plan focusing on the city wide UGI network. The planning strategy does not

aim to refer to individual user views but rather balance multiple views at the various UGI locations. Specific user demands and expectations such as the installation of specific sporting areas or platforms for events in UGI are furthermore limited by the holistic approach of a city wide UGI planning respecting regulatory conditions and legal restrictions.

The analysis of socio-economic and demographic characteristics of survey respondents furthermore reveals a medium to strong bias towards younger, female persons with a slightly higher monthly income than the average Leipzig citizen (Stadt Leipzig 2019, StadtLabor Tröger+Mothes GbR 2019). People that were not born in Germany are furthermore underrepresented. This underlines the limitations of this survey in representing views and opinions of a heterogeneous urban population. Older persons and people with different ethnic and cultural backgrounds are underrepresented although demands of vulnerable groups are crucial to integrate in planning processes to meet environmental justice aspects of UGI (Kabisch and Haase 2014).

6.2.3. Statistical analysis and study approach

In total, only 18 parks and 18 brownfields were observed and visitors interviewed there, so statistical power of the regression analysis for UGI characteristics and ES use may be limited.

Benefit perception and use may further be influenced by other factors on the demand and supply side that have not been analysed in this dissertation. Examples for important factors that determine the use of urban parks are nature orientation of UGI users (Lin et al. 2014) or other demographic factors such as cultural or ethnic background (Özgüner 2011, Akpinar 2016) that were not assessed here. In addition, there may be other factors on the site level such as the presence of paths, other facilities or certain nature aspects like large trees or specific plant species. Future research can strengthen this approach by further assessing the association between ES flow of certain user groups and site characteristics. A focus could be, for example, differences in preferences, perceptions and used ES in UGI between people with different cultural backgrounds.

Concerning assessed park characteristics, the pre-analysis revealed a high correlation between available sports infrastructure (e.g. table tennis, football or basketball fields and running tracks) and inhabitant density in 300m neighbourhood (Spearman' rank correlation 0.86), meaning that we counted more sports facilities in parks with high inhabitant density within 300m. Hence, it cannot be clearly determined, which of these characteristics are finally influencing ES use and benefit perception. Nevertheless, both UGI characteristics were tested in separated models and the model with the better fit (lower BIC) is assumed to have better explanatory power.

6.3. Implications for planning resilient UGI for human well-being

With regard to the current COVID-19 pandemic, cities emerged to be especially vulnerable to the spread of the virus due to their high inhabitant density (IPBES 2020). The current pandemic is only one example of possible hazards caused by socio-economic failure or natural disasters emerging from climate change that may affect (not only) urban areas in the future. Land use change including the transformation of wildlife habitats and forests to settlements or agricultural areas is one of the main causes that drive pandemics, which are strongly interlinked with biodiversity loss and climate change (IPBES 2020). Although urban settlements and their underlying land use patterns may not be able to prevent the spread of diseases, a qualitative UGI providing multiple benefits and ES can help to mitigate negative impacts from the crisis. During lock-down, UGI became important places for isolation from other people underlining the multiple and adaptive functions of urban and suburban green spaces (Ugolini et al. 2020). Uglioni et al (2020) found out that nearby urban parks as well as suburban UGI were among the most frequently used green areas for urban residents during lock-downs. Although assessed before the pandemic, the findings of this thesis underline this by revealing a request for an increased quantity and the relevance of access and tree cover to enhance ES provision. A general focus of UGI planning should therefore aim at:

i. **Increasing the spatial extent of UGI by fostering its diversification, access and integrating diverse tree cover levels.**

The potential for increasing the quantity in terms of more green spaces is of course limited in a compact and growing city due to competing land demands for other purposes such as education, housing or transport. The lack of available land for more extensive UGI puts planners to the challenge of creating more urban green at decreasing available land. More available and diverse urban green, may it be ever so small, contributes to ES delivery, reduction of use conflicts, and the compensation of overcrowded parks that do not only lead to conflicts but may be harmful to human health during a crisis such as the pandemic. The integration of small-scale greening in dense neighbourhoods, more trees in urban green spaces and on streets, vertical and façade greening, and the conversation of informal UGI can offer opportunities to meet this challenge. The use of brownfields for several ES and the request of survey respondents for the preservation of brownfields and vacant lots as open (green) spaces illustrate the potential of informal and unconventional green elements for a city that provides sufficient green spaces. The presence of trees in urban parks positively affects other important components of human health and well-being, because of their positive effect on air quality, noise reduction, and stress relief (Lohr et al. 2004, Roy et al. 2012). My results underpin these relationships by providing evidence that regulating ES are indeed enjoyed more often in parks with high tree cover. A majority of citizens in Leipzig appreciate and request the integration of more trees in the cityscape. Under consideration of increasing temperatures in the summer and increasing ageing of the

population, the presence of trees providing shade is especially important for older age groups (Knight et al. 2018, Kabisch and Kraemer 2020) and should thus be a central focus of inclusive UGI planning.

Not only in Leipzig most urban parks were highly used during lockdowns in the pandemic (Venter et al. 2020), which highlights the undersupply of open spaces in many city districts. Those who do now own their private garden or backyard depend on qualitative public green for recreation, physical exercise, and relaxation that is ideally near people's homes or easily accessible by public transport. UGI planning should therefore carefully assess spatial deficits in dense residential areas to compensate them and improve sustainable urban-rural partnerships to connect urban dwellers also to suburban UGI. Sustainable mobility concepts can support these urban-rural connections by offering adequate public transport and improving green connections for cycling and walking. Green routes for cyclists and walkers can facilitate people to take longer cycling routes (Lu et al. 2019, Nawrath et al. 2019) and thus enhance accessibility of UGI in the periphery.

ii. Integrating more near-natural conditions and urban wilderness to facilitate human well-being and biodiversity.

Enhancing natural elements such as trees, natural habitats, and flowering diversity were among the most frequently mentioned suggestions for UGI improvement and were perceived as important benefits across all age groups. Important features are biodiverse lawns, meadows, and habitats that facilitate, for example, bird and insect richness. In the Leipzig case study but also in other European cities (Weber et al. 2014, Ignatieva et al. 2017), there seems to be increasing appreciation of diverse and colourful meadows and "wild" nature with lower maintenance in the city. Integrating diverse perennial urban meadows with lower mowing frequencies into urban parks or other green spaces can provide higher aesthetical values and are able to buffer effects of climate change such as heatwaves and drought during the summer, because they offer, for example, better water management capacities (Yuan et al. 2017, Ignatieva and Hedblom 2018). Furthermore, has the effect of biodiversity on human health been highlighted in studies that found evidence for the positive relationship between (urban) biodiversity on the habitat or species level and mental health and well-being (see review: Marselle et al. 2019) as well as on recreational values (Qiu et al. 2013). Hence, fostering species richness in UGI by those measures offer opportunities to support urban biodiversity and climate adaptation on the hand and human health on the other hand.

However, the place-specific study in 18 urban parks (chapter four), did not reveal a concrete relationship between present richness in tree or flowering species and actually used ES. This may be caused by limitations of the approach (see section 6.2.1) or it points to the fact, that actual species richness does not directly influence ES flow. The relationship between biodiversity, human well-being, and ES flow is complex and depends, for example, on habitat types and people's ecological knowledge (Qiu et al. 2013). Interestingly it is often perceived, for example appearing by the number of colours

in flowering species, rather than actual species richness that has a positive effect on human well-being (Dallimer et al. 2012). This means that diversity has a positive effect on human well-being as long as people *think* or *know* that (urban) ecosystems are rich in plant or animal species. This proposes that UGI planning can take advantage of this effect by providing information on biodiversity protection projects in urban green spaces. Information could, for example, communicate the presence and protection of rare or endangered species, which are often more valued than common species (Angulo and Courchamp 2009). This can enhance awareness and thus acceptance of measures to protect biodiversity. UGI planning aiming at species protection accompanied by measures for climate adaptation and fair usability has then good chances to create multifunctional and high qualitative green spaces in cities that are widely valued and accepted by residents.

iii. Enhance elements of green and grey infrastructure and socio-economic aspects to diminish disservices and create inclusive UGI.

To account for justice aspects referring to demands of residents and especially vulnerable groups, such as older people, it is important to know their demands and visions in order to meet the manifold expectations of the local population (McPhearson et al. 2015). Assessing demands from older persons, for example referring to accessibility and a safe environment for physical activity (Knight et al. 2018), and meeting these in adapted UGI planning can enhance justice aspects and create inclusive green spaces for this vulnerable population group (Kabisch and Kraemer 2020). As Leipzig is driven by population growth mainly caused by young adults who move into densely populated areas, it is helpful to know their preferences for residential green in those areas as well as potential conflicts among uses and users so that also vulnerable are represented in UGI design. Adding on to the knowledge about the importance of facilities, size, and distance for physical activity (Kaczynski et al. 2008, Toftager et al. 2011, Schipperijn et al. 2013), I disentangled associations between UGI features and ES and benefit flow with regard to age groups. In general, residents of Leipzig frequently requested more and adapted facilities in public green. Neighbourhood parks in residential areas with high inhabitant density should thus include appropriate facilities for resting recreation, playing, or doing sports as well as open lawns that do not only facilitate physical interactions but also strengthen social relations between people, both being components of human health and well-being (Maas et al. 2009, Hartig et al. 2014, MEA 2005). Facilities for physical activities were especially important for adults and younger age groups (young adults between 18 and 30 years), while older people place more importance on aesthetical and experiential benefits of UGI.

However, littering and insufficient waste management were some of the main disservices/disturbances perceived by all age groups in Leipzig's UGI. This leads to a reduced quality of UGI and residents may feel less connected to or avoid poorly maintained green spaces (Wright Wendel et al. 2012). Poor maintenance may furthermore cause reduced safety and fear of crime, which leads to decreased use (Adinolfi et al. 2014, Liu and Xiao 2020). Adjusting maintenance by applying

shorter cleaning and maintenance cycles and increasing safety aspects by installing sufficient lighting or increasing the presence of the regulatory authority, should thus be central components of UGI planning. This may be especially important for groups that are more concerned and vulnerable to safety aspects, mainly women and older persons (Koskela and Pain 2000, Sreetheran and van den Bosch 2014). Integrating the citizens' knowledge about place-specific deficits and focussing on green spaces that are highly frequented can thereby help to apply target-oriented UGI management.

iv. Facilitate citizen's participation in management and maintenance of UGI

In order to assess local demands and usability constraints of all user groups, the fourth implication for resilient UGI planning suggests increasing citizen participation opportunities. Adaptive and flexible planning and management of UGI implementing citizen's participation and neighbourhood initiatives is able to meet particular local demands, reduce disservices, and thus increases urban resilience. The participation of citizens in maintenance, for example, offers opportunities to meet one of the main disservice/disturbance in urban parks, brownfields, and other UGI: littering and rubbish. Residents that have access to vacant lots and brownfields and taking care of its maintenance can enhance their usability and safety. The installation of more and adapted rubbish bins and improved waste management in urban parks could contribute to quality of publicly managed UGI. With regard to results from the online survey, there is high potential for strengthening the role of citizen's in maintenance in Leipzig's UGI, which cannot only increase benefit provision, enhance social interaction and sense of community but also minimize conflicts (Faehnle et al. 2014, Dennis and James 2016a, Fors et al. 2018). The citizens' expertise can provide planners with place-specific information about local actors and experiences, natural and ecological functions in a spatial context, the potential and capacity of ES, and the quality of the planning process and the success of planning practices (Faehnle et al. 2014).

6.4. Applicability and transferability of the results

Although the assessment is based in Leipzig, Germany, results suggest design principles that can be applied beyond the city's border. For instance, the integration of species-rich habitats and near-natural conditions on the one hand and the provision with adequate facilities for active and resting recreation, on the other hand, can enhance biodiversity protection and ES delivery for human health also in other cultural settings. Common socio-economic, geo-political, and environmental conditions may lead to similar demands, expectations and functions of UGI in European cities. However, with regard to climate change leading to different effects in cities that are located in different environmental settings, the importance and relevance of ES may vary (Gómez-Baggethun and Barton 2013). The city of Leipzig located in Central Europe might be affected by increasing droughts and summer temperatures, while cities in Southern Europe and the Mediterranean region are especially vulnerable to forest fires and coastal flooding (European Environment Agency 2016a). Our comparative study across three case

studies from UrbanGaia (Priess et al. 2021), for example, presents many common, but also sub-sets of different ES flows in urban parks with similar features in Coimbra (Mediterranean region) Leipzig (central Europe), and Vilnius (northern Europe). We found differences in used ES between cities revealing higher importance of regulating ES in Leipzig than in other cities, which could be explained by extremely hot summer temperatures in 2018 that were less pronounced in Portugal or Lithuania (Priess et al. 2021). This exemplifies how different environmental and climate settings can affect ES flow and priorities in UGI planning, for example in Central Europe for adapted tree species that are more resilient against droughts and contributing to temperature regulation in the summer. The focus in UGI planning and its measures to adapt to risks from climate change should therefore implicitly consider local environmental and socio-economic specificities.

To assess ES flow and quality of UGI, planning and management must also consider local data feasibility with regard to local contexts and requirements (Carmen et al. 2020). In Carmen et al (2020), we present a framework for a comparative UGI quality assessment across four UrbanGaia case studies that is based on a hierarchical structure inspired by the IPBES framework (Díaz et al. 2015). On the highest level, the evaluation framework covers the three main dimensions of human-nature relationships: physical dimension (nature as itself, ecological values), contributions to people (ES and benefits to people) and the social dimension (values that contribute to quality of life). It remains to the local context, which specific contributions or social values (e.g. regulation of hot summer temperatures and focus on stewardship in Leipzig vs. wildfire regulation and economic aspects in Portugal) may gain higher importance as performance indicator for the quality evaluation of UGI. Nevertheless, cities are facing similar challenges all relating to climate change, biodiversity loss, social injustice or other extreme situations like the COVID-19 pandemic (European Commission 2011, IPBES 2020). This framework can hence form a basis for the assessment of locally specific demands to UGI that can be transferred to different locations and leading target-oriented planning.

6.5. Final conclusions

To maintain and improve ecosystem service provision and resilience of UGI, planning has to take account of the different perspectives that shape benefit flow and balance diverse expectations from citizens. This dissertation highlights which UGI characteristics and planning approaches enhance ES and benefit flow, reduce conflicts and meet the demands of the local population. Enhancing city-wide tree cover can serve as a tool for climate change adaptation by increasing shade provision and supplying opportunities for experiential and aesthetical ecosystem services. Facilities ranging from infrastructure for play, resting and physical activity to adequate lighting and safe paths should be a central focus of local planning strategies to increase usability and justice for user groups of different ages. Involving citizens in the maintenance and management of UGI can increase the sense of community and social cohesion and can get the littering problem under control. Informal types of UGI can thereby play an important role for neighbourhood initiatives and represent unconventional types

of urban green and alternative concepts in planning. Preserving and integrating those informal sites into the city-wide UGI, especially in densely populated neighbourhoods, can then contribute to reduce conflicts that occur between users and activities in public parks and therefore reduce trade-offs between ecosystem services. They can further contribute to urban biodiversity by their near-natural or low maintenance activities creating valuable habitats for plant and animal species. Biodiversity, justice aspects, and the reduction of conflicts are central aspects in growing cities and this dissertation project highlights empirical evidence of how these requirements can be met by integrating citizens' perceptions and ideas. With regard to their local socio-economic, environmental, and political circumstances, my findings provides valuable insights to topics and principles that are important to people and guide the current debate about UGI design in Europe in order to meet challenges from climate change and other environmental or socio-economic hazards.

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Supplementary material[45]

[45] The survey S1, Table S4, Table S5, and Table S6 are published in the supplementary material of (Palliwoda and Priess 2021). The Figure S3 is published as Appendix B in (Palliwoda et al. 2020)

S1: Survey about the use of nature in parks and brownfields

Question 1
What do you use/enjoy/disturbs you here? (1 possible answer only)

[ ] Collecting food from plants (berries, herbs, etc.)
[ ] Drinking water (surface/ ground water)
[ ] Coolecting medicne, fibres, etc.
[ ] Using energy from plants (wood, etc.)
[ ] Draft animal or mount

[ ] Providing shade and shelter/ cooling effect
[ ] Mediation of noise, smell, visual impacts

[ ] Experiencing diversity of plants & animals
[ ] Watching plants or animals

[ ] Enjoy landscape beauty
[ ] Experience cultural heritage, sense of place
[ ] Environmental education
[ ] Sacred or religious plants or animals
[ ] Being inspired by nature

[ ] sport fishing or hunting
[ ] Biking
[ ] Walking the dog
[ ] Walking, strolling, hiking
[ ] Jogging, running
[ ] Meeting people
[ ] Picnicing, barbequeing
[ ] Camping
[ ] Gardening
[ ] Doing other activities in nature, which are:
_____

OR:
[ ] Unsightly landscape
[ ] Causes hayfever/ allergic reaction
[ ] Pests (mosquitos, flies)
[ ] Bad water quality (due to natural reasons)
[ ] Threatening site
[ ] Other problems (animal excrements,etc.)

Question 2 How important is that use/ experience for you? [ ] unimportant [ ] almost unimportant [ ] intermediate important [ ] important [ ] very important	**Question 2 (when grey at Q1 only)** How severe is that problem to you? [ ] Very low [ ] Low [ ] Intermediate [ ] High [ ] Very high	**Question 3** How often do you use/do you experience this? [ ] Less than annual [ ] Yearly [ ] Monthly [ ] Weekly [ ] Daily	**Question 3 (when grey at Q1 only)** What is the origin of the problem? [ ] Human [ ] Mostly human [ ] Natural/ human [ ] Mostly natural [ ] Natural
Question 4 By which means of transport did you get here? [ ] By foot [ ] Bike, e-bike [ ] Moped, scooter, motorcycle [ ] Car, SUV [ ] Local (bus, metro, tram) [ ] Regional (bus, metro, regional train) [ ] Other:		**Question 5** Why do you do this here and not at other places? [ ] Wilderness/nature, landscape or fresh air [ ] Tranquillity or seclusion [ ] Physical space for activities [ ] Social/ cultural interaction [ ] Close to home, accessible, shortcut [ ] Other:	

What do you like and dislike about this site? Other comments:

A few questions about a few personal data (voluntary of course):

Where is your place of living?

City: _____

Street: _____

Postcode: _____

Gender: [ ] female [ ] male [ ] diverse

Age: ___ or [ ] < 18 [ ] 20-29 [ ] 30-39 [ ] 40-49 [ ] 50-59 [ ] 60-69 [ ] 70+

Thank you for participating in the survey!

Internal notes

Date/ weekday:	
Time (start-end):	
Site ID:	
Observer:	
Weather (cloudy, sunny, unsettled):	
Shade of POIs:	
Location (path, meadow):	
Moving/Resting:	
Other:	

Stadt Leipzig

Stadt Leipzig | Martin-Luther-Ring 4 | 04109 Leipzig

Umfrage

Masterplan Grün - Umfrage zu Stadtgrün und Gewässern in Leipzig

Ihre Meinung zu Stadtgrün und Gewässern in Leipzig

Ihre Meinung zu Stadtgrün und Gewässern in Leipzig

Stadtgrün und Gewässer in Leipzig | © Freiraumkonzepte GbR

Wie wichtig sind Ihnen Stadtgrün und Gewässer für Ihr persönliches Wohlbefinden und Ihre Lebensqualität in Leipzig?

- ☐ sehr wichtig
- ☐ eher wichtig
- ☐ weder / noch
- ☐ eher unwichtig
- ☐ überhaupt nicht wichtig

Bitte nur eine Antwort auswählen.

Was ist Ihnen besonders wichtig an Stadtgrün und Gewässern in Leipzig?

	sehr wichtig	eher wichtig	teils / teils	eher un-wichtig	sehr un-wichtig	weiß nicht
viel Grün im gesamten Stadtgebiet	☐	☐	☐	☐	☐	☐
möglichst große grüne Flächen	☐	☐	☐	☐	☐	☐
das Grün soll in der Nähe meiner Wohnung sein	☐	☐	☐	☐	☐	☐
Spielmöglichkeiten	☐	☐	☐	☐	☐	☐
Sport- und Bewegungsmöglichkeiten	☐	☐	☐	☐	☐	☐
Barrierefreiheit	☐	☐	☐	☐	☐	☐
Ruhe	☐	☐	☐	☐	☐	☐
guter Zustand der Wege	☐	☐	☐	☐	☐	☐
Sicherheit	☐	☐	☐	☐	☐	☐
Sitzmöglichkeiten	☐	☐	☐	☐	☐	☐
Sauberkeit/ Ordnung	☐	☐	☐	☐	☐	☐
Beleuchtung	☐	☐	☐	☐	☐	☐
Gewässer sollen zugänglich sein	☐	☐	☐	☐	☐	☐
Wasserqualität der Gewässer	☐	☐	☐	☐	☐	☐
Wegeverbindungen durchs Grün und an Gewässern	☐	☐	☐	☐	☐	☐

Bitte jeweils nur eine Antwort auswählen.

Weshalb suchen Sie Stadtgrün und Gewässer hauptsächlich auf? *(Sie können mehrere, maximal 5 Antworten geben.)*

- [ ] zur Entspannung
- [ ] um spazieren zu gehen
- [ ] um Zeit in der Natur zu verbringen
- [ ] um Tiere und Pflanzen zu sehen
- [ ] um mit meinen Kindern im Freien zu spielen
- [ ] um sportlich aktiv zu sein
- [ ] wegen der frischen Luft
- [ ] um bei Hitze Schatten zu suchen
- [ ] um andere Menschen zu treffen
- [ ] als Verbindungsweg zwischen A und B
- [ ] wegen Festen und Veranstaltungen
- [ ] um meinen Hund auszuführen
- [ ] um zu gärtnern
- [ ] um Zeit an/ auf Gewässern zu verbringen

Bitte wählen Sie minimal 0, maximal 5 Antworten aus.

Nutzen Sie Stadtgrün und Gewässer auch noch anderweitig (oben nicht genannte Aktivitäten)? Wenn ja, wie?

Bei der Nutzung von Stadtgrün und Gewässern gibt es unterschiedliche Interessen und Gruppen. Dabei kann es auch zu Konflikten kommen. Woran stören Sie sich persönlich? *(Sie können mehrere Antworten geben.)*

- [ ] Müll und Dreck
- [ ] Grillen
- [ ] laute Gruppen
- [ ] laute Musik
- [ ] Hunde
- [ ] Hundekot
- [ ] bestimmte Sportarten
- [ ] mich stört nichts
- [ ] Sonstiges ...

Gibt es Orte im Grünen oder an Gewässern, die Sie meiden?

- [ ] nein
- [ ] ja, und zwar ... (bitte Ort und Grund der Meidung ergänzen)

Bitte nur eine Antwort auswählen.

Ist es für Sie in Ordnung, wenn Teilbereiche des Stadtgrüns naturbelassen sind und weniger gepflegt werden, weil sie Lebensraum für viele Tiere und Pflanzen sind?

- [ ] Ja vollkommen, ich finde Stadtgrün sollte überwiegend natürlich und wenig gepflegt sein!
- [ ] Sowohl gepflegtes als auch naturbelassenes Grün haben ihre Berechtigung.
- [ ] Nein, ich finde Stadtgrün sollte überwiegend gepflegt aussehen!
- [ ] Dazu habe ich keine Meinung.

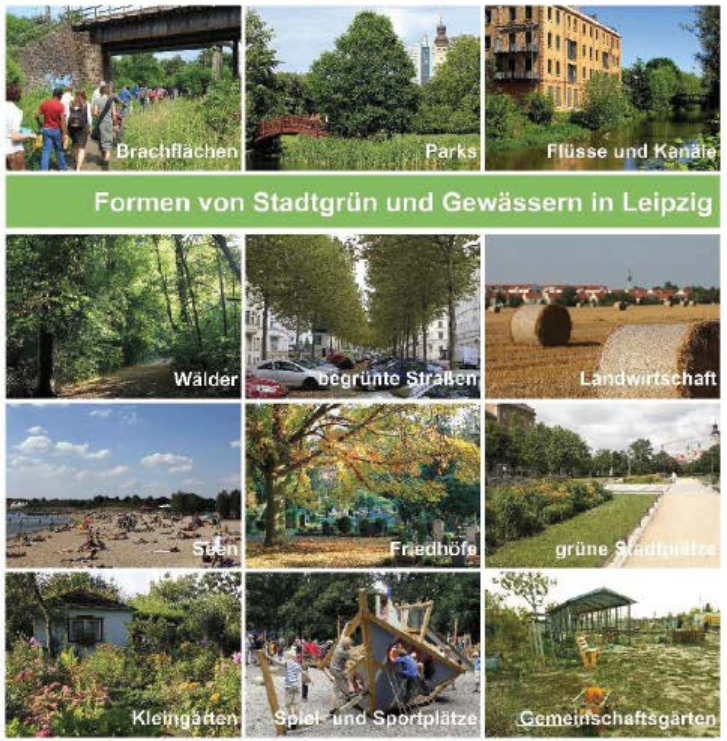
Bitte nur eine Antwort auswählen.

Haben Sie einen Lieblingsort im Grünen bzw. an Gewässern in Leipzig? Wenn ja, welcher ist das?

Was gefällt Ihnen dort besonders gut?

Haben Sie konkrete Ideen, wie das Leipziger Stadtgrün und die Gewässer verbessert werden können?

Formen von Stadtgrün und Gewässer



Wie häufig haben Sie im letzten Jahr folgende Formen von Stadtgrün und Gewässern in der Stadt genutzt?

	mehr-mals pro Woche	ca. einmal pro Woche	ca. 1-3-mal pro Monat	ein bis einige Male im Jahr	(fast) nie	weiß nicht
Parks	☐	☐	☐	☐	☐	☐
Wald	☐	☐	☐	☐	☐	☐
grüne Stadtplätze	☐	☐	☐	☐	☐	☐
begrünte Straßen	☐	☐	☐	☐	☐	☐
Flüsse / Kanäle	☐	☐	☐	☐	☐	☐
Seen	☐	☐	☐	☐	☐	☐
Kleingärten	☐	☐	☐	☐	☐	☐
Gemeinschaftsgärten	☐	☐	☐	☐	☐	☐
Spiel- und Sportplätze	☐	☐	☐	☐	☐	☐
Friedhöfe	☐	☐	☐	☐	☐	☐
landwirtschaftliche Flächen	☐	☐	☐	☐	☐	☐

Bitte jeweils nur eine Antwort auswählen.

Wenn Sie an folgende Formen von Stadtgrün und Gewässern denken, was verbinden Sie damit? *(Sie können mehrere Antworten geben.)*

	Erho-lung	Aktivi-tät und Sport	Gesel-ligkeit	Natur-erleben	All-tags-wege	Kultur
Parks	☐	☐	☐	☐	☐	☐
Wald	☐	☐	☐	☐	☐	☐
grüne Stadtplätze	☐	☐	☐	☐	☐	☐
grüne Brachflächen	☐	☐	☐	☐	☐	☐
Flüsse / Kanäle	☐	☐	☐	☐	☐	☐
Seen	☐	☐	☐	☐	☐	☐
Kleingärten	☐	☐	☐	☐	☐	☐
Gemeinschaftsgärten	☐	☐	☐	☐	☐	☐
Spiel- und Sportplätze	☐	☐	☐	☐	☐	☐
Friedhöfe	☐	☐	☐	☐	☐	☐
landwirtschaftliche Flächen	☐	☐	☐	☐	☐	☐

Funktionen von Stadtgrün und Gewässern

Funktionen von Stadtgrün und Gewässern

Die Formen des Stadtgrüns und der Gewässer werden auch als **urbane grün-blaue Infrastruktur** verstanden. Der Begriff verweist darauf, dass Stadtgrün und Gewässer - wie andere Infrastrukturen auch - zahlreiche wirtschaftliche, soziale und ökologische Leistungen erbringen und **Funktionen** erfüllen. Leipzig steht vor vielfältigen Herausforderungen, für die die grün-blaue Infrastruktur wichtige Beiträge leistet.

Der Masterplan Grün wird diesbezüglich folgende **5 Leitthemen** in den Vordergrund stellen:

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Gesundheit

Stadtgrün schafft gesunde Lebensbedingungen in Leipzig. Es sorgt für frische Luft und schafft Raum für Bewegung und Erholung.
Ziel ist es, Umweltbelastungen zu reduzieren, Erholungs- und Bewegungsräume zu schaffen und die Gesundheit und das Wohlbefinden von Menschen in der Stadt zu fördern.

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Klimaanpassung

Das Stadtklima verändert sich, wie im letztjährigen Hitzesommer sehr deutlich wurde. Stadtgrün kühlt die Stadt, mildert die Folgen von Starkregen, speichert CO2 uvm.
Ziel ist es, Leipzig an den Klimawandel anzupassen und Belastungen für hier lebende Menschen, aber auch für das Stadtgrün selbst zu verringern.

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Biodiversität

Leipzig ist nicht nur Lebensraum für Menschen, sondern auch für eine Vielzahl an Pflanzen und Tieren.
Ziel ist es, die biologische Vielfalt in der gesamten Stadt zu fördern und für Menschen erlebbar zu machen.

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Umweltgerechtigkeit

Alle Menschen sollten möglichst gleichberechtigt von Stadtgrün und Gewässer profitieren.
Ziel ist es, Grün- und Freiräume sowie Gewässer für verschiedenste Nutzergruppen zu entwickeln, Begegnung und Kommunikation zu ermöglichen und Zugänglichkeit zu schaffen.

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umweltgerechte Mobilität

Leipzig möchte den Verkehr umweltfreundlich und sicher gestalten. Wege druchs Grün und entlang von Gewässern können einen Beitrag leisten, Mobilität zu Fuß oder mit dem Rad zu fördern.
Ziel ist es, Grünräume und Gewässer auch landseitig zu vernetzen und damit sichere und attraktive Bewegungsräume und Alltagswegeverbindungen zu schaffen.

Welche Bedeutung messen Sie den Leitthemen bei?

	sehr wichtig	eher wichtig	eher unwichtig	überhaupt nicht wichtig
Gesundheit	☐	☐	☐	☐
Klimaanpassung	☐	☐	☐	☐
Biodiversität	☐	☐	☐	☐
Umweltgerechtigkeit	☐	☐	☐	☐
umweltgerechte Mobilität	☐	☐	☐	☐

Bitte jeweils nur eine Antwort auswählen.

Grün in meinem Stadtteil

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Bitte geben Sie Ihre Postleitzahl an:

Mein Stadtteil ist meiner Meinung nach ausreichend mit Grün ausgestattet.

- ☐ trifft voll und ganz zu
- ☐ trifft eher zu
- ☐ weder / noch
- ☐ trifft weniger zu
- ☐ trifft überhaupt nicht zu

Bitte nur eine Antwort auswählen.

Welche Formen des Stadtgrüns würden Sie sich mehr in Ihrem Stadtteil wünschen? *(Sie können mehrere, maximal 5 Antworten geben.)*

- ☐ Parks
- ☐ Wald
- ☐ grüne Stadtplätze
- ☐ begrünte Straßen (Straßenbäume)
- ☐ grüne Brachflächen
- ☐ Kleingärten
- ☐ Gemeinschaftsgärten
- ☐ Spiel- und Sportplätze
- ☐ grüne Wegeverbindungen
- ☐ Gewässer

Bitte wählen Sie minimal 0, maximal 5 Antworten aus.

Wie wichtig war Ihnen bei der Wahl Ihres Wohnstandorts Stadtgrün im näheren Wohnumfeld?

- ☐ sehr wichtig
- ☐ wichtig
- ☐ teils / teils
- ☐ eher unwichtig
- ☐ überhaupt nicht wichtig

Bitte nur eine Antwort auswählen.

Meine Wohnung oder mein Haus verfügt über: *(Sie können mehrere Antworten geben.)*

- ☐ Balkon / Terrasse
- ☐ Garten, den ich allein nutzen kann
- ☐ Garten, den meine Nachbarn mitbenutzen
- ☐ begrünten Innenhof
- ☐ Dachbegrünung
- ☐ Fassadenbegrünung
- ☐ nichts davon, ist mir auch nicht so wichtig
- ☐ leider nichts davon, aber ich würde mir wünschen:

Wodurch fühlen Sie sich an Ihrem Wohnort wie stark belastet?

	sehr stark	stark	weder / noch	eher weniger	(fast) gar nicht
schlechte Luft	☐	☐	☐	☐	☐
Lärm	☐	☐	☐	☐	☐
Hitze	☐	☐	☐	☐	☐

Bitte jeweils nur eine Antwort auswählen.

Auf meinen alltäglichen Wegen zur Arbeit / Schule, zum Einkaufen oder zu Freizeitaktivitäten habe ich die Möglichkeit, Wege durchs Grün oder am Wasser zu benutzen.

- ☐ ja
- ☐ nur bedingt
- ☐ nein
- ☐ kann ich nicht beurteilen

Bitte nur eine Antwort auswählen.

Würden Sie für Wege durchs Grün zu Fuß oder mit dem Rad, auch Umwege in Kauf nehmen.

- [ ] ja, auf jeden Fall
- [ ] teilweise
- [ ] eher nicht
- [ ] nein

Bitte nur eine Antwort auswählen.

Wie bewegen Sie sich in der Stadt fort?

	regelmäßig	selten	nie
Bus und Bahn	☐	☐	☐
privates Auto	☐	☐	☐
Fahrrad	☐	☐	☐
zu Fuß	☐	☐	☐
Carsharing	☐	☐	☐

Bitte jeweils nur eine Antwort auswählen.

Gärtnem Sie? *(Sie können mehrere Antworten geben.)*

- [ ] nein, gar nicht
- [ ] ja, auf meinem Balkon
- [ ] ja, in meinem Garten an meinem Haus/ meiner Wohnung
- [ ] ja, im Kleingarten in einer Kleingartenanlage
- [ ] ja, im Gemeinschaftsgarten in der Stadt
- [ ] ja, im Garten außerhalb der Stadt
- [ ] ja, und zwar..

Über mich

Über mich

Wie alt sind Sie?

Datenformat: Ganzzahl

Welchem Geschlecht fühlen Sie sich zugehörig?

- [ ] weiblich
- [ ] männlich
- [ ] inter / divers
- [ ] keine Angabe

Bitte nur eine Antwort auswählen.

Wie hoch ist Ihr durchschnittliches Nettoeinkommen im Monat?

- [ ] unter 150€
- [ ] 150 – unter 400€
- [ ] 400 – unter 600€
- [ ] 600 – unter 800€
- [ ] 800 – unter 1200€
- [ ] 1200 – unter 1600€
- [ ] 1600 – unter 2000€
- [ ] 2000 – unter 2600€
- [ ] 2600 – unter 3400€
- [ ] 3400 – unter 4200€
- [ ] mehr als 4200€

Bitte nur eine Antwort auswählen.
Ihr Nettoverdienst (nicht ihr gesamter Haushalt), d.h. Lohn oder Gehalt nach Abzug von Steuern und Sozialversicherungsbeiträgen

Welchen höchsten schulischen Abschluss haben Sie (bisher)?

- [ ] (noch) keinen
- [ ] 8. oder 9. Klasse (Hauptschule)
- [ ] 10. Klasse (Realschulabschluss)
- [ ] Fachhochschulreife/ Fachabitur
- [ ] Allgemeine Hochschulreife/ Abitur

Bitte nur eine Antwort auswählen.

Welchen höchsten beruflichen Abschluss haben Sie (bisher)?

- [ ] (noch) ohne abgeschlossene Berufsausbildung
- [ ] abgeschlossene Berufsausbildung, Teilfacharbeiter/-in
- [ ] Meister-/ Technikerausbildung oder Fachschulabschluss (auch der ehem. DDR)
- [ ] Fachhochschulabschluss
- [ ] Hochschul-/ Universitätsabschluss (oder höher)

Bitte nur eine Antwort auswählen.

Sind Sie in Deutschland geboren?

- [ ] ja
- [ ] nein

Bitte nur eine Antwort auswählen.

Zu guter Letzt

Zu guter Letzt

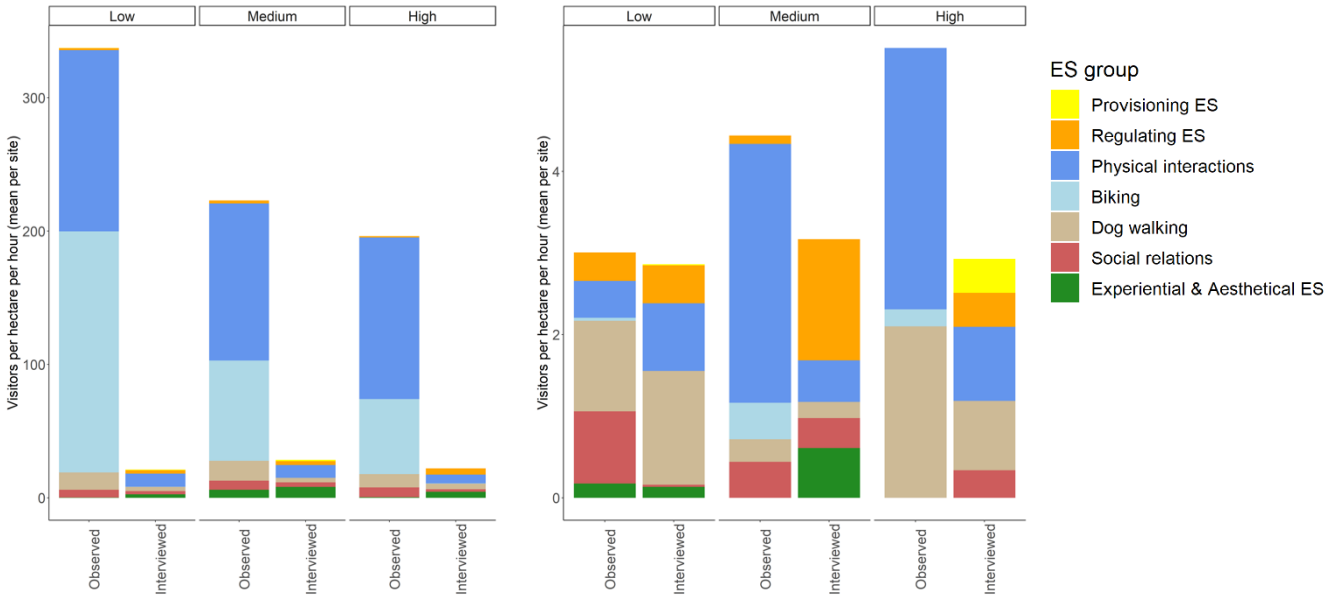
Wie sind Sie auf diese Umfrage aufmerksam geworden? *(Sie können mehrere Antworten geben)*

- [ ] Zeitung
- [ ] Stadtmagazine
- [ ] Amtsblatt
- [ ] Internetseite Stadt Leipzig
- [ ] Umweltverbände
- [ ] Familie/ Freunde/ Kollegen
- [ ] soziale Medien
- [ ] Sonstige ...

Es gibt weitere Themen rund um Stadtgrün und Gewässer die Sie bewegen? Sie haben Hinweise oder Themenvorschläge, denen sich der Masterplan Grün widmen soll? Bitte teilen Sie uns diese mit!

Vielen Dank für Ihre Teilnahme!

Figure S3: Visitor density of observed and interviewed users and their ecosystem service (ES) group use for **a)** parks and **b)** brownfields with 3 tree cover classes (low, medium, high). Users are scaled to person/hectare^{-1}; means are calculated only for sites used by visitors. Please note the different y-axis scales of parks and brownfields.



a) b)

	Confidence interval	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1- Gardening & environmental education	**0.05**	1	-0.53	-0.22	-0.47	-0.38	0.1	-0.42	-0.62	-0.23	-0.14	-0.01	-0.26	-0.25	0.04
	0.95	1	0.19	0.59	0.53	0.41	0.73	-0.12	-0.22	0.55	0.56	0.59	0.45	0.45	0.74
2- Green landscape/ aesthetics	**0.05**	-0.52	1	-0.44	-0.21	-0.66	-0.43	-0.05	-0.17	-0.11	-0.17	-0.33	-0.28	-0.52	-0.31
	0.95	0.2	1	0.61	0.68	0.23	0.5	0.57	0.66	0.66	0.71	0.5	0.56	0.52	0.55
3- Natural elements	**0.05**	-0.17	-0.48	1	-0.14	-0.33	-0.55	-0.19	-0.6	-0.15	-0.28	-0.45	-0.09	-0.44	-0.51
	0.95	0.6	0.59	1	0.69	0.59	0.51	0.48	0.11	0.57	0.7	0.36	0.62	0.48	0.53
4- Regulating ecosystem services	**0.05**	-0.44	-0.23	-0.18	1	-0.59	-0.7	-0.22	-0.18	0.01	-0.6	-0.39	0.18	-0.54	-0.67
	0.95	0.5	0.67	0.69	1	0.17	0.08	0.4	0.55	0.75	0.18	0.42	0.77	0.19	0.28
5- Sense of place	**0.05**	-0.4	-0.65	-0.35	-0.58	1	-0.32	-0.5	-0.73	-0.47	-0.4	-0.65	-0.36	-0.51	-0.29
	0.95	0.41	0.23	0.59	0.18	1	0.59	0.08	-0.18	0.34	0.48	0.1	0.46	0.38	0.61
6- Social & cultural interactions	**0.05**	0.09	-0.44	-0.56	-0.71	-0.3	1	-0.71	-0.8	-0.43	0.57	-0.3	-0.56	-0.15	0.7
	0.95	0.72	0.52	0.51	0.1	0.59	1	-0.21	-0.31	0.51	0.92	0.59	0.28	0.62	0.93
7- Urban wilderness	**0.05**	-0.43	-0.03	-0.21	-0.21	-0.52	-0.72	1	0.3	-0.33	-0.42	-0.42	-0.42	-0.6	-0.65
	0.95	-0.12	0.6	0.49	0.38	0.07	-0.22	1	0.84	0.51	0.21	0.47	0.56	0.59	-0.27
8- Art & buildings	**0.05**	-0.59	-0.15	-0.61	-0.18	-0.71	-0.79	0.28	1	-0.28	-0.68	-0.55	-0.37	-0.75	-0.78
	0.95	-0.22	0.67	0.12	0.56	-0.17	-0.3	0.83	1	0.51	0.02	0.46	0.41	0.26	-0.05
9- Dog-friendly	**0.05**	-0.23	-0.13	-0.18	0.04	-0.47	-0.4	-0.35	-0.31	1	-0.36	-0.2	0.55	-0.66	-0.35
	0.95	0.57	0.67	0.6	0.74	0.35	0.49	0.5	0.53	1	0.53	0.62	0.88	0.11	0.57
10- Infrastructure	**0.05**	-0.17	-0.15	-0.25	-0.58	-0.42	0.57	-0.44	-0.68	-0.33	1	-0.33	-0.4	0.05	0.44
	0.95	0.57	0.72	0.72	0.2	0.49	0.92	0.19	0.04	0.5	1	0.52	0.39	0.68	0.87
11- Park design & maintenance	**0.05**	-0.02	-0.32	-0.46	-0.41	-0.65	-0.34	-0.41	-0.56	-0.19	-0.34	1	-0.04	0.11	-0.48
	0.95	0.59	0.49	0.37	0.41	0.11	0.57	0.47	0.44	0.63	0.5	1	0.61	0.77	0.39
12- Seclusion	**0.05**	-0.24	-0.29	-0.11	0.18	-0.34	-0.55	-0.37	-0.4	0.55	-0.43	-0.08	1	-0.38	-0.52
	0.95	0.45	0.55	0.63	0.76	0.43	0.26	0.57	0.39	0.89	0.38	0.64	1	0.43	0.3
13- Size/ availability & location	**0.05**	-0.25	-0.53	-0.47	-0.52	-0.48	-0.16	-0.59	-0.76	-0.66	0.03	0.11	-0.41	1	-0.27
	0.95	0.47	0.5	0.43	0.17	0.42	0.63	0.45	0.31	0.13	0.69	0.78	0.43	1	0.61
14- Sport facilities	**0.05**	0.01	-0.33	-0.5	-0.68	-0.3	0.71	-0.65	-0.78	-0.35	0.44	-0.43	-0.52	-0.28	1
	0.95	0.71	0.57	0.55	0.29	0.62	0.93	-0.27	-0.04	0.51	0.88	0.36	0.34	0.6	1

Table S4: Lower and upper confidence intervals for 1000 bootstrapped correlation coefficients for weighted Spearman's rank-correlation of benefits in urban parks. Confidence intervals that do not include zeros (= are below or above zero) are suggesting significant correlations (p<0.05).

	Confidence interval limit	1	2	3	4	5	6	7	8	9
1- Green landscape/ aesthetics	**0.05**	1	-0.33	-0.43	-0.16	-0.05	-0.02	-0.51	0.18	-0.35
	0.95	1	0.84	0.85	0.89	0.95	0.95	0.72	0.95	0.85
2- Natural elements	**0.05**	-0.3	1	-0.37	-0.18	-0.16	0	-0.75	-0.55	-0.23
	0.95	0.87	1	0.82	0.88	0.98	0.95	0.17	0.69	0.92
3- Social & cultural interactions	**0.05**	-0.42	-0.45	1	-0.16	-0.26	0.06	-0.25	-0.32	0.08
	0.95	0.86	0.81	1	0.93	0.91	0.95	0.91	0.95	0.94
4- Urban wilderness	**0.05**	-0.27	-0.18	-0.12	1	0.14	0.69	-0.56	-0.07	0.31
	0.95	0.88	0.89	0.95	1	0.97	1	0.72	0.9	0.97
5- Dog-friendly	**0.05**	0.03	-0.14	-0.32	0.09	1	0.31	-0.77	0.19	-0.12
	0.95	0.96	0.99	0.91	0.97	1	0.99	0.57	0.94	0.96
6- Freedom/ no regulations	**0.05**	-0.01	-0.02	0.01	0.73	0.31	1	-0.61	-0.09	0.61
	0.95	0.93	0.95	0.95	1	0.99	1	0.62	0.88	0.97
7- Infrastructure	**0.05**	-0.52	-0.74	-0.26	-0.61	-0.74	-0.61	1	-0.5	-0.59
	0.95	0.75	0.26	0.91	0.72	0.6	0.66	1	0.75	0.69
8- Seclusion	**0.05**	0.2	-0.55	-0.33	-0.12	0.2	-0.02	-0.44	1	-0.34
	0.95	0.95	0.72	0.94	0.91	0.94	0.9	0.74	1	0.85
9- Size/ availability & location	**0.05**	-0.34	-0.24	0.09	0.39	-0.06	0.59	-0.59	-0.33	1
	0.95	0.86	0.91	0.94	0.97	0.97	0.97	0.72	0.83	1

Table S5: Lower and upper confidence intervals for 1000 bootstrapped correlation coefficients for weighted Spearman's rank-correlation of benefits in green brownfields. Confidence intervals that do not include zeros (= are below or above zero) are suggesting significant correlations (*p<0.05*)

Site ID	UGI-Type	Place name	Share of tree cover	Tree rich-ness per 100 m2	Flow ering rich-ness per 100 m2	Size of the site (ha)	Inha-bitants within 300m	Seating possibi-lities per hectare	Light-ing per hectare	Sport facilities (sum)	Mean age of respon-dents	Number of surveys
B01_1	B	Saalfelder Str.	21.04	0.22	4	1.21	3437	0	0	0	39	30
B08_1	B	Torgauer Platz	8.74	0.22	2.89	2.38	4077	0	3.36	0	38.31	15
B08_2	B	Kirschberger str.	38.67	2.37	0.59	5.1	2971	0	0.78	0	48.83	38
B10_1	B	Bayerischer Bahnhof	6.67	0.44	1.96	8.81	7239	0	0.57	0	34.97	38
B11_1	B	Kochstr.	14.82	0.32	32	0.06	3272	47.32	0	0	42.83	6
B12_2	B	Friedrich-Ebert-Str.	53.73	0.27	14	0.4	3811	2.49	0	0	30	6
B16_3	B	Zweinaun-dorfer Str.	97.66	0.89	0.22	1.67	4574	0	0	0	32.2	10
B17_2	B	Saarlaender Str.	36.02	0.15	12	0.39	250	0	5.12	0	25	1
B17_3	B	Luetzener Str./Oderma nnstr.	96.13	0.92	8	0.1	4488	0	0	0	32.56	10
B18_1	B	Zschocher-sche/ Makran-staedter Str.	7.54	0	2.67	1.33	1692	0	0	0	29.73	11
B18_2	B	Delitzscher Str.	37.57	0.67	4	0.13	3416	0	0	0	NA	0
B19_3	B	Bernhardi-platz	77.86	0.41	0	0.29	5162	0	0	0	NA	0
B20_3	B	Ossietzkystr.	70	1.02	0	0.09	3270	0	0	0	NA	0
B21_2	B	Eisenbahn-str.	54.64	0.54	10	0.17	6627	30.22	0	1	27	19
B21_3	B	Friedhof Mockau	82.13	1.56	0	1.37	2322	0	0	0	NA	0
B22_1	B	Jahrtausend-feld	2.2	0.67	3.56	2.65	4840	1.51	0	1	31.57	64
B22_3	B	Max-Liebermann Str.	75	2.44	0	0.72	610	0	0	0	NA	0
B24_2	B	Bernhard-strasse	64.94	0.77	10	0.12	4669	0	0	0	30	2
P01_2	P	Arthur-Bretschnei-der Park	58.44	1.11	0.67	3.05	4157	8.2	0	0	43.69	111
P02_3	P	Heinrich Schuetz Platz	76.85	0.44	0	1.45	8443	5.51	5.51	3	39.49	80
P03_3	P	Gustav Schwabe Platz	89.59	2	0	1.19	3549	15.94	6.71	1	49.49	51
P04_1	P	Rabet	18.4	0.59	0.44	6.28	11526	8.29	8.29	8	37.34	117
P04_2	P	Lenné Anlage	65.76	0.67	0.44	1.38	1744	7.27	2.91	0	34.29	71
P04_3	P	Richard Wagner Platz	79.19	0.89	0.89	1.02	3436	5.9	7.86	0	44.46	97

Table S6/1: Green, spatial, and grey characteristics of the 36 study (B-Brownfield, P-Park) sites in Leipzig, mean age of respondents and number of conducted valid suryes. The last number of the site ID indicates the tree cover class (1-low, 2-medium, 3-high).

Site ID	UGI-Type	Place name	Share of tree cover	Tree rich-ness per 100 m2	Flow ering rich-ness per 100 m2	Size of the site (ha)	Inha-bitants within 300m	Seating possibi-lities per hectare	Light-ing per hectare	Sport facilities (sum)	Mean age of respon-dents	Number of surveys
P05_1	P	Henriettenpark	9.72	0.67	1.56	1.18	5988	12.68	18.6	2	33.18	88
P05_2	P	Goethestrasse/ Schwanenteich	53.82	1.56	0	2.55	1654	6.28	3.53	0	43.74	102
P08_1	P	Rosental	13.84	0.05	0.44	21.32	3167	3.05	0	0	43.75	103
P08_2	P	Palmengarten	55.54	0.53	0.81	20.96	4329	3.34	1.1	0	39.72	78
P08_3	P	Wilhelm Kuelz Park	68.55	0.44	0	18.52	1282	2.65	1.03	0	42.73	26
P09_2	P	Friedenspark	61.62	0.5	0.33	18.02	6045	1.66	0.06	7	38.9	81
P09_3	P	Emmauskirchplatz	84.11	0.67	0.22	0.73	2798	8.22	4.11	0	45.85	60
P10_2	P	Mariannenpark	62.28	0.74	0.15	16.78	5355	5.96	0	2	36.61	87
P11_1	P	Alexis Schumann Platz	23.09	1.11	2.89	0.72	6761	16.63	6.93	1	29.35	86
P11_3	P	Reudnitzer Park	72.8	1.78	0	2.1	6454	9.53	3.81	2	35.75	80
P13_1	P	Lene Voigt Park	19.91	0.67	0.11	9.26	12214	7.34	6.8	7	32.16	111
P14_1	P	Abtnaundorfer Park	32	1.33	2.11	8.85	1138	2.15	0	0	45.52	71

Table S6/2: Green, spatial, and grey characteristics of the 36 study (B-Brownfield, P-Park) sites in Leipzig, mean age of respondents and number of conducted valid suryes. The last number of the site ID indicates the tree cover class (1-low, 2-medium, 3-high).

Category	Group	Definition
(Inter)national network	Ideas, Topics	Exchange with other cities (national or international), best practise from other cities
Accessibility	Ideas, Topics	Barrier-free UGI, improve accessibility for persons with disabilities
Adapt planting and pruning	Ideas, Topics	Use of climate adapted species, adapted cutting/ pruning of trees
Air quality	Ideas, Topics	Preservation of ventilation isles, improve air quality in residential areas
Compensation management	Ideas, Topics	Compensation of soil sealing and housing construction
Connection of UGI	Ideas, Topics	Connecting green and blue spaces, create network for cycling, walking
Cultural events & uses	Topics only	Support cultural events and uses in UGI
Edible city / community gardening	Ideas, Topics	Community gardens, edible plants and fruit trees in public green, support regional food provision by urban gardens
Environmental education & awareness	Ideas, Topics	Environmental education for children, school, raise awareness for nature and biodiversity, installation of information signs
Façade greening / rooftop gardens	Ideas, Topics	Support façade and rooftop green, especially on public buildings
Flowerbeds/ flowering aspects	Ideas, Topics	More flowering aspects in public green
Heat / increase shade	Ideas, Topics	Increase shade provision in the summer, heat stress
Improve facilities and paths	Ideas only	Improve condition of paths (pot-holes, pavement), more and improved playgrounds and facilities for children, drinking water/ fountains in public parks, benches and seating possibilities, toilets, bathrooms, more gastronomic supply
Improve cycling & pedestrian infrastructure	Ideas, Topics	Improve cycling lanes, safety for cyclists and pedestrians
Improve dog meadows	Ideas, Topics	More dog facilities and improved dog meadows (e.g. with fences)
Improve maintenance	Ideas, Topics	More cleanliness, more maintenance of flowerbeds, improve maintenance and quality of urban water (ponds in public green, lakes, streams)
Improve public transport / car sharing	Ideas, Topics	Improve public transport and transport connection, more bus/ tram stops, cheaper tickets, support car sharing concepts
Improve/ more sport facilities	Ideas, Topics	More sport facilities (fitness parcours, table tennis, football fields)
Increase biodiversity	Ideas, Topics	Preserve biodiversity, create habitats for animals (e.g. nesting boxes, shrubs for nesting birds), flower meadows for insects, more native plant species
Increase urban wilderness	Ideas, Topics	More wild corners with low maintenance activities, near-natural corners
Less building development	Ideas, Topics	Sustainable land use and construction of new housing

Table S7/1: Definition and examples of categories from open ended questions about ideas and topics for the future development of Leipzig's UGI from the online survey of the Master Plan Green.

Category	Group	Definition
Less cars / parking space	Ideas, Topics	Reduce parking space for cars for green spaces, speed limits or banning cars in certain areas (e.g. in residential areas)
More beaches/ use of water	Ideas only	Increase sustainable use and access to urban water canoeing, swimming, water sports)
More green in residential areas	Ideas only	More green close to home
More housing / parking space	Topics only	More parking space for cars, more houses instead of more green
More or adapted lightning	Ideas, Topics	Installation of lights in public parks, adapted light concept
More regulatory authority & fines	Ideas, Topics	Increase the presence of regulatory authority and fines (e.g. for dog owners, loud music) in public green and blue spaces
More trees / less clearance of trees	Ideas, Topics	Planting of trees in streets and public green spaces, less clearance of old trees
More urban green spaces	Ideas, Topics	More green spaces in Leipzig, preservation of present UGI, micro-greening
Near-natural maintenance	Ideas, Topics	Less mowing, no leaf litter removal, no heavy machines, no pesticides
No motorboats	Ideas, Topics	Prohibit the use of motorboats and motorized tourism on urban water
Noise	Ideas, Topics	UGI for noise reduction, reduce noise exposure in residential areas
Other ideas	Ideas, Topics	Other ideas and topics that were not as frequent to build a category for themselves
Participation of citizens	Ideas, Topics	More transparency in planning and governance, more participation in design, implementation and management of UGI
Political & administrative decisions	Ideas, Topics	More cooperation with NGOs, scientific communities
Preservation of brownfields	Ideas, Topics	Preservation or renaturation of gaps between houses/ brownfields instead of building houses
Protection zones	Ideas, Topics	Designation of No-Go areas, protection zones for plants and animals
Renaturation of urban water	Ideas, Topics	Renaturation of streams, rivers, riparian forest
Rubbish / more rubbish bins	Ideas, Topics	Installation of rubbish bins and waste containers, adapted design of rubbish bins (e.g. protected from animals looking for food)
Safety	Ideas, Topics	Increase safety, crime prevention
Separated use areas	Ideas, Topics	Designated use zones in public green (e.g. for barbequing, dogs, specific sports)
Social & environmental justice	Topics only	More social housing, support alternative housing projects
Sustainable energies	Topics only	Support sustainable energy consumption (wind, solar)
Sustainable tourism	Ideas, Topics	Support sustainable tourism/ eco-tourism
Urban climate	Ideas, Topics	Reference to climate change and adaption strategies to increasing temperatures in the summer

Table S7/2: Definition and examples of categories from open ended questions about ideas and topics for the future development of Leipzig's UGI from the online survey of the Master Plan Green.

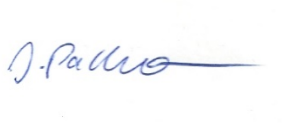
Personal information and curriculum vitae

Name	Palliwoda, Julia
Academic degree	Master of Science
Date of birth	04.05.1988
Place of birth	Perleberg
Gender	Female
Nationality	German
Field of the PhD	Applied landscape ecology
Education and professional experience	
07/2020 – 05/2021	Research associate at Helmholtz Centre for Environmental Research – UFZ Leipzig in the research project „Bioshare”
03/2017 – 05/2020	PhD Candidate at Helmholtz Centre for environmental research – UFZ, Leipzig in the research project “UrbanGaia”
08/2016 – 12/2016	Research associate at Technical University Berlin in the research project „Bridging in Biodiversity Science (BIBS)“
10/2012 – 09/2015	Master program Urban Ecosystem Science/ Urban ecology at Technical University Berlin Degree: Master of Science, Final grade: 1.5
10/2007 – 09/2011	Bachelor program Geography at Humboldt University Berlin, Minor subject: Social Science Degree: Bachelor of Arts, Final grade 1.8
08/2009 – 01/2010	Erasmus at University of Amsterdam, Netherlands (Department of Geography, Planning and International Development)

Declaration under Oath

I declare under penalty of perjury that this thesis is my own work entirely and has been written without any help from other people. I used only the sources mentioned and included all the citations correctly both in word or content.

Leipzig, 11.06.2021



Date

Signature of the applicant